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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE **149**

PARTNERSHIPS FOR INNOVATION: PRIVATE-SECTOR CONTRIBUTIONS TO INNOVATION IN THE HIGHWAY INDUSTRY

TRANSPORTATION RESEARCH BOARD
National Research Council

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an assurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NOTE: The Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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NOTICE

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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The Transportation Research Board evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to administrators, researchers, and private-sector business leaders in the highway industry. Information is presented on how the public and private sectors can promote innovation in the highway field.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

The highway industry needs to encourage on a national and state level the introduction of innovative new technologies in design, construction, operations, and maintenance. This report of the Transportation Research Board describes the current practices of federal, state, provincial, and local governments to foster innovation in the highway industry. Reasons for the very limited successes of the past are discussed, and suggestions for creating an industry environment in which innovation will take place are made.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

PARTNERSHIPS FOR INNOVATION: PRIVATE-SECTOR CONTRIBUTIONS TO INNOVATION IN THE HIGHWAY INDUSTRY

SUMMARY

Although major technological advances in many consumer products have been provided by private industry, this has not been the case in the highway industry. Public agencies are constrained by procurement regulations, specifications, and other processes intended to provide quality controls for the highway agencies and by regulations providing for equal, competitive opportunities for industries serving the highway program. In meeting these goals, highway agencies have created procurement processes that may not permit the ready use of innovative alternatives, and therefore, private-research goals have been diverted from highways to more accessible markets. The challenge to highway agencies is to find new ways to define design and construction objectives that provide quality control, competition, and opportunities for innovation.

Current studies show that there needs to be practical, cooperative working arrangements between the private sector, academia, and government. Arrangements have to be made that satisfy the private sector's need to be competitive and academia's need to advance knowledge and address government's concern for the public good. There needs to be an equitable sharing of the rights to new technologies along with an equitable apportionment of the potential risks. Research priorities need to be clearly established, and existing gaps in our knowledge have to be filled.

To determine what activities public agencies are currently undertaking to bring private industry into the highway research and development effort, a survey was taken of U.S. state and Canadian provincial transportation agencies. Only 6.5 percent of the respondents said that they held regular conferences with private industry, but 48 percent participated in joint committees with private industry to identify needs for innovation in materials, design, equipment, and services. In response to innovations offered by private industry, 89 percent of the agencies said they perform trial installations and 67 percent conduct prompt, receptive evaluation procedures.

Eleven private industries also responded to a survey concerning their involvement in transportation research. The large size of the highway market was an important positive consideration to 55 percent of the companies when making research and development decisions. The second most frequent positive factor (45 percent) influencing highway market research by private companies was their development of new technologies for other markets that were also potentially applicable to highways.

Several other factors were reported in the survey that influence the R&D decisions of private industries serving the highway market. Although the market for new highway products is large, it is diverse, cost-sensitive, and very competitive. The public-agency buyers of highway products are reluctant to take the risks that innovation may require; public employees are vulnerable to tort liability suits. Private industry may face product liability charges in this litigious society.

The highway community needs new technology to contain costs and improve the performance of its systems. Public funds supporting research will continue to be needed in the future, along with a significant contribution to technological advancement by the private sector.

Public agencies at the federal, state, and local levels are aware of the difficult environment for private innovation and seek to provide new opportunities and research incentives for the private sector. Value engineering clauses in construction contracts, which invite contractors to offer innovative alternatives in design or construction procedures, are generating additional profits for contractors and cost savings for highway agencies. Joint industry-agency committees and interaction on national committees serve to identify research needs and explore other new effective relationships.

Highway programs in the United States are facing major challenges as aging and often overloaded roadway facilities cause agencies to shift requirements from new construction to maintenance and rehabilitation. Program demands exceed available funds under present revenue-generating legislation. The highway community, the public, and state and national governments recognize the need for new technology. New support for research is evident in such programs as the Strategic Highway Research Program and the University Transportation Centers federal grants. Major responsibility for highway research will continue to rest with the public agencies building and operating the highway systems.

Private industry has made significant contributions to highway technology, but the full potential for technological advancement through the private sector has not been realized. To bring about this badly needed involvement of the private sector, positive actions by the public sector need to be advanced and emphasized. Consideration should be given to such steps as the following:

- Centralize or regionalize the testing and approval of innovative highway products offered by the private sector.
- Develop and incorporate "value engineering" clauses in highway contracts for construction, rehabilitation, and maintenance.
- Refine and expand the use of quality bonuses as an incentive to contractors to perform above the minimum specifications and other contract quality controls.
- Develop tools for managing performance specifications and life-cycle cost analyses for use in awarding contracts.
- Draft and update periodically a research needs list that represents a national consensus (public and private) on technological gaps in the highway industry.

Highway agencies and private industry must join together to find new and effective ways to foster and introduce innovation. Through such partnership efforts the challenges of international competition and the ever-increasing need for additional capacity, economical service, and safety on our nation's highways can be met.

CHAPTER ONE

INTRODUCTION

In an economy and a society driven by high technology developed largely by private industry, the U.S. highway market has often been bypassed. With annual expenditures in excess of $60 billion, the national highway and street system would appear to be an inviting market to private industry and one in which research and development investments could be expected to provide a good return. However, government officials with a national overview recognize that the market includes many barriers to private-sector innovations (*1*). The reasons for this undesirable status, the successful technology contributions to highway design, construction, and operation that have been made by private industry, and the ways in which future opportunities for innovative technology can be enhanced are the subjects of this synthesis.

ISSUES

In the early 1950s, when the American Association of State Highway Officials (AASHO) Road Test was drawing to a close, pavements on major highways were being constructed using compacted subbase and base materials, generally local soils and aggregates, over which asphalt concrete or portland cement concrete layers were placed. Batching plants produced the paving mixes and paving machines placed and screeded the materials on the roadway. Almost 40 years later, the pavement cross section, materials, and construction processes are little changed.

Also in the early 1950s, the engineers responsible for pavement design were using slide rules for preliminary estimate computations and large, expensive electric calculators for final computations. The calculators could perform four functions: addition, subtraction, multiplication, and division, each done mechanically and somewhat laboriously in a machine costing about $1000 with about the same bulk as an electric typewriter. Forty years later, the design engineer can carry in a pocket an electronic calculator the size of a business card that costs $10 or less, and it can perform all of the functions of that earlier electric calculator and more in a fraction of a second, using solar power or a minuscule battery for energy. For the price of that earlier electric calculator, engineers can own and operate a microcomputer capable of an infinite variety of mathematical functions to serve their unique design needs.

Rate of Change

Why the difference in technological advancements in these two scenarios? Part of the difference in technological change between the highway and the calculator is attributable to ownership. The highway is almost always owned by government. Calculators and computers are tools (or toys) that enjoy widespread consumer (private) ownership.

Part of the slow rate of change in highway technology can be attributed to scale. A calculator or even a microcomputer is a small, portable, relatively inexpensive investment that is usually depreciated fully over five years or less. A highway system is a massive, costly, "permanent" investment in the tens of millions of dollars. The large quantities of materials, particularly the aggregates that are key components in pavement systems, are costly to transport, and the use of local materials is often mandated by economic considerations.

Part of the difference in the rate of technological change can be attributed to the difference in market incentives to private industry to invest in research and development. Consumers are quick to accept new high-technology products. Highway agencies have been slow to accept change because of the legal barriers in public-procurement processes and the liability threats when failures occur. They often require evidence of performance based on lengthy field trials, and acceptance or rejection of innovations usually occurs one state at a time.

In the highway industry it is unlikely that major changes will occur in the ownership of the road network, although a renewed program of toll road construction is forecast for the next decade. The potential increase in toll road construction in the early future is accompanied by another potential change—the construction of privately owned toll roads. The Virginia state legislature, in its 1989 session, passed landmark legislation permitting private organizations to apply for permits to build and operate toll roads. Private ownership may provide a different marketplace for innovative processes and products. Although private ownership of toll roads has not been a part of the U.S. highway system since colonial days, the feasibility of such an arrangement cannot be dismissed. The highly successful private toll highway agency Cofiroute (*2*) was created in 1972 by the French government. Since its creation, Cofiroute has raised FRF7 billion (US$1.165 billion) through a combination of shareholders' equity, loans, and refundable state advances. The 1987 Cofiroute network (on which revenue exceeded expenses by US$49 million) covered 680 km, with an additional 73 km under construction.

Changing Market for Innovation

The job of highway agencies and the private organizations serving them is changing from the construction of new highways on new rights-of-way to the repair and rehabilitation of existing highways. This new role and the technical and operational requirements to satisfy it are not fully defined or fixed by past experience and practice.

Individual highway rehabilitation projects are likely to be unique in several respects. Many may need job-site innovations in order for the required work to be performed. Thus, the opportunity for new or innovative technology from the private sector may be greater than would be the case for conventional new construction. In this era of shrinking highway budgets and growing highway needs, technological advances that yield safer and more effective operations, more efficient construction and reconstruction procedures, more effective designs, and more economical, durable materials offer great hope for the future.

Barriers to Private R&D

Publicly funded research has and must continue to play an important role in highway programs, but marshaling the financial and technical resources of private industry will also be an essential element in successfully meeting our future highway needs. There are opportunities to remove or change the barriers that prevent private industry from playing a more effective role in bringing new technology to the highway field.

The Office of Technology Assessment (OTA), in a 1987 study (*3*), found that "simply increasing R&D expenditures [in construction technologies and materials for transportation and water-related infrastructure components] without also taking steps to alleviate these barriers and disincentives, will do little to advance the materials, machinery, and methods by which we design, build, and maintain our Nation's public works."

The OTA found significant barriers and economic disincentives to nonfederal R&D, including procurement processes, risk-related issues, and splintered private and governmental roles. The OTA report offers persuasive evidence that even modest additional investments for materials R&D for highway repair, maintenance, and construction could yield $15 billion to $35 billion in savings in 10 to 20 years.

Need for Innovation

In an open letter to American industry's chief executive officers (*4*), the American Association of Engineering Societies (AAES) said that the United States leads the world in the generation of basic scientific knowledge, but U.S. industry fails to convert that knowledge to invention, commercialization, and exploitation as effectively as do foreign industries. The *Wall Street Journal* reports (*5*) that Japan believes that it has caught up with other industrialized nations in applied research and wants to take a lead in pure science. Japanese companies are setting up basic research laboratories, and the government is sponsoring programs to encourage basic research. The Japanese goal is to "seed" future industries. Toshiba Corporation plans to spend 20 percent of its research budget on basic research within the next five years, up from nearly 0 in 1983.

The AAES challenged U.S. industry to exploit its lead in basic knowledge by taking action independently and in cooperation with the government to overcome the major shortfall in "middle ground R&D"—invention and implementation. The National Council on Public Works Improvement, in its study of the current status of the nation's infrastructure (*6*), suggested five ways to address the great but essential needs in this area: (a) focus on performance rather than facilities, (b) modernize decision-making processes, (c) find new funding sources, (d) ensure adequate human resources, and (e) accelerate innovation. John Diebold (*7*) suggests that the two most important elements in a national research strategy are: (a) education and (b) mechanisms for bringing scientific discoveries from the laboratory to the marketplace.

Legislation

Speaking at a workshop on highway research, Dwight Sangrey (*8*) presented construction industry research statistics that showed the relative commitment of construction industry resources to research in the United States and Japan to be:

U.S. contractors	0.016%
U.S. product and equipment manufacturers	0.270%
Japanese contractors	1.000%

A growing national consensus of the need for innovation is reflected by activity in the U.S. Congress on legislation that funds accelerated research programs and positions government as a catalyst for private and public research and development. The 1987 session of the 100th Congress produced the Surface Transportation and Uniform Relocation Assistance Act (STURA), under which the Strategic Highway Research Program (SHRP) is funded by an allocation of 0.25 percent of the major federal highway construction program authorizations. This new, five-year, $150 million research program is directed primarily toward pavement, highway construction material, and maintenance technology.

Also a part of STURA 1987, Section 314 of Public Law 100-17 authorizes the establishment and funding of the University Transportation Centers Program. The program provides grants for transportation research and training at nonprofit institutions of higher learning through a University Transportation Center in each of the 10 federal regions.

Another bill that was passed by Congress in the 1988 session was the Omnibus Trade Competitiveness Act. This bill upgraded the National Bureau of Standards to a National Institute of Standards and Technology (NIST) with an explicit mission to aid U.S. industry in the development of technology. Also, the bill contains "a three-year Pilot State Technology Extension Program to support innovative state projects to transfer federal technology to businesses." An Advanced Technology Program in the bill gave the Secretary of Commerce authority to encourage private-sector research efforts, particularly joint research and development ventures.

A preliminary draft of a bill called the Public Works and Infrastructure Innovation Act was prepared in the 1987 session of the U.S. Senate. The draft proposed to "promote research, development and innovation in the field of public works and infrastructure technology" by establishing a Council on Public Works and Infrastructure Innovation and funding a staff and contract research program through transfer of funds from federal operating agency accounts. The proposed bill was not advanced in the 100th Congress and not reintroduced in the 101st Congress. Some of the concepts for funding and implementation of a revitalized research and development program in infrastructure technology are likely to appear in future federal legislation.

CHAPTER TWO

FACTORS AFFECTING INNOVATION

There are many factors that have influenced the dramatic difference in advances in highway technology and in consumer or similar high-technology developments such as communications and electronics. Some of these factors deserve further discussion when the highway industry is considered.

MARKET SIZE

A paradoxical factor that both hampers and invites the introduction of new technology is the size of the highway program and the magnitude of the quantities of materials used. Annually, more than $50 billion is invested in constructing, maintaining, and operating the U.S. street and highway system. More than $10 billion of that is for asphalt pavements and more than $1 billion for cement (*9*).

When new technologies are successful in winning approval in the highway marketplace, the large sales volumes may provide a substantial return on the R&D and marketing investment. The 3M Company's reflective sheeting for highway signs is a good example of such success.

Conversely, the soils, aggregates, cements, asphalts, and steel used on highways and bridges are commodities that are low in unit cost and used in great quantities. Consequently, very small changes in these unit costs may result in major changes in project costs. This has led highway agencies to resist changes that affect unit costs, even when those changes may represent higher quality. Improved quality is not easily identified or proved, and credible, easy, and quick methods for cost-benefit analyses are often lacking.

Variability in the size of the highway market—the demand for goods and services—from year to year and season to season may detract from the appeal of the highway market to some private organizations.

RISK/REWARD

Another factor that may dampen the introduction of new technology to the highway program is the sometimes negative risk/reward environment for employees in highway agencies. Established, proven, accepted processes, materials, and designs offer the lowest risk, and practitioners are more likely to be rewarded for stability than for risk taking. New, innovative concepts bring with them the potential for failure. Failure of a material, design, or product on a highway may cause many undesirable results: adverse publicity and possible political ramifications; interruptions of service or reduced levels of service to the highway user until the failure is corrected; reduced levels of safety; adverse environmental effects; and related to all of the foregoing is the issue of liability and the threat of legal action by affected parties. Because of this environment, many highway agencies have been slow to implement innovations from private industry.

PROCUREMENT PRACTICES

Public-procurement laws are another barrier to the introduction of new technology to the highway agencies. The laws are intended to protect the integrity of the procurement process, to establish open, equitable, competitive procedures for the spending of public funds, and to assure all qualified private goods and services suppliers of a fair and equal opportunity to do business with the government.

To achieve these objectives, however, it is necessary for the government to describe very clearly what goods or services are desired, either in terms of the physical (and/or chemical) characteristics of the product, the on-site construction procedures, or the performance of the product. Highway agencies have usually chosen, for major highway components, to specify: the description of the product, the materials to be used, and the way in which the product is to be constructed or produced. Procurement practices based on lowest first costs rather than service life costs are most often used by highway agencies. Lowest first costs are easily computed and compared. Annual budgeting, current year project needs, and political pressures to do more for less all weigh heavily in favor of first costs.

The limited use of service life costs and performance requirements in competitive public-procurement programs has been based on other factors as well. Although public agencies have recognized the potential benefits to be realized by these alternatives, the tools needed to determine service life and to evaluate future performance are still limited in number and reliability. As accelerated testing capabilities are developed and new performance models accredited, opportunities to use "open" specifications and provide new incentives for innovation by the private sector may emerge.

Innovative technologies are being introduced and development encouraged in the private sector in highway network operations and traffic control systems. Joint public-private studies (*10*) of vehicle-in-motion identification, weight, speed, and location using electronic "signatures" placed in the vehicles and read by field installations of remote sensors are examples, as are the studies (*11*) to develop "smart" highways and "smart" vehicles that provide operators with visual information about the vehicle location, roadway network traffic conditions, and alternative or optimum routes under those conditions.

SPECIFICATIONS

When coupled with the requirement in public-procurement laws to award a contract to the "lowest and best" bidder, the detailed prescriptive specification becomes a formidable barrier to innovation. If a bidder proposes to meet the stated specifications for the lowest price, it is difficult for a highway agency to award a contract to another bidder at higher costs, even though the quality of the alternative bidder's product may be higher than that of the low bidder. After all, the agency selected the specification for which it solicited bids, and one could argue that if the agency wanted a higher quality product it should have specified one. Thus, the private supplier of goods and services under the public-procurement system, to compete successfully in the marketplace, must seek to supply the materials, services, and products that meet the minimum requirements of the specifications at the lowest costs.

The competitive process, in turn, may drive the highway agency to develop ever more restrictive specifications to assure the quality level it seeks. Most highway agencies attempt to control the quality of materials by specifying certain standard tests to which the materials must be subjected and the minimum (and sometimes the maximum) acceptable test results. Constructed products, such as pavements and structures, are controlled by both material specifications and specified construction procedures that even include the generic types of equipment and the way they are to be used in construction.

PERFORMANCE

The purpose of the specifications—to achieve an acceptable quality level in the constructed highway—is not always accomplished, even when the specifications are met. This occurs in part because the variability in materials and processes may not be adequately controlled by the specifications and in part because the laboratory and field tests used for quality control may not correlate very well with performance under field conditions.

An obvious alternative for the highway agency would be to specify performance in the procurement process rather than prescriptive specifications that attempt to control quality. This alternative is one of the promising alternatives being considered by the highway community. If performance was the requirement against which competitors could bid, the opportunity for them to develop and incorporate innovative new technologies in materials, equipment, and construction processes could be largely unconstrained. At the same time, if performance was described to incorporate a time element so that performance levels and service life were considered in evaluating competitive bids, then life-cycle costs for the specified performance level could be the basis for awarding contracts, and private industry would include durability as one of its goals for research and development in highway markets.

The deterrents to the use of performance specifications and life-cycle costs are the lack of accelerated tests that correlate reliably with long-term performance and the impracticality of requiring long-term performance guarantees in the contracting industry. Because pavements and structures are intended to perform for many years (20 to 50 respectively), it would not be possible for most contractors to post performance bonds for that length of time and then accumulate additional bonded obligations each construction season in which new projects were completed. Further discussion of performance-testing tools and means to use this incentive for innovation are presented later in this synthesis.

DISPERSED MARKET

Another deterrent to the introduction of new highway technology by the private sector is the dispersed character of the highway market. If a private company develops a new product for the highway market, it faces a formidable challenge and marketing expense in winning acceptance of that product by each highway agency. In some instances this is necessitated by the variations in environmental conditions, local materials, and practices in different highway agencies. In other instances, government agencies are simply unwilling to accept information that they did not develop. In any event, the specification-based procurement process currently must be addressed on a state-by-state basis. There is no single agency through which acceptance and approval is won for the full national market. Furthermore, specifications are usually prepared on a generic basis. Proprietary products are not incorporated by trade name in the specifications, and highway agencies usually want assurances that multiple, competitive sources are available for products that meet the specifications.

VARIABILITY IN PRODUCT REQUIREMENTS

Although aggregates, cement, asphalt, and steel are used for highway work in great quantities nationally, there is a tendency on the part of individual state and local governments to want slightly different products for their agencies. Consequently, many materials producers are faced with offering many variations of their products to meet larger interstate markets or offering a single product grade and settling for a smaller local market.

Variability in the market demand for highway products also affects the private sector. In northern states, construction seasons may be short, and suppliers of perishable materials or bulk materials that require major storage areas may find it difficult to accommodate the demand for these materials. Contractors face difficulties in maintaining or reassembling experienced construction work forces from season to season. These annual scheduling problems are compounded when federal or state legislative bodies fail to fund annual construction programs in a timely and consistent manner.

COMMUNICATIONS GAPS

High-technology companies that could contribute valuable new technologies to the highway industry may not be familiar with the industry and its technology needs. At the same time, some companies offer new products that are ill-suited for highway use. The marketing efforts in such cases are costly to the producers and to highway agencies.

STANDARDIZATION AND INTERCHANGEABILITY

Manufacturing industries serving mass markets achieve significant economies by standardization of products and interchangeability of components. Although highway agencies have recognized and adopted standardization in some products (such as steel guardrail cross sections), there are still many different specifications and characteristics for the same generic highway materials and components required by separate highway agencies. Thus the economies of scale may be lost to the highway agencies, and the incentives of market size lost to the manufacturers and suppliers.

CHAPTER THREE

CURRENT PRACTICES BY PUBLIC AGENCIES

Recognition of the need to advance a broad spectrum of science and technology, including transportation, in the United States through collaboration among federal laboratories, state and local governments, universities, and the private sector resulted in an executive order (*12*) issued by President Ronald Reagan on April 10, 1987. In the order, he directed federal agencies to encourage and facilitate collaboration by:

- entering into cooperative research and development agreements with the private sector and
- licensing, assigning, or waiving rights to intellectual property developed under such agreements.

The executive order promotes the commercialization of patentable results of federally funded research by encouraging and authorizing the granting of titles to patents to contractors in exchange for royalty-free use by or on behalf of the federal government. It encourages an exchange program of temporary assignments of private engineers and scientists to government laboratories and government engineers and scientists to private laboratories. The order also directs the Secretary of Defense (who represents a department where a large portion of federal research and development funds are expended) to identify a list of funded, unclassified technologies that would be potentially useful to U.S. industries and to accelerate efforts to make these technologies available to U.S. industries.

In 1987, the U.S. Congress passed a law, signed by the President, establishing grants for new transportation research centers to be established by universities or consortiums of universities in each of the 10 U.S. federal districts. The legislation called for each center to receive up to $1 million per year in federal funds when matched by equal funds from nonfederal sources. The program provides for funding for each year of a five-year program. The federal funds are to be taken from the annual authorizations to the Urban Mass Transportation Administration and the Federal Highway Administration (FHWA). The centers, established in FY 1988, offer an important new opportunity for government and industry to collaborate in providing needed transportation research and innovative products for the future.

In an issue paper prepared for the Public Affairs Council of the AAES, Smith (*13*) identified the factors currently influencing the industry/academic research interface as:

- the proprietary rights to new knowledge generated by industry-academic partnerships (industry seeks patents, academia seeks to publish),
- incentives or disincentives for research and development,
- the information gap about the nature and extent of industry support that is needed, and
- the extent of government support and emphasis on research.

Smith suggests that the current modes of research cooperation in the United States include:

- focused university program centers serving industry objectives and university intellectual goals,
- independent institutes with multiple company and university governance,
- industry consortia through which private-sector research is stimulated and funded,
- state government initiatives for matching federal government and industry support of research in academic centers, and
- federal initiative to stimulate public research and educational activities.

The Smith report concludes that a compromise among the competitive goals of industry, the advancement of knowledge of academia, and the public concerns of government may be the means to solve major social and economic needs in the United States.

Coates (*14*) states that technological innovations that would have significant marginal benefits are available in vast numbers for improving the transportation system. He cites improved materials for roads, roadbeds, and highways; recycling of aggregates; and improved methods of road construction and maintenance as examples, but suggests that the scale (magnitude) and administrative complexity of the transportation programs prevent or at least deter change.

In another article (*15*), Coates and Jarrate suggest that

> the introduction of a radically new system, as an alternative way of achieving an objective, runs into the obstacles of the established commitments to the in-place system which it threatens. All of those who have economic, occupational, or psychological commitments to the old system line up against. . .the new invention.

Therefore, they suggest that "incremental improvement is the most prolific single source of enhancement of any technological system."

In planning that preceded the start of SHRP, innovation was one of the key objectives cited by the planners. In addition to the structured budget and objectives of the research program, the SHRP leadership explored other activities that could be used to create an atmosphere that invited creative thinking and innovative approaches to the major goals of the program. Hyman (*16*) described some of the principles for fostering innovation and creativity, including: conceptual leaps, courting the illogical, counterintuitive and contradictory ideas, and establishing loose/tight goals and objectives. Out of the recommendations from a special workshop on innovation and industry, SHRP established a separate program category, Innovation Deserving Exploratory Analysis (IDEA), and earmarked a portion of its research funds for unsolicited, innovative proposals offering alternative concepts to reach the goals and objectives of SHRP. In addition to innovation, the SHRP-IDEA program seeks to open the program to "new players" who have not been ongoing participants in highway research in the past but who see an opportunity to apply unique alternatives/products in which they have expertise.

INVITING INNOVATION

In order to assess the interface between industry and state or provincial government agencies responsible for highways, a brief mail survey was sent to each U.S. state and Canadian provincial highway agency. The responses have been summarized in Table 1. (A complete set of the responses is given in Appendix A.)

Of the 41 states and four Canadian provinces responding to the survey, only the Ministry of Transportation in Ontario reported publishing or distributing to the private sector a "wish list" of needed new technology. This suggests that highway agencies have: (a) looked to their own research staffs or those of FHWA, the National Cooperative Highway Research Program (NCHRP), and other joint government research programs as the most appropriate recipients of their "wish lists" of needed new technology; (b) chosen to develop their internal research activities and support external research programs without focusing on a "list" of needed new technologies; or (c) avoided the distribution of such lists to private industry because of concerns about potential conflicts that such action might create with legal requirements for competitive procurement procedures.

Twenty-three responding agencies said that they participate in conferences with the private sector as a means of inviting innovation, and 22 have joint committees with the private sector, as discussed in the next sections of this synthesis. Seventeen use value engineering procedures for construction contracts and eight use value engineering on other projects as well. Eleven engage in joint research with private sponsors, some through university transportation research centers funded in part by private companies. Five states reported that they take none of the actions listed in the survey to invite innovation by the private sector.

JOINT COMMITTEES

There are a number of local and national committees or organizations through which research needs are discussed jointly by government and the private sector. Forty-nine percent of the states responding to the survey reported that they participate in joint committees with industry.

In Alaska, a law passed in 1986 (Appendix B) established a five-member Science and Engineering Advisory Commission that includes an academician, a researcher, a representative from a state department having research needs, a representative from private industry, and the senior science adviser in the governor's office, who serves as chairman.

TABLE 1

SURVEY OF STATE AND PROVINCIAL TRANSPORTATION AGENCIES

		Number	Percent
1)	What does your agency do to invite innovation in the materials, equipment, designs, and services provided to you by the private sector?		
	Wish list published	1	2
	Conferences with private sector	23	51
	Joint research with private sponsors	11	24
	Joint committees with private industry	22	49
	Value engineering for construction contracts	17	38
	Value engineering for other projects	8	18
	Other	17	38
2)	What does your agency do to respond to invited and uninvited innovation offered by private sector?		
	Prompt, receptive evaluation procedures	30	67
	Trial installations	41	91
	Joint evaluation	24	53
	Consultation and guidance	27	60
	Other	6	13

The Alaska commission is charged with:

- recommending an integrated state research policy,
- receiving scientific and engineering information from academia and industry,
- assessing state agency research needs and priorities,
- facilitating cooperation among state agencies, universities, and industry,
- suggesting methods for sharing information and data with state, public, and private institutions,
- acting in an advocacy role and recommending methods to improve support for research, and
- recommending research priorities for the next year to the governor.

NEW HIGHWAY MATERIALS

At the national level, three major associations, the American Association of State Highway and Transportation Officials (AASHTO), the Associated General Contractors, and the American Road and Transportation Builders Association, participate jointly in a Subcommittee on New Highway Materials. The subcommittee provides a liaison between industry and highway agencies to develop new materials through highway agency testing grounds and to identify for industry new materials that need to be developed. The subcommittee chair is shared by one highway agency representative and two private-industry representatives, with FHWA providing the recording secretary, thus maintaining a balance of government and industry leadership. The staff support is provided by FHWA to the subcommittee. The high level of public and private leadership committed to this effort has been a significant factor in the effectiveness of its work.

In 1987 the subcommittee accomplishments included:

- Geotextiles—Specifications were developed, eight test methods were adopted, and development of a design procedure was initiated.
- Earth Reinforcement—Draft design guidelines for use of extensible reinforcement for mechanically stabilized earth walls, draft specifications for soil-nailed structures, and revised draft specifications for permanent ground anchors were prepared.

Similar activities and document developments were reported by 24 active task forces of the subcommittee. It is interesting to note, however, that one task force, looking at the applicability of performance specifications to present construction practice, was dissolved in 1980 without record of any advancement in this area.

TRANSPORTATION RESEARCH BOARD

The Transportation Research Board (TRB) provides many opportunities for interaction among industry, academia, and government in the development of new transportation technology through the work of various volunteer committees. The TRB technical committees are appointed to include individuals (not as representatives of organizations) who bring experience and expertise from a broad spectrum of backgrounds to address specified areas of transportation technology. The TRB committees provide a forum for the discussion of emerging technologies and the identification of research needs. Industries that develop and supply equipment, materials, and services to the highway industry are well represented on the committees and in the programs of TRB.

The TRB has established a special Task Force on Innovative Contracting Practices, A2T51, to consider practices that affect quality, progress, and costs. Study items that are to be considered by the task force include:

- Procedures and specifications that stifle initiative and innovation and those that encourage them.
- Ways that current procedures and specifications adversely affect quality or unfairly assign risk.
- Experience with various types of quality assurance, performance-based specifications that have been demonstrated to improve quality and equitably assign risk.
- The effects of penalties and incentives.
- Methods of contract award, other than low bid, that have been used successfully or might be tried.
- Administrative, legal, and other problems that need to be considered.
- Strategies for implementation.

The task force is preparing a report that is expected to be published in the late summer or early fall of 1990.

HIGHWAY RESEARCH COORDINATING COUNCIL

Acting on a 1987 report by an AASHTO task force on national research roles (*17*), AASHTO requested that TRB serve as the organizing agency to establish a Highway Research Coordinating Council (HRCC) comprising top-level representatives of major national research sponsors or program managers such as TRB, FHWA, SHRP, the U.S. Army Corps of Engineers, NIST, the U.S. Forest Service, the National Science Foundation, the American Public Works Association, and the National Association of County Engineers.

In the report, the task force recommended that the HRCC provide a forum for:

- The discussion of ongoing highway-related research programs;
- The identification and resolution of potential areas of undesired duplication;
- The recognition of apparent gaps in the collective research effort; and
- The development of opportunities for cooperation and interaction that will strengthen the combined national program.

The AASHTO report also recommended the establishment of an industry-HRCC committee comprising representatives from major private industries undertaking research applicable to highway technology and an equal number of HRCC representatives. The industry-HRCC committee charge is to develop recommendations and advise the HRCC on:

- The most effective role for private industry in national highway research and the action needed to permit industry to play that role.

- Performance specifications or other means to permit and encourage private-sector innovation and the tools and actions needed to employ those means.
- The identification and definition of R&D project turnover points where publicly funded research should end and privately funded development should begin.
- Feasible, functional alternatives for working relationships that permit joint government-industry development of needed new technology, specifically addressing patent rights, manufacturing licenses, and other industry incentives.

With TRB serving as the project administrator and AASHTO, the U.S. Army Corps of Engineers, and FHWA providing initial funds, the HRCC organizing committee essentially completed in 1989 the development of a charter, operating by-laws, a common research classification system, a tentative schedule for early council meetings, and a plan, budget, and source of funds for staff support. Also, the organizing committee supported a concurrent action plan to establish the industry-HRCC committee as a new TRB committee under Group 1. A statement of the scope and a list of candidate members were being prepared at the close of the year 1989.

ACTIONS RESPONDING TO INNOVATION

Although the survey of state transportation agencies indicated a low level of activity inviting industry innovation, the states are active in responding to innovations offered through private-sector initiatives. Thirty agencies (67 percent of those responding) reported that they have established evaluation procedures for innovative products or concepts offered by private industry. An even greater number, 41 agencies (91 percent), conduct trial installations of new products and 24 (53 percent) make joint evaluations with industry. Twenty-seven (60 percent) offer consultation and guidance to private industry regarding innovative products being offered.

EVALUATION PROCEDURES

New-product evaluation procedures vary widely from state to state. This concerns national agencies managing, coordinating, and funding highway programs, as well as major highway industry companies designing, supplying, or building highways.

The concerns pertain to the quality of the evaluation procedures and the availability and applicability of data used. What are the evaluation criteria for complex new products? Is the evaluation procedure technically valid, statistically significant, and cognizant of limiting factors such as local materials, construction practices, and climate? Is cost-effectiveness used in the evaluation? How? Are the results compared and shared with other highway agencies? With industry representatives?

New-product evaluation procedures were studied in an earlier TRB synthesis (*18*) in 1982. At that time, many highway agencies were moving away from what had been an unstructured, informal process to a more formal and efficient arrangement. Typical of the improved processes were organizational actions that: (a) assigned all new-product evaluation responsibilities to a single department; (b) directed all vendor approaches and applications to the designated department head or his representatives; and (c) organized an evaluation committee to include representatives from both potential-user departments and from other organizational units to realize a variety of viewpoints in the evaluation process.

Shortcomings in the process that were described in the 1982 report included: lack of a full-time staff responsibility for new-product evaluation and resulting variability in the quality of the evaluations and the effective dissemination of the results and inadequate follow-up information on the observed performance of the accepted new products to confirm or revise the initial evaluation data.

In 1986, in response to a request from the U.S. Congress, the General Accounting Office (GAO) began a study of the adoption processes used by state highway agencies to incorporate new pavement technologies in their programs. The final report (*19*) of this study, published in 1988, states that the GAO found the adoption processes to be fragmented, varying widely from state to state, and often based on less than comprehensive evaluations.

Typical of the evaluation procedures are those performed by two of the survey respondents from state DOTs. The procedures include sending a brief letter outlining the process to the industry representative and enclosing an application form on which the industry representative can describe the product and its proposed use to the highway agency. An initial appraisal of the application is made by the review committee or research manager. If the product is approved for evaluation, the industry representative is invited to submit samples as required and to assist in the field trials, if they are a part of the application. In any event, the product-evaluation results are furnished to the submitting industry and considered public information thereafter. When applications are not accepted for product evaluation, the submitting industry is informed of this decision by the highway agency and the reasons for this decision are explained.

CHAPTER FOUR

CURRENT PRACTICES BY PRIVATE AGENCIES

Eleven private agencies responded to a study survey designed to assess the important characteristics of the highway market that influence R&D decisions by the private sector. Table 2 summarizes the results of that survey and a complete listing of the respondents and their answers is provided in Appendix A. Six of the agencies cited the size of the market as a major incentive in their R&D decisions. Only three firms indicated that receptivity of public agencies to innovation was an incentive. Five firms indicated that innovations developed for the highway market were the result of technical developments for other purposes that were recognized as having potential application to highways. Technological gaps (or research needs) listed by public agencies were considered in R&D investment decisions by four of the responding private organizations. This suggests that although highway agencies are not publishing wish lists as a means of inviting innovation, they are communicating those needs to some industries and getting a positive response.

The private companies responding to the survey indicated an almost equal interest in specialty sales, negotiated contracts, and public bids, with approximately half reporting those as markets they seek. Only two companies included contractor sales in their markets.

CORPORATE RESEARCH MANAGEMENT

One major national materials company, Dow Chemical (*20*), follows a well-developed decision path for its corporate research and development program (Figure 1). Dow finds that there are always more good ideas available than there are resources for

TABLE 2

SURVEY OF PRIVATE ORGANIZATIONS INVOLVED IN TRANSPORTATION RESEARCH

		Number	Percent
1)	How do you decide whether or not to invest in R and D for the public highway market? Please offer explanatory comments.		
	Size of market	6	55
	Characteristics of highway marketplace	4	36
	Receptivity of known public agencies	3	27
	As a result of other potentially applicable technical development	5	45
	As a result of recognized gaps (needs) listed by public agency	4	36
	Other (specify)	5	45
2)	What markets do you seek? Please offer explanatory comments on why these markets were chosen or rejected.		
	Contractor sales only	2	18
	Specialty sales	6	55
	Negotiated sales (not bid)	6	55
	Small local governments only	1	9
	Open, public bids	5	45
	Other (specify)	4	36

research. Consequently, ideas are screened and ranked before those to go into the program are chosen.

Dow seeks a balance between support of current products and development of new products. In screening an idea, Dow managers consider several key questions:

- Will it fill an unmet need in the market?
- Will it give the company a competitive advantage?
- Is it compatible with the company's existing activities and products?
- Does it offer a potential return on investment when considering the development, capital investment, and potential sales volume?
- What are the liability risks?

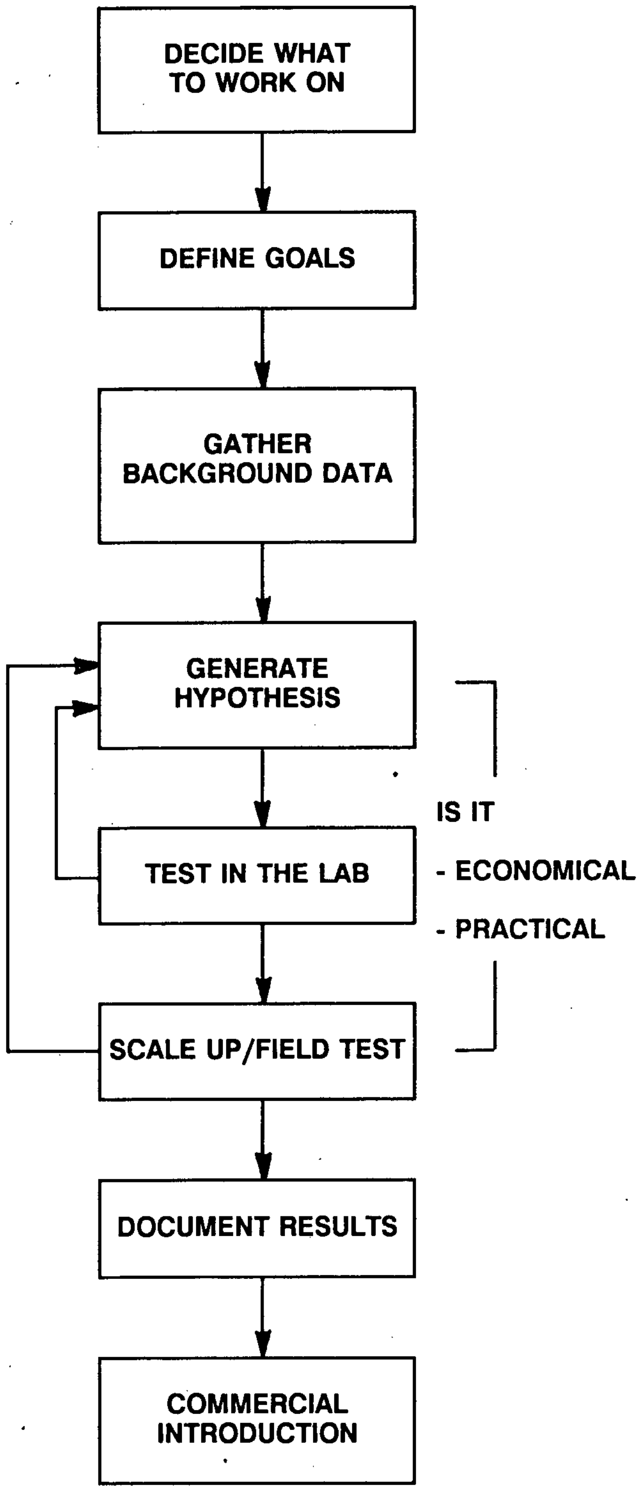

FIGURE 1 Dow Chemical research flow chart.

When ideas are included in the Dow research program, a clear definition of the research project goals is developed as the initial step. Dow then undertakes an active effort to gain indepth knowledge of the needs of the potential customer or clients who will use the new product. In gathering this information, discussions are held with transportation officials, contractors, suppliers, and others. Literature searches, patent searches, technical conferences, and contacts with internal experts, consultants, universities, and other research groups build background information for the research project.

Traps that Dow tries to avoid are the "not invented here" syndrome and the "we tried that before and it won't work" attitude, which can create artificial barriers to the advancement of new technology. The company also seeks to avoid the development of products that have few or no prospects for near-term commercialization and products that challenge vested interests held by other vendors, consultants, and universities.

As hypotheses are set up and tested in the laboratory, Dow researchers are concerned with some basic questions about the process:

- Are the laboratory tests valid indicators of field performance?
- Can the experimental results be replicated?
- Are they statistically valid?
- Are the right variables being considered?

Field tests are expensive and time-consuming but a very necessary part of the developmental program.

Dow, recognizing that technology transfer is an important element in its commercial introduction of a new product, incorporates a technology transfer effort into the process. This effort includes preparing literature and technical application guidelines, scheduling technical seminars and presentations for in-house personnel and customers, participating in conferences and trade shows arranged by other parties, and supplying training and field assistance to customers.

One Dow product that offers an interesting case history is latex-modified concrete. After several years of development, latex was introduced by Dow to the highway market in the early 1960s for use in bonded concrete overlays on bridge decks with surface deterioration.

Early failures occurred on several latex-modified concrete deck overlays using Dow latex placed by contractors who did not have the necessary quality controls and expertise in placing this new material. As a consequence, Dow withdrew from marketing this latex product for several years to improve the application technology and review its marketing strategy. When the latex was reintroduced to the highway market in the early 1970s, Dow exercised special care in application quality control, restricting the use of the material to trained and licensed contractors to ensure quality control and construction expertise. The resulting high-quality performance of the deck overlays won acceptance in many highway agencies. Today, latex-modified concrete deck overlays (with latex supplied by Dow and other manufacturers) are an accepted bridge repair technology in most, if not all, of the state highway agencies in the United States. However, the generic specifications that had to be prepared for the latex materials have resulted, according to some state highway officials, in a reduction in the quality of recently constructed overlays and have reduced confidence in the technology.

An example of an innovation seeking a market is provided by the Du Pont Company (*21*). Du Pont chemists in the early 1960s undertook a research and development project to develop a super-tough fiber as a follow-on to the earlier development of nylon and Dacron. Their efforts met with impressive success; the result was a new product, Kevlar, a lightweight fiber that is five times stronger than steel.

The challenge, however, proved to be the development of a market for Kevlar, which took 25 years of effort, $700 million in capital costs, and $200 million in operating costs. Initially, Du Pont planned for Kevlar to replace the nylon in automobile tires. However, tire manufacturers rejected Kevlar in favor of steel because of the public popularity of the phrase "steel-belted radials."

Another target market for Kevlar was the U.S. Army, which was seeking an improved version of the nylon flak jackets that were already in use. Here, a successful market was established, but only after seven years of testing and evaluation by the army. Today, protective clothing is an important market for Kevlar. Other markets that have emerged include the aerospace industry, where Kevlar replaces glass fibers in panels and shapes. Du Pont continues the quest for other mass-market applications. Du Pont is reported to have changed its R&D operating policy as a result of the Kevlar experience. Instead of inventing new products and then seeking a market, it is attempting to identify markets (customer needs) and then seeking to develop new products for those markets.

At the Battelle Memorial Institute, much of the research is commissioned by industry or public-agency sponsors. The Ford Motor Company funded a Battelle effort (*22*) that led to the development of a system using holography to project the image of dashboard instruments into a driver's vision just above the front end of the car. The Battelle researchers believe this same technology could be used to project signs into drivers' vision at locations where a sign structure would be expensive or hazardous. Ford and Battelle have indicated a willingness to license patents to applicants who wish to work on special applications.

PRIVATE-INDUSTRY RESEARCH CHARACTERISTICS

The characteristics and operational strategies of U.S. industry may also be a factor in the limited contributions of the private sector to highway technology. Reporting in the *Wall Street Journal* about Japan's smokestack industries (*23*), Yoder said that Kawasaki Steel Corporation moved into a new high-technology research tower costing $33 million in 1987 while expecting to post a company loss for the same year of $330 million. Kawasaki cut salaries, plants, and employees but not R&D, according to Yoder. Managers were quoted as saying, "We have to bite the bullet today to be able to eat tomorrow. If we don't open new areas, we can't survive. Without research muscle, we have no future." Another Japanese firm, Toshiba, was reported to have developed 30 percent of its products within the last three years. Its management said, "Research is like food—it's the last thing you cut out."

At the same time in the United States, Yoder reported, a major U.S. steel corporation cut research spending in 1982 when losses began and made further cuts in 1983 and 1984, reducing its research staff from 1000 to 450 and finally selling its research center. Other mature U.S. industries have taken similar action regarding research investments.

Weaknesses found in government, industry, and academic support for engineering research may be curtailing U.S. international competitiveness, according to a 1987 Engineering Research Board (ERB) report (*24*). Key opportunities offering the greatest potential for contributing to the economy, national security, and quality of life were reported to include:

- engineered materials such as ceramics;
- construction robotics to reduce labor requirements and increase productivity;
- transportation technologies such as computer detection of road hazards and coordinated vehicle control through radar braking, traction control on slippery pavements, guided steering, and new traffic control systems; and
- deterioration (condition) monitoring in highways and bridges to prevent failures and extend service life.

The OTA, in the 1987 staff paper referred to earlier, reported that privately sponsored R&D by major companies connected with construction amounts to less than 0.33 percent of the total annual value of new construction of the United States. Manufacturers of construction equipment (Deere, Caterpillar, and CMI were studied by OTA) spend about 4.8 percent of sales income on all research (including R&D expenditures for manufacturing processes) but only 0.53 percent on new technologies and processes.

In a case study cited by OTA to illustrate the complex and time-consuming process of implementing an infrastructure innovation, the acceptance and use of precast, prestressed concrete panels for U.S. bridge deck replacement was discussed. The technology for prestressing concrete was initially studied and developed in France in the 1920s, used extensively in Europe for bridge repairs in the 1940s, and used in the United States in the 1950s and 1960s. The OTA report suggests that the U.S. use of precast, prestressed panels for bridge deck reconstruction finally began as a response to a need for reducing traffic disruption rather than because of a new technological development. The redecking of the Woodrow Wilson Bridge across the Potomac River on the southern link of the Washington, D.C. beltway was cited as an example of the effective use of this technology to reduce construction time (in this example by 225 days or 39 percent of the contract completion requirement).

The premise of the ERB report that U.S. technology is not keeping pace with that of international competitors is confirmed by SHRP's selection for use in the long-term pavement-performance study of U.S. pavements of a pavement-surface monitoring device developed in Japan, a falling-weight pavement-deflection-measuring device developed in Europe, and an Accelerated Loading Facility (ALF) developed in Australia.

The United States' research systems suffer from cumulative neglect and from a decentralized and fragmented federal system for research support, according to an article by Bloch (*25*). He recommends increased research support from industry, state and local governments, and other institutions, with the federal government acting as a catalyst rather than sole provider. Bloch also sees a need for improved relations and communication among disciplines, institutions, and industries interested in research.

PRODUCT LIABILITY

In today's litigious society, product liability may be a deterrent to the introduction of new materials by private companies, just as tort liability is to the highway engineer. The principles of product liability law, according to Owen (*26*), are based on four definitions of "wrongful conduct," when a manufacturer:

- misrepresents the safety of a product;
- incorrectly produces a product varying from his own design specifications;
- sells a product without adequate warnings of hidden danger or adequate instructions for safe use; or
- designs a product in a manner that exposes consumers to undue risk.

Current problems cited by Owen include a shift by the courts in the doctrine of liability law, from negligence to strict liability (a no-fault concept), and a shift from "contributory negligence" by a consumer (as a defense for the manufacturer) to principles of "comparative fault," in which a consumer who is at fault in the use of a product can still collect damages on that percentage of the problem attributed to the product. The administration of product liability litigation is exceedingly expensive, time-consuming, enervating, and demoralizing for the participants. Lay jurors may not comprehend sophisticated, complex engineering design issues, and the allowance of punitive damages or damages for intangible losses such as "pain and suffering" invite the typical juror to favor excessive damages against a "world of faceless institutional monoliths," says Owen.

When legal disputes of a technical nature are brought before the courts, the use of arbitrators, as permitted by some states, has reduced legal costs and enabled litigants to be judged on the basis of technical merit rather than "deep pockets" or other emotional bases.

CHAPTER FIVE

CONCEPTS FOR INCREASING INNOVATION—LOOKING AHEAD

With the Congress and national professional and industry organizations showing a renewed interest in and understanding of the need for new transportation technology, the promise of additional activity in highway research is strong. The greatest benefit of such new research, however, should be realized by involving not only government resources but also the funds and talent of the private sector as well. In the following sections, concepts that may remove barriers, provide incentives, and develop tools for private-sector innovation are discussed.

PERFORMANCE SPECIFICATIONS

For at least two decades, the highway community has discussed the merits of performance specifications for highway construction. Progress in advancing this concept, however, has been slow at best, and today relatively few performance specifications are in use in the highway construction industry.

Why such limited progress in developing performance specifications? There are at least two major barriers:

- "Performance" of highway pavement and structure components is required for long periods of time (20 to 50 years or more) and there are no accredited tests or accelerated stress and wear procedures that correlate satisfactorily with long-term performance.
- Warranties, bonds, and other performance guarantees by highway constructors may not be feasible for such long periods under existing insurance underwriting practices.

These two barriers are candidates for research in national publicly funded programs. Such research might seek to develop new tools and processes for administration of highway construction programs that invite innovation.

The Swedish National Road Administration shared in funding a research program (*27*) to explore and assess the use of performance specifications for highway pavements. In the experimental program, the specifications for pavements were confined to two items: a pavement "envelope" or cross section and surface profile and a minimum serviceability index value at or above which the pavement must perform for a specified multi-year service life. The contractors in this experimental program were free to use any materials and designs they chose, provided the pavement envelope and profile requirements were met. The serviceability levels did not have to be met on a maintenance-free basis for the specified life, but the pavement contractor was required to perform any maintenance or rehabilitation work needed to hold the specified minimums during the specified service life.

In order to guarantee the pavement performance, the Swedish experimental program included an innovative approach to performance bonding that enlisted the creative input of the financial community. The resulting program concepts included in the experiment provided for a gradual transition of financial responsibility for the constructed pavement from the contractor to the bonding company. Continuous protection is provided to the owner of the highway. Figure 2 illustrates the concept, with a high level of responsibility (or risk) placed on the contractor during the earliest years, when construction quality is considered the greatest factor in performance, and with a higher responsibility placed on the bonding company in later years, when the risk is lower and the bonding costs and responsibility levels can be lowered for the contractor.

The Swedish experimental concepts require the administration by the highway agency of a long-term contract commitment with the contractor and the bonding company. With a multi-project annual program, under this concept a highway agency could accumulate a substantial number of long-term contracts to be managed for pavements in various stages of life. Also, differences in actual versus projected traffic characteristics and volumes on the pavement would need to be addressed and adjustments agreed on by the contractor/bonding company to recognize the changes in the conditions for which the performance guarantee was made. Although this introduces a new element in the program, a well-designed pavement management system, which should be in place in any event, could monitor contract responsibilities on site-specific pavement sections without difficulty.

Administration of a highway construction contract program based on performance could be simplified by accelerated testing of the newly constructed highway components in place. Today, few if any accelerated tests are accredited, but research under way may provide these tools in the future. The development and acquisition of an ALF by FHWA is a major step toward accelerated pavement performance testing on the site of a constructed highway. The long-term pavement performance studies under SHRP also should contribute to the improvement of pavement performance prediction models that include geographic and environmental factors as well as axle loads.

CONTRACTOR INCENTIVES

Historically, construction contracts in the highway industry have used both bonuses and penalties to motivate contractors

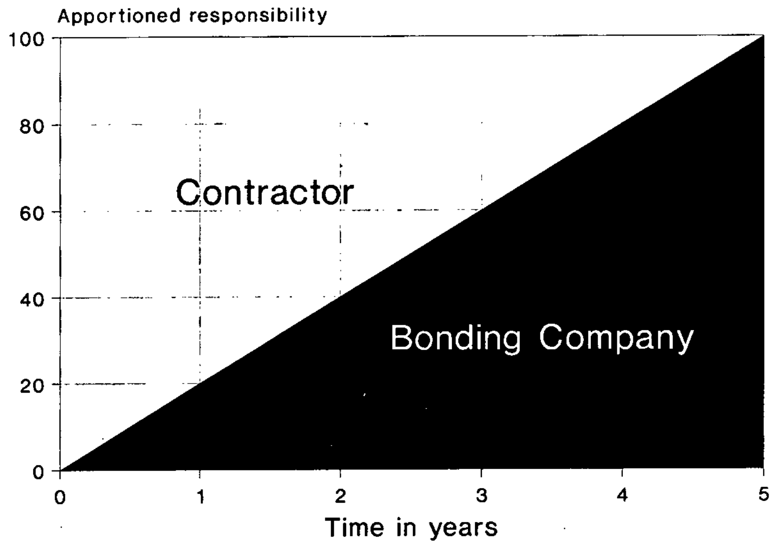

FIGURE 2 Concepts used for pavement performance guarantees in Swedish experimental program.

to meet or improve upon completion dates. In quality control, however, penalties in the form of reduced payments to contractors for highway components that fail to meet specifications (e.g., pavement thickness less than specified), or penalties in the form of requirements to remove and rebuild nonconforming components, have been the primary processes used by public agencies to influence contractor performance. Only a limited number of states, including Oregon, Montana, Arizona, New Jersey, and Virginia, have entered into contracts that recognize and reward contractors for providing enhanced quality of the constructed product. The FHWA has encouraged state DOTs to develop quality incentive clauses in construction contracts, although there are no published policies or guidelines yet developed by FHWA. Approval by FHWA on federal-aid projects has been on a case-by-case basis. One basic requirement for FHWA approval is that a tangible value or benefit must result from the higher quality. A recent study of the quality assurance procedures for highway construction (*28*) included the use of positive incentives or bonus provisions in construction contracts, which allow work of exceptionally high quality to be paid for using factors greater than 100 percent of the bid price. The report presents statistical analyses of improved asphalt pavement densities over a seven-year period in Virginia where an incentive clause was included in the specifications for this pay item. Appendix C provides supplementary information about the New Jersey program for quality bonuses.

VALUE ENGINEERING

In a 1981 review (*29*) of then-current value engineering in highway construction programs (VEIC), eight state DOT programs were evaluated. The reviewers reported that the findings supported the conclusion that the value engineering (VE) programs were effective enough to warrant increased use by state highway agencies. At the same time the reviewers reported that many members of the highway community still believe that the words "value engineering" are just popularized buzzwords for traditional cost-cutting reviews already being done by their agencies. The 1981 study suggested that highway agency executives need to gain a clear and accurate understanding of both the process and the payoffs gained by supporting VE programs.

Although the lack of a nationally accepted definition of value engineering may have affected responses to this project questionnaire, it appears that in the eight-year interim (since the 1981 study) there has been an increasing acceptance and use of VE clauses in construction contracts by state DOTs. Of the 43 states responding to the survey, 18 (42 percent) indicated that they include a value engineering program as a part of their construction contract activities. The basic objective of value engineering clauses in construction contracts is to encourage cost savings by sharing them with contractors who can develop an alternative design or construction procedure that provides an equal or better product for a lower cost. State DOTs with value engineering programs have prescribed procedures for receiving proposals for alternatives from contractors, reviewing and approving or rejecting the alternatives, and sharing the cost savings.

A PennDOT Circular Letter outlining its VEIC program is included in Appendix D. The PennDOT VE program, which was begun in 1979, has realized an annual savings of more than $17.9 million through cost-savings changes in the design and construction of projects (Table 3). PennDOT encourages contractors to participate in the program and has established procedures that reduce the initial costs to a contractor, by inviting a "concept proposal" for preliminary review and action before the contractor invests in a large design effort, and expedite the review process to provide a response to the contractor within seven days of receipt of both the "concept proposal" and of the design proposal (Figure 3). When a concept proposal is approved, the contractor is asked to indicate the date when the final design proposal will be ready for review. PennDOT then appoints a five-person review committee, designates a team leader and work place, and relieves the review team of all other duties during the seven-day (maximum) review period.

TABLE 3

PENNDOT VALUE ENGINEERING SUMMARY

Year (Jan.-Dec.)	Total Projects	Original Cost	Design Projects	Cost Savings Design	Construction Projects	Cost Savings Construction	Total Cost Savings
1979	1	17,652,000	1	438,060			438,000
1980	26	334,021,000	17	13,151,138	9	450,038	13,601,176
1981	76	397,829,161	64	14,307,043	12	786,826	15,093,869
1982	108	385,486,691	90	15,785,448	18	318,733	16,104,181
1983	171	552,684,749	159	26,302,437	12	912,684	27,215,121
1984	180	561,550,097	160	17,242,561	20	1,313,682	18,556,243
1985	201	733,166,419	182	24,132,323	19	472,640	24,604,963
1986	164	806,676,155	145	25,260,212	19	1,803,792	27,064,004
1987	131	677,359,354	118	17,564,896	13	1,007,014	18,571,910
9 years	1058	4,466,425,626	936	154,184,118	122	7,065,409	161,249,527

Average cost savings per project equals 3.6 percent.

The Maine Department of Transportation permits a contractor who proposes and wins approval of a cost-reduction change in a contract to deduct all "reasonably incurred costs" in developing the proposal before computing cost savings to be shared equally with Maine DOT.

In the North Carolina DOT, value engineering activities are handled by a Pavement and Value Engineering Section. The section, a permanent part of the Design Services Unit of North Carolina DOT, handles new-product evaluation and construction contract value engineering proposals and initiates other studies to evaluate cost-avoidance or cost-saving opportunities.

Some of the states employing a value engineering clause in construction contracts stipulate that the concepts and data presented by the contractor for evaluation, if approved and accepted by the state, are thereafter available to the state for its future use. In effect, this means that the value engineering concept wins for the contractor an award of, typically, 50 percent of the resulting cost savings on the project for which the change was approved, and the state realizes an equal savings on the project and a cost-saving alternative for use in future projects.

LIFE-CYCLE COSTS

The use of life-cycle costs rather than initial costs for highway construction contracts is another concept that could invite innovation from the private sector. Currently, the same limitations that prevent the use of performance specifications affect life-cycle costing: a lack of reliable accelerated testing from which to establish service life and the impracticality of long-term guarantees in the construction contracting industry. Some degree of life-cycle cost analysis is practiced by most highway agencies in selecting materials, designs, and construction practices to be incorporated in specifications, even though the resulting contracts are awarded on the basis of lowest first costs. Such procedures, however, involve only limited, if any, participation by private industry and thus fail to invite the innovation that might be offered by industry to provide optimum life-cycle costs.

In other areas of highway technology, progress is being made in the use of service life costs. An example is provided by the "total cost bid" process (*30*) used by the Michigan Department of Transportation for certain maintenance equipment purchases (Appendix E). The Michigan program determines the total cost bid for equipment units to be the base purchase price, added to the guaranteed scheduled maintenance cost and the guaranteed repair cost over a pre-established service life, less the guaranteed repurchase price.

COOPERATIVE RESEARCH

The California Department of Transportation (Caltrans) has begun a three-year highway research project (*31*) to test the feasibility of electronically linking traffic condition information with computerized mapping devices in automobiles.

The research project is a cooperative venture between Caltrans, FHWA, and General Motors. General Motors has donated 25 cars, each specially equipped with an electronic map of Los Angeles streets displayed on a console screen on the dashboard. The in-vehicle navigation system will receive and display traffic and accident information from Caltrans's traffic operations center and display alternate routing information.

Caltrans is providing $900,000 for the research project, and FHWA is contributing $750,000 and technical support.

PRODUCT EVALUATION

Aside from the construction contracting process, there are other opportunities for highway agencies to invite innovation from the private sector. Product evaluation is performed in a typical highway agency for the purposes of determining product acceptability for direct purchase by the agency to use in its operations and maintenance practices or for use by contractors for incorporation in the constructed highway. In either event, the evaluation, if successful, may lead to the incorporation, in

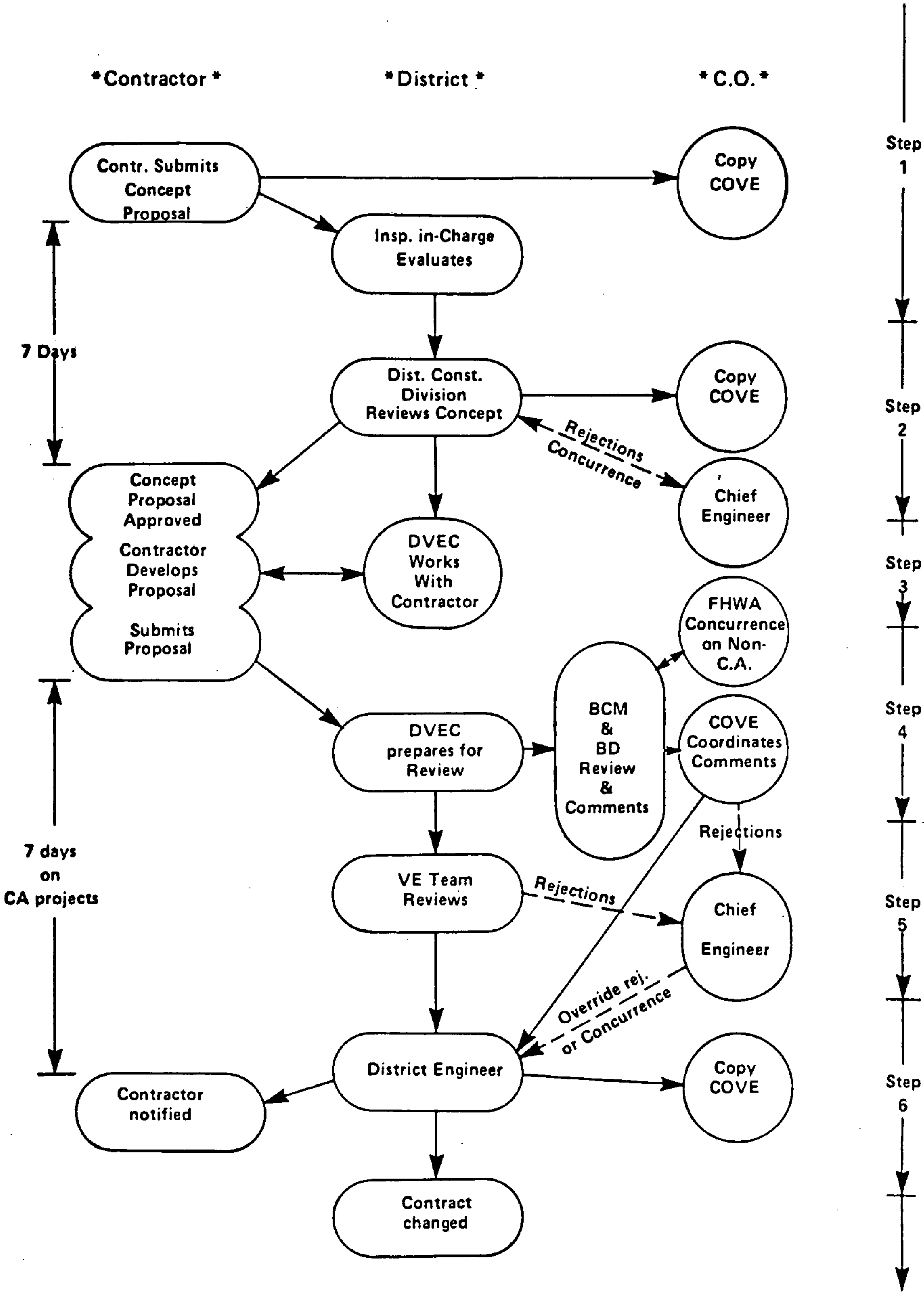

FIGURE 3 Construction value engineering flow chart.

the highway agency specifications, special provisions, or other documents, of stipulations necessary to accept that product in future purchase orders or construction contracts. When funding for the contracts is provided in part by FHWA or another agency, final acceptance of the innovative product will depend on the validity of the evaluation as viewed by that funding agency.

As noted earlier, 67 percent of the agencies surveyed reported that they have formal evaluation procedures, usually administered by an evaluation committee and documented by the agency staff. Although some evaluations of performance last as long as five years before acceptance, most state highway agencies can show a long list of new products that have passed through the evaluation process successfully and are now accepted norms of practice in those states. A significant factor, however, is the similarity of those lists. Many products have been evaluated in each state with probable duplication of costs in time and money to both the state highway agencies and the manufacturer. Table 4 lists some of the new products reported by one or more of the state or provincial agencies responding to the survey. An inspection of this list suggests that many of the products are of regional or national interest and could be evaluated by regional or national centers more efficiently.

At a 1988 highway research conference (*32*) in Florida, the conferees concluded that "much redundant evaluation is done for many new products because there is no national data base for evaluation data and the sharing of data between states is minimal." The conference recommendations included strong support for a national clearinghouse for evaluation data.

An alternative not currently available but one that appears to have merit is a system whereby the testing of a new product would be done by a single testing entity, national or regional, and the results of the tests accepted and acted on (either approving or disapproving use of the product) by all state highway agencies or all in the region. In the consumer goods industries, testing and acceptance done by such organizations as the Underwriters Laboratory may serve as an example for application in highway markets.

TABLE 4

SUCCESSFUL PRODUCTS REPORTED BY PUBLIC AGENCIES SURVEYED

Aluminized steel	Long-life coatings for structural steel
Aluminum culvert	MDM drainage mat
Antistripping additive	Microsilica additive for concrete
Asphalt boiler slag	Mudjacking with fly-ash grout
Asphalt pavement recycling cold, in-place	Neoprene pads for capping cylinders
Bituminous adhesive for raised pavement markers	Pavement rollers
Bitumuls cationic emulsified asphalt	Plastic-coated dowel bars
Calcium chloride	Polymer concrete patching materials
Carsonite modular glare screen	Polymer fibers in cold asphalt patching materials
Cathodic protection	Pozzolith, Master Builders
Concrete sealers	Pressure injection of urethane grout
Corrosion inhibitors for PCC	PVC underdrains
Corrugated polyethylene culvert pipe	Quick-set cements
Emulsified asphalt primers	Roadglas fabric
Emulsified asphalt hot mix	Roller-compacted concrete
Epoxy paints, pavement markings	Rubber RR crossings
Ero-mat erosion control	Rut depth & cross section measuring systems
Fabriform erosion-control mats	Safebrite reflector
Falling-weight deflectometer	Silicone joint sealers for PCC
"Fast-track" concrete for short-cure, early-use paving	Single-component polyurethanes
Flex-A-Heat system for bridge decks	Skid testers
Flexible-post traffic channelizers	Slurry seal
Flexible delineator posts	Snow fence
Fly ash in PCC	Soil-retention blanket
Geogrids, Tensar	Soil-reinforcement fabrics
Geotextiles	Sound barriers
Glass capsule anchors	Spiral rib aluminum pipe
Hilti resin anchor system	Stimsonite 948 raised pavement markers
Hold-Gro, Gulf States Paper	Styrofoam, Dow Chemical
Hot lime slurry for soil stabilization	Teflon bridge bearings, DuPont
Hydro-Mulch	Temporary lane line markers
Hydraway edgedrains	Tensar reinforcement grid
Inertial profilometers	Thermoplastic pavement-marking materials
Laser & video technology for pavement evaluation	Thin-bonded concrete resurfacing, bridge deck overlays
Latex	Tunnel-icing warning system
Latex-modified concrete overlays	Water blaster for concrete removal
Laykold resurfacer, Chevron Asphalt Company	Water-reducing admixtures
Lead silica chromate paints	Watson-Bowman Waboflex joint systems
Lignon sulfate road binder	
Lignosulfate dust palliatives	
Lime in asphalt	

There have already been some limited moves in the direction of national or regional testing centers. Through an agreement with NIST, AASHTO operates a National Materials Reference Laboratory (AMRL). Housed on the NIST grounds in Maryland, AMRL operates a program of monitoring state materials laboratory performance to promote uniformity and consistency in testing procedures and test results throughout the AASHTO membership and to provide certification for those state research and testing laboratories that meet the required standards. The AMRL program, however, only applies to standard materials tests and does not monitor or evaluate new-product testing procedures or results.

At the Conference on Pavement Marking and Signing Materials (*33*) held in Mississippi in 1987, the delegates approved the concept of establishing a regional test facility for pavement marking and sign materials. At the subsequent 1987 Southeastern Association of State Highway and Transportation Officials (SASHTO) Convention in South Carolina, an ad hoc committee was assigned the responsibility of evaluating and reporting on the initial and continuing operating requirements and costs for such a regional test facility.

At Pennsylvania State University FHWA has established a Pavement Marking Test Center as a two-year demonstration program. This center develops data on the initial cost and performance of various pavement-marking materials to produce life-cycle cost information suitable for use in procurement procedures for states where environmental conditions are similar. Betsold reports (*1*) that representatives in the states of Washington and Wisconsin have expressed interest in similar test centers in their regions.

On a national level, a 1987 report on FHWA research (*34*) included a recommendation that consideration be given to expanding the activities at the Turner-Fairbank Highway Research Center to include service as a national testing center for new highway materials, hardware, and other technologies.

RESEARCH NEEDS LISTS

Private organizations serving the highway community need a clear understanding of the technological gaps and problem areas for which the highway agencies are seeking solutions. Although there is a dampening effect on technological changes caused by the massive quantities of basic materials used to build highways, there are opportunities to overcome some of this effect if the highway community can act in concert.

None of the surveyed state highway agencies and only one provincial agency indicated that they published a research needs list for distribution to industry.

A strong national consensus on top-priority, critical research needs could be published and publicized by a national highway organization on an annual or biennial basis. With the definition of the market for a product filling that need, and evidence that the marketplace would be open to new innovations, such a publication should encourage private industry to respond with a focused R&D effort.

The creation in 1988 by AASHTO of a new Standing Committee on Research, with broad responsibilities for fostering and coordinating highway research activities, provides a candidate organization to undertake the development of a national consensus on priority research needs. Such a consensus could serve as a guide to the Nationally Coordinated Program of Highway Research, Development, and Tecnology, NCHRP, and other public-program research agendas as well.

There are many activities under way that are already open to private industry that identify research needs in the highway community. Through its committees, special studies, and conferences, TRB gives a major emphasis to the identification of research needs, and has published periodic statements of researchable problem areas of national significance (without specific funding sources suggested). The TRB also has prepared and published periodically in *TR News* a listing and discussion of "critical issues" to the transportation community. These "issues" often include technological needs for which additional research is required. With appropriate participation by AASHTO and FHWA, the TRB "critical issues" discussions might be expanded to include a more specific definition of research needs and be published on a regularly scheduled annual or biennial basis. Many states have established joint committees with private industry to discuss technology needs and opportunities. When established by the Highway Research Coordinating Council, the HRCC-industry committee will provide another valuable interface with public highway agencies and an opportunity to exchange information on new research needs, ongoing research programs, and opportunities for industry participation in research.

JOINT RESEARCH EFFORTS

Jointly funded research involving government agencies, nonprofit agencies, or private companies offers many advantages but presents many complexities and difficulties. In the advantage category, industry and government joint research taps the talent and financial resources of the nation; provides insight from the manufacturer and marketer viewpoint and from the purchaser and user perspective; and should result in products more readily accepted by highway agencies.

Efforts to resolve issues that may have complicated joint research efforts in the past, such as ownership of intellectual property, processes for selecting private-agency partners, and managing the research partnership, have been assisted or at least opened to new alternatives for resolution, by the previously discussed federal initiative.

CHAPTER SIX

CONCLUSIONS

The highway programs in the United States are facing multiple challenges in this time of change. The physical facilities, particularly pavements and bridges, are deteriorating because of age and heavy traffic use. Highway agency responsibilities are shifting from new construction to maintenance and rehabilitation. Program demands exceed available funds under present revenue-generating legislation.

In the face of these challenges, the highway community is recognizing the need for new technology to reduce the costs and improve the performance of the system. Renewed support for research is evident in national programs such as SHRP and the University Transportation Centers.

Private industry has made significant contributions to the advancement of highway technology, both in privately funded research and in cooperative product-development efforts with government agencies. The full potential for technological advancement through the private sector, however, has not been realized. When compared with the products being developed and marketed in other areas such as electronics and communications, the highway industry has lagged far behind.

A look at the status of industry involvement in highway technology development reveals several important findings. Valuable contributions have been made by private industry. For example, pavement-evaluation equipment, including deflection measurements, roughness, rutting, surface distress, and skid-testing equipment, is available today using state-of-the-art technology for sensing and recording data. Construction equipment and materials developments through private-manufacturer research have increased the quality and productivity of construction and rehabilitation projects.

Partnerships for research and development between public agencies and private organizations have been established and have been effective in bringing new technology to the highway community, although they can be difficult and time-consuming. Usually, the "partnership" is informal and consists of a government agency calling in manufacturers to take a concept or prototype developed by the public agency and complete the production engineering and manufacturing processes needed to bring that technology to the market. A good example of a partnership effort is offered by the development of epoxy-coated reinforcing bars, where public research advanced the concept for protection of embedded steel in concrete structures and private development brought the epoxy material and coating process to the market.

Public-agency procurement processes have a major impact on the innovation coming out of the private sector. On the positive side, the incorporation of value engineering clauses in construction contracts has stimulated the contracting industry to evaluate construction activities and to seek and present cost-saving alternatives to the public-agency owner. The establishment of formal new-product evaluation programs in state transportation departments is beneficial in that it gives the private sector a "place to go" and, in some instances, promises early action and feedback on the results of the evaluation.

However, national guidelines are needed to reduce or eliminate the variability of the evaluation processes and to provide comparable documentation of results. National or regional acceptance of innovative technology is still largely a state-by-state process. The lack of national guidelines and a data clearinghouse for new-product evaluation has contributed to much redundancy and sometimes inadequate processes. Also, procurement processes are still limited in their ability to accommodate life-cycle costs (which invite higher quality, innovative products) instead of first costs as the basis for contract awards.

Communication between public and private organizations concerning the nationwide needs for new technology or concerning the availability of new products does take place in most states and at the federal level. The effectiveness of such communications may be hampered when done on a state-by-state basis, and may be more effective when it is accomplished on a structured basis by national joint committees or regional subcommittees.

Definitions of many product requirements continue to specify physical or chemical characteristics that may prevent innovative alternatives from being offered by private industry. Reliable, usable, accelerated tests of product performance have not been developed for many highway products in the United States. Although the merits of performance specifications (where a specific service for a specific period of time is stipulated) are recognized, progress in developing definitions or in developing accelerated tests that correlate with long-term performance has been slow and has limited the use of performance specifications in the United States for highway construction, maintenance, or rehabilitation.

CHAPTER SEVEN

RECOMMENDATIONS

There are several positive actions that can be taken by the highway community to foster R&D investments by the private sector. In each case, some preliminary or limited steps are already under way, but there is not yet a national focus and commitment to move industry into a major role in advancing highway technology.

It is unlikely that private industry will ever assume the primary responsibility for research in highway technology. First, because the highways are funded, planned, designed (in-house or by a consultant), and operated by public agencies, the public agencies are responsible for meeting the technological needs. Second, the technological needs do not, in all cases, represent an opportunity for new commercial products or major markets. For example, the earlier traffic engineering research that led to the use of one-way streets in urban areas did not involve significant new products or new market opportunities for private industry. Third, to define the needs and share the risks, public agencies must serve as catalysts through early development of basic technologies that can be adopted, refined, produced, and marketed by private companies.

Private-sector contributions to highway technology are more likely to supplement rather than supplant publicly funded highway research. Indeed, the need is sufficiently great that maintaining or increasing public highway research programs is essential, even if supplemented by a substantial increase in private-sector research in highway technology. The challenge, then, lies in operating public research programs that advance and encourage the commercialization of new technology, and in operating public-procurement systems that accommodate and reward private-sector investments in research and development. The following actions can contribute to those objectives.

Centralize testing and approval of innovative highway products offered by the private sector. A national laboratory and/or several regional laboratories should be established to design and conduct unique tests and evaluations of innovative new products and processes. (The facilities should *not* perform the standard tests that any qualified commercial laboratory can provide.) Such facilities could significantly reduce the time and cost of testing new technology both to industry and to highway agencies. In order to be effective such facilities would need to have certain characteristics. They should:

- Be staffed and equipped with highly qualified people and state-of-the-art testing equipment and facilities.
- Serve as an information clearinghouse for test results and field performance records of new products from in-house evaluations and from other reliable sources.
- Develop and refine evaluation guidelines and new procedures, as required, for product testing.
- Be supported by an advisory organization whose members are drawn from the federal, state, and local government highway operating agencies. The involvement of these advisory groups should be such that the agencies they represent will accept and act on the tests and evaluations as their own.
- Invite cooperation and observation of the testing and evaluation procedures by the private organization submitting the new product for testing and evaluation. Such cooperation will permit private industry to learn from the tests and evaluations where further development may be required, where applications are most effective, or where successes and failures can guide decisions of the private organization.
- Be operated independently by an existing or newly formed public agency, and be self-supporting through appropriate fees paid by the private-technology innovators for the tests performed. Testing and evaluation fees also will serve to screen out casual or excessive submissions by unqualified or unprepared applicants.

Develop and incorporate value engineering clauses in highway contracts for construction, rehabilitation, and maintenance. The use of value engineering provisions to share cost savings with manufacturers or contractors is an effective means to invite innovation and to realize immediate returns. The development of national standard value engineering provisions, suitable for incorporation in most state or local government construction contracts, would provide a valuable, consistent, standard tool for street and highway agencies and contractors. Although value engineering changes in construction contracts are more likely to encompass changes in design or changes in construction processes, it is possible that alternative materials and equipment may be introduced by this route as well.

Develop and expand the use of standard contract provisions that provide quality incentives for construction contractors. The concept of providing contractors with extra compensation for useful enhancement of construction products above the specified minimum quality levels may offer another opportunity for private-sector innovation to be introduced to the highway community. Important to quality-incentive clauses in construction contracts are the criteria to be used to confirm or reject the "useful" requirement in assessing the enhanced quality. Longer service life, better ride quality, greater visibility, fail-safe design, safer installation/operation, and easier/quicker replacement are some of the criteria that may be considered in defining "useful" increases in quality. Additional studies and regular monitoring of projects already built under quality-incentive programs may be needed if quality levels are to be quantified as well as classified.

Develop performance specifications and life-cycle cost analyses. The option to use life-cycle costs in highway construction contracts is currently limited by the lack of reliable, accredited analytical procedures. The current increased research on materials in SHRP may provide new accelerated performance-testing capabilities. Alternative routes to performance specifications also need to be explored. This could involve the development of contracts in which the long-term responsibility for the constructed highway rests with the contractor. Such contracts might use the concept being studied in Sweden for sharing the long-term performance risk between the construction contractor and the bonding company. Another alternative that merits study is the development of a two-part contract in which the contractor bids on the construction of the highway and on the annual maintenance of the highway (for some multi-year term such as five years) in a single total cost bid. Such an arrangement should motivate the contractor to seek the most cost-effective combination of original construction costs and annual operating costs. Including a contract-renewal option for the highway agency for another maintenance term might provide an additional incentive for the contractor to build for long-term service life.

In a construction and maintenance contract, it would be necessary to address the effect of maintenance on the highway user also. Some arrangement to assure continuous proper service levels for highway users would be required in the contract.

The primary objective for establishing performance specifications is to permit the contractor to use chosen design, materials, and construction procedures (within the owner's "design envelope") so long as the highway components perform as specified over the specified life term. Such a contract program could invite and encourage innovation, but the administration of the program would require special care in establishing prequalification standards for contractors.

An additional requirement for performance specifications is the development and accreditation of accelerated testing and evaluation procedures that correlate well with long-term performance and that still leave the contractor free to use chosen design, materials, and construction procedures as long as they produce highway components that satisfy the accelerated tests.

Draft and update periodically a research needs list that represents a national consensus on technology gaps in the highway industry. If this exercise is given sufficient exposure through the available communications systems, and if the development and updating of technological needs draws upon the major public-works organizations (such as AASHTO, TRB, U.S. Army Corps of Engineers, FHWA) with a strong and evident consensus among the street and highway agencies, it could serve as an important motivator for private-industry R&D efforts if industries see potentially marketable, profitable products as the results.

The process of identifying technological needs and assigning priorities to these needs will require careful planning and development in a joint effort with broad representation of public highway agencies and private organizations serving the highway industry. The HRCC, being formed by TRB at the request of AASHTO, could be an effective existing organization to contribute to this task. Through the planned HRCC-industry committee private industry could contribute to the identification of the technology needs and priorities as developed by HRCC and also serve as direct-line communicators in informing others in the private sector of markets and opportunities.

The HRCC-industry committee might undertake several tasks as a part of setting a research agenda:

- Develop a procedural plan whereby the private sector could contribute specific recommendations for the regular periodic identification of technological needs to serve highway systems.
- Expand the technology needs information to include recommendations regarding the research programs or organizations under which each need should be addressed, including key roles for industry and public-private partnerships.

With the exception of performance specifications, the recommendations can be acted on at an early date. Performance specifications will require additional study of technical and procedural issues (both legal and administrative), but such studies can and should also begin at an early date.

Highway agencies and private industry must find new and effective ways to establish partnerships for the introduction of innovation. Through such partnerships we can meet the challenges of international competition, provide for a healthy domestic economy and satisfy the ever-increasing need for service and safety on our nation's highways.

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APPENDIX A

STATE, PROVINCIAL, AND PRIVATE-SECTOR QUESTIONNAIRES AND RESULTS

A. Public Agencies

1) What does your agency do to invite innovation in the materials, equipment, designs, and services provided to you by the private sector?

a wish list published

b conferences with private sector

c joint research with private sponsors

d joint committees with private industry

e value engineering for construction contracts

f value engineering for other projects

g other

2) What does your agency do to respond to invited and uninvited innovation offered by private sector?

a prompt, receptive evaluation procedures

b trial installations

c joint evaluation

d consultation and guidance

e other

3) What successful products, introduced within the last five years, are you now using as a result of one or more of the foregoing actions? List products and processes leading to acceptance.

B. Private Agencies

1) How do you decide whether or not to invest in R and D for the public highway market? Please offer explanatory comments.

a size of market

b characteristics of highway marketplace

c receptivity of known public agencies

d as a result of other potentially applicable technical development

e as a result of recognized gaps (needs) listed by public agency

f other (specify)

2) What markets do you seek? Please offer explanatory comments on why these markets were chosen or rejected.

a contractor sales only

b specialty sales

c negotiated sales (not bid)

d small local governments only

e volume markets

f open, public bids

g other (specify)

3) What innovative products have you succeeded in selling to the public market within the last ten years?

Please list products' processes for introduction to market, time required, and general level of funds expended in the effort.

Public Agencies

AGENCY	1a	1b	1c	1d	1e	1f	1g	2a	2b	2c	2d	2e
Georgia DOT		X			X			X	X	X	X	
Vermont Agcy. Trans.		X						X	X		X	
Hawaii DOT					X						X	
Illinois DOT				X	X		X	X	X	X	X	
Wyoming Highway Dept.							X				X	
Nevada DOT							X		X	X	X	X
Missouri Highway & Trans.		X	X	X			X	X	X	X	X	
Idaho Trans. Dept.		X		X					X		X	
Manitoba DOHT		X	X					X	X	X	X	
Minnesota DOT		X	X	X	X	X	X	X	X	X	X	X
South Dakota DOT		X			X				X			
Texas DH&PT		X		X				X	X	X	X	
Rhode Island DOT							X		X			
Maryland SHA			X		X			X				
Iowa DOT		X	X	X		X		X	X	X	X	
Kansas DOT		X	X	X	X			X	X	X	X	
Neb. Dept. Roads							X		X			X
New York SDOT		X		X	X		X	X	X		X	
Arkansas SH&TD								X	X			X
Florida DOT				X	X	X		X	X	X	X	
Washington S. DOT		X	X	X	X	X	X	X	X	X		
Louisiana DOT		X	X	X				X	X	X	X	
Indiana DOT		X		X				X	X			
Michigan DOT				X	X			X	X	X	X	
Ohio DOT				X					X	X	X	
North Dakota SHD					X							X
Mississippi SHD		X		X				X	X	X		
Colorado DOH								X	X			

AGENCY	1a	1b	1c	1d	1e	1f	1g	2a	2b	2c	2d	2e
Arizona DOT				X	X		X	X	X	X	X	
North Carolina DOT						X		X	X			
Mass. DPW									X	X		
Ontario MOT	X	X						X	X			
Maine DOT				X	X		X		X			
Connecticut DOT							X	X	X	X		X
Wisconsin DOT		X		X					X		X	
Virginia DOT		X				X		X	X			
PennDOT		X		X	X		X	X	X	X	X	
Sas-katchewan		X	X	X				X	X	X	X	
D.C. DPW		X					X		X	X	X	
West Va. DOH		X		X	X	X	X	X	X	X	X	
N.M. SHTD							X	X	X			
Caltrans		X	X	X	X	X		X	X	X	X	
Alabama SHD								X	X			
Tenn. DOT			X						X		X	
New Brunswick							X		X	X	X	

Private Agencies

AGENCY	1a	1b	1c	1d	1e	1f	2a	2b	2c	2d	2e	2f	2g
Amoco Oil Co.	X	X					X					X	
GM Research Lab				X		X		X	X				
Trucking Res. Inst.					X								X
3M Co.				X	X	X	X	X	X	X	X	X	
K.J. Law, Inc.	X	X							X			X	
Nat'l. Asphalt Pavmt. Assoc.			X			X		X	X		X	X	
Pavt. Cond. Eval. Services	X	X	X		X								X
Chemical Lime Co.	X	X		X				X					
Harco Tech-nologies Corp.	X			X				X	X				
Engineering Devel. Co.						X		X					X
Infrastruc-ture Mgmt. Services	X		X	X	X	X			X		X	X	X

APPENDIX B

ALASKA LAW ESTABLISHING A SCIENCE AND ENGINEERING ADVISORY COMMISSION

LAWS OF ALASKA

1986

Source

CSHB 693(SA) am

Chapter No.

32

AN ACT

Establishing the Alaska research policy.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF ALASKA:

THE ACT FOLLOWS ON PAGE 1, LINE 8

Approved by the Governor: May 24, 1986
Actual Effective Date: August 22, 1986

AN ACT

Establishing the Alaska research policy.

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* Section 1. AS 44.19 is amended by adding new sections to read:

ARTICLE 14A. ALASKA RESEARCH POLICY ACT.

Sec. 44.19.250. PURPOSE. The purpose of the Alaska Research Policy Act is to establish state research policy, priorities, and goals, and to provide a plan for basic and applied scientific research for the state, including natural resources and materials, physical, biological, and health sciences, and social and behavioral sciences.

Sec. 44.19.252. STATEMENT OF POLICY. It is the policy of the state in AS 44.19.250 - 44.19.264, to recognize the important role that scientific and engineering research and science education play for the people of the state and the entire nation. The policy will make it possible to

(1) find, develop, and manage the natural renewable and nonrenewable resources of the state's land and water economically and in an environmentally acceptable fashion;

(2) manage the unique features of the environment, fauna, and flora of the state and protect them from harmful man-made and natural influences;

(3) investigate and mitigate the effects of natural hazards such as earthquakes, volcanic eruptions, avalanches, permafrost, and other hazards that occur in the state;

(4) construct, operate, and maintain transportation

systems, communications, housing, and other facilities suited to the state's conditions;

(5) develop new technologies adapted to the unique conditions and needs of the state;

(6) improve the health and well being throughout the life cycle of the state's inhabitants; and

(7) identify and address future social and economic challenges facing the state.

Sec. 44.19.254. SCIENCE AND ENGINEERING ADVISORY COMMISSION. The science and engineering advisory commission is established as a permanent advisory agency in the Office of the Governor.

Sec. 44.19.256. MEMBERS OF COMMISSION. (a) The commission is composed of five members appointed by the governor as follows:

(1) one member is to be appointed from individuals from the academic institutions of the state with expertise in areas of research relating to the state including the physical, biological, health, environmental, social, and behavioral sciences;

(2) one member is to be appointed from individuals who are engaged in activities furthering the welfare of the human and physical environment and who have expertise in areas of research relating to the state, including the physical, biological, health, environmental, social, and behavioral sciences;

(3) one member is to be appointed from state departments with research needs; and

(4) one member is to be appointed from individuals familiar with the state and representative of the needs and interests of private industry;

(5) the senior science advisor in the governor's office, who serves as chairman and director of the commission.

(b) The members must be residents of the state and shall be appointed without regard to political affiliation.

Sec. 44.19.258. TERM OF MEMBERS OF COMMISSION. Members of the commission, other than the senior science advisor, serve staggered terms of four years and until a successor qualifies and is appointed.

Sec. 44.19.260. EXPENSES AND PER DIEM. A member of the commission serves without compensation but is entitled to travel expenses and per diem prescribed for state boards and commissions under AS 39.-20.180.

Sec. 44.19.262. DUTIES OF THE COMMISSION. The commission shall

(1) with the senior science advisor, develop and recommend an integrated state research policy;

(2) provide policy information to the governor and the legislature on matters that have scientific and engineering significance;

(3) receive scientific and engineering information from the academic and industrial communities;

(4) act in an advocacy role for scientific and engineering issues and science education important to the state that might otherwise be overlooked;

(5) assist state agencies in assessing research needs and establishing priorities among them;

(6) facilitate cooperation between state agencies and the University of Alaska and other academic institutions and industry;

(7) recommend methods to improve logistical planning and support for needed state research;

(8) suggest methods for improving efficient sharing and dissemination of data and information in the state among interested public and private institutions;

(9) promote science education and training for young scientists and engineers to pursue careers in the state and the Arctic;

(10) cooperate with the Federal Arctic Research Commission in the formulation of the Arctic research policy; and

(11) not later than September 30 of each year, present to the governor the commission's recommended research priorities of the state for the next fiscal year.

Sec. 44.19.264. SHORT TITLE. AS 44.19.250 - 44.19.264 may be cited as the Alaska Research Policy Act.

* Sec. 2. Notwithstanding AS 44.19.258, added by sec. 1 of this Act, the initial terms of members of the science and engineering advisory commission, other than the senior science advisor, shall be set under AS 39.-05.055(2).

CONSTRUCTION

OPERATIONS BULLETIN

OB Number	O.B. 89-2A
Effective Date	8/23/89
Approval	M. B. Kjetsaa, Director Const. & Maint. Engr. Support

TITLE:

STATISTICAL CONCRETE SPECIFICATION

I. PURPOSE

To instruct Construction Personnel in procedures required using the new Statistical Concrete Specifications under Section 914 of the NJDOT Specifications.

II. SUPERSEDE

This Bulletin supersedes Construction Operations Bulletin 89-2, dated 5/8/89.

III. RESPONSIBILITY

Resident Engineer and Project Personnel
Regional Materials Personnel

IV. PROCEDURE

A. Determination of Lot Size

1. The maximum lot size is one day's production for each class of concrete; however, at the option of the Engineer, any lot may be subdivided into two or more smaller lots.

2. The quantity of each lot will be the plan quantity of the item that was poured or the amount delivered and used. For example, if pouring an entire footing with a plan quantity of 30 C.Y., the lot size will be 30 C.Y. If the entire item is not completed in one day's pour, the lot size will be equal to the amount of concrete delivered and used (not counting any waste) each day except for the final day's pour which will be equal to the difference of the plan quantity minus the previous lots poured.

Example:

A retaining wall with a plan quantity of 130 C.Y. is being poured over 3 days.

Day 1 - 45 C.Y. delivered to project
Day 2 - 45 C.Y. delivered to project
Day 3 - 45 C.Y. delivered to project

The lot sizes will be as follows:

Day 1 - 45 C.Y.
Day 2 - 45 C.Y.
Day 3 - 130 C.Y. - 45 C.Y. - 45 C.Y. = 40 C.Y.

3. Information for all concrete pours must be relayed to Regional Materials personnel. When requesting the Regional Materials personnel for plant inspection, the Resident Engineer will give the following information for each lot:

a) Item number and description
b) Class of concrete
c) Amount of pour (C.Y.)
d) Pay unit of item (L.F., C.Y., S.Y., etc.)

When the pour is completed, Regional Materials Personnel will contact the Resident Engineer for the actual pay unit quantity for each item inspected.

B. Requesting the "Pay Factor Summary Report"

1. When requesting the "Pay Factor Summary Report", Form T-CYL-1723 must be completed (original and copy for project records). DP Number, Job Description and Federal Project Number must be entered in the designated spaces. Also, the desired FROM and TO dates must be entered in the proper spaces. (See Attached Sample)

2. The Form must then be sent to the Statistical Concrete Coordinator at the Bureau of Materials for processing.

C. Pay Factor Summary Report

The Pay Summary Report is a computer generated report that summarizes the contract adjustments that will be made due to the results of the concrete testing as set forth in the statistical concrete specification. Bonus and/or credits are summarized for each lot of a particular item and on a project-wide basis if the lot status is ACCEPT. If the lot status is designated FAILED, the initial strength tests have failed and a retest must be performed either through non-destructive testing (Swiss Hammer, etc.) or through coring. These procedures are detailed in Section 914.02 of the Supplemental Specifications.

Each month when processing the Monthly Estimate, the Resident Engineer should make payment for the bonus and/or credits. These payments or credits will be made under a contract item. If this item does not exist, it must be created by change order.

D. Rejection of Concrete

1. The Supplemental Specifications, Section 914.02 specify three options available when the core test results exceed the maximum allowable percentage in Table 914.4:

   a. Require the contractor to remove and replace the defective lot without additional compensation.
   b. Allow the contractor to leave the defective lot in place and receive a percent pay adjustment (PPA) of minus 50 percent, or
   c. Allow the contractor to submit a plan, for approval, for corrective action to be performed at no expense to the Department. If the plan for corrective action is not approved, either option (a) or (b) may be applied.

   NOTE: All of these options shall be discussed with Design, Materials and the Regional Construction Engineer to determine the proper course of action. The contractor shall be notified in writing of this decision.

2. When options (a) or (b) are chosen, Form T-CYL-1749 must be filled out (original and copy for project records) and sent to Statistical Concrete Coordinator at the Bureau of Materials. Construction personnel must complete the DP Number Job Description, Lot Number, Date Cast, Item Number and Status. All entries should be right justified. This information can be obtained from the "Pay Factor Summary Report". Do not enter Job Number (Cols. 1-6). This will be filled in by Materials personnel. Enter the following for status:

   "X" - If concrete has been approved for 50% payment.
   "R" - If concrete has been rejected.

   (Refer to attached samples and flow chart).

IV. STANDARD DISTRIBUTION B

EXAMPLE #1 (Pay-Adjustment Item)

Item: Bridge Deck

Class: A ← (Table 914-2)

28-day Test Results: 4870, 4630, 4180, 4520, 4360, 4490 ← (Test = average strength of cylinder pair)

N = 6 (RETEST LIMIT for pay-adjustment item, Class A, Table 914-4)

X_{min} = 4180 ← (Lowest test value ≥ 3600, retest not required)

$\overline{X}$ = 4508 ← (Average, to nearest whole value)

S = 235 ← (Standard deviation, Eq. 3, Subsection 914.02 (e), to nearest whole value)

(CLASS DESIGN STRENGTH, Table 914-3)

$Q = \frac{4508 - 4200}{235} = 1.31$ ← (Eq. 2, Subsection 914.02 (e), to nearest hundredth)

PD = 8.48 ← (Percent defective, Table 914-5, N = 6)

PPA = 2.0 - 0.2 x 8.48 = 0.30 ← (Percent pay adjustment, Eq. 1, Subsection 914.02 (e), to nearest hundredth)

(BASE PRICE, concrete in superstructure, deck slabs, Subsection 914.02 (e))

PAY ADJUSTMENT = 0.0030 x 500 x 145.75 = +$218.62

(PPA in decimal form) (PLAN QUANTITY, CY) (BONUS)

EXAMPLE #2 (Non-Pay-Adjustment Item)

Item: Footing — Class: B ← (Table 914-2)

28-Day Test Results: 3580, 3720 ← (Test = average strength of cylinder pair)

(RETEST LIMIT for non-pay-adjustment item, Class B, Table 914-4)

$X_{min} = 3580$ ← (Test value < 3600, retest required, pay-adjustment section now applies. Otherwise, accept and pay 100 percent.)

Core Results: 3650, 3760, 3280, 3640, 3430, 3590

$N = 6$ ← (Retest rate, Class B, Table 914-4)

$\bar{X} = 3558$ ← (Average, to nearest whole value)

$S = 174$ ← (Standard deviation, Eq. 3, Subsection 914.02 (e), to nearest whole value)

(RETEST LIMIT for pay-adjustment items, Table 914-4)

$Q_{REJECT} = \frac{3558 - 3000}{174} = 3.21$ ← (Eq. 4, Subsection 914.02 (e), to nearest hundredth)

$PD_{REJECT} = 0.0$ ← (Table 914-5, N = 6, Q positive and beyond range of table. PD is less than REJECTION LIMIT = 10 in Table 914-4 so lot is not rejectable.)

(CLASS DESIGN STRENGTH, Table 914-3)

$Q = \frac{3558 - 3700}{174} = -0.82$ ← (Eq. 2, Subsection 914.02 (e), to nearest hundredth)

$PD = 100.00 - 21.49 = 78.51$ ← (Percent defective, Table 914-5, N = 6, table value subtracted from 100 because Q is negative)

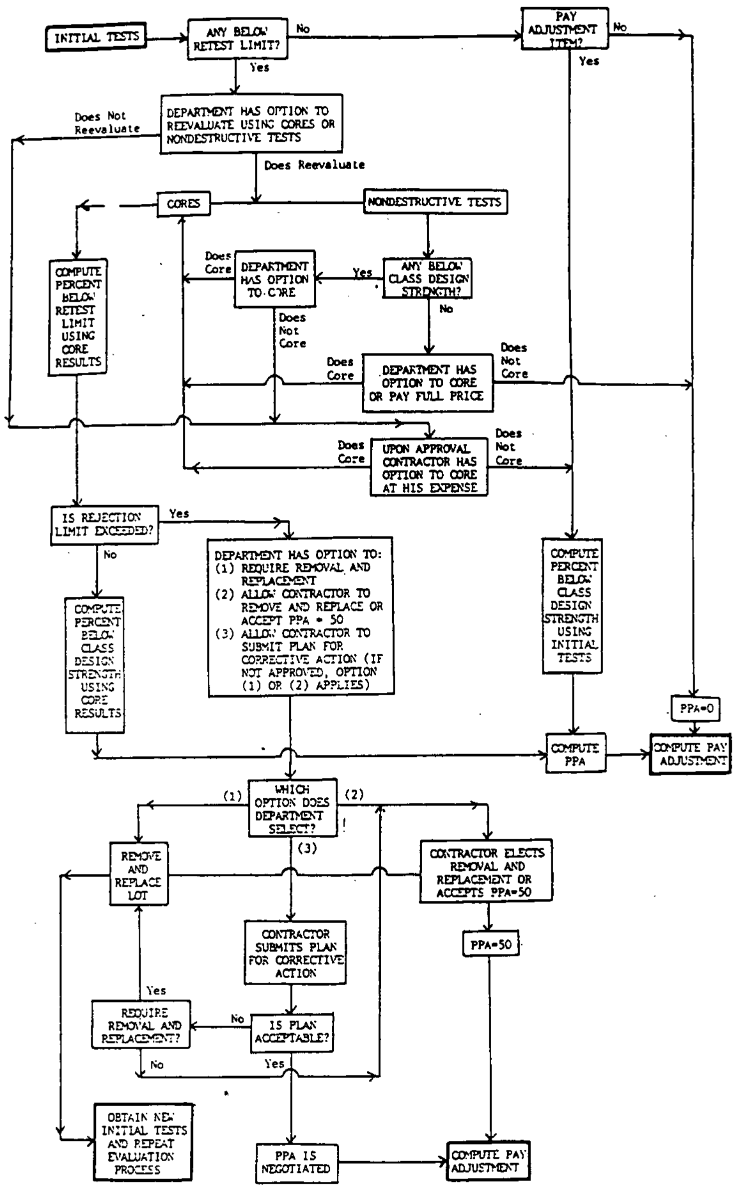
$PPA = 2.0 - 0.2 \times 78.51 = -13.70$ ← (Percent pay adjustment, Eq. 1, Subsection 914.02 (e), to nearest hundredth)

(BID UNIT PRICE)

PAY ADJUSTMENT = $-0.1370 \times 215 \times 49.53 = -\$1458.91$

(PPA in decimal form) (PLAN QUANTITY, CY) (REDUCTION)

ATTACHMENT to O.B. 89-2A



(G) ACCEPTANCE TESTING FOR CONCRETE SURFACE COURSE (CLASS X).

(1) GENERAL.

THIS SPECIFICATION COMBINES THE ACCEPTANCE REQUIREMENTS FOR SURFACE SMOOTHNESS, THICKNESS, AND STRENGTH OF CONCRETE SURFACE COURSE INTO A SINGLE ACCEPTANCE PROCEDURE. THE SURFACE SMOOTHNESS REQUIREMENTS OF SUBSECTION 405.15 ARE ESSENTIALLY UNCHANGED. SUB-SECTION 405.21, TOLERANCE IN SURFACE THICKNESS, IS SUPERSEDED BY THIS SPECIFICATION WHICH ALLOWS VARIATIONS IN THICKNESS AND STRENGTH TO OFF-SET ONE ANOTHER, SUBJECT TO THE LIMITATIONS DIS-CRIBED IN TABLE 914-6. PAY REDUCTIONS ARE ASSESSED FOR DEFICIENT QUALITY AND BONUSES ARE AWARDED FOR SUPERIOR QUALITY. THE SURFACE SMOOTHNESS PROVISION DOMINATES SINCE IT CONTROLS THE MAXIMUM PAY FACTOR THAT CAN BE AWARDED. ALL OTHER GENERAL REQUIREMENTS OF SECTION 914 APPLY TO CONCRETE SURFACE COURSE.

(2) ACCEPTANCE TESTING FOR THICKNESS.

SAMPLING AND ACCEPTANCE TESTING FOR THICKNESS WILL BE PER-FORMED BY THE ENGINEER.

THE ACCEPTABLE QUALITY LEVEL IS DEFINED IN TABLE 914-6. LOT SIZES AND SAMPLING RATES ARE GIVEN IN TABLE 914-7.

(3) ACCEPTANCE TESTING FOR STRENGTH.

SAMPLING AND ACCEPTANCE TESTING FOR STRENGTH WILL BE PER-FORMED BY THE ENGINEER.

THE ACCEPTABLE QUALITY LEVEL IS DEFINED IN TABLE 914-6. LOT SIZES AND SAMPLING RATES ARE GIVEN IN TABLE 914-7.

(4) ACCEPTANCE TESTING FOR SURFACE SMOOTHNESS.

SAMPLING AND ACCEPTANCE TESTING FOR SURFACE SMOOTHNESS WILL BE PERFORMED BY THE ENGINEER IN ACCORDANCE WITH SUBSECTION 405.15.

THE ACCEPTABLE QUALITY LEVEL IS DEFINED IN TABLE 914-6. LOT SIZES AND SAMPLING RATES ARE GIVEN IN TABLE 914-7 AND SUBSEC-TION 405.15, RESPECTIVELY.

(5) RESTESTING FOR THICKNESS, STRENGTH, AND SURFACE SMOOTHNESS.

RETESTING BY THE ENGINEER WILL BE PERFORMED WHENEVER ANY OF THE RETEST CRITERIA OF TABLE 914-7 IS EXCEEDED. RETESTING WILL BE PERFORMED ONLY FOR THOSE CHARACTERISTICS NECESSITATING THE RETEST.

FOR THICKNESS AND STRENGTH, RETESTS WILL BE PERFORMED BY THE ENGINEER AT NEW LOCATIONS. FOR SURFACE SMOOTHNESS, 100 PER-CENT SAMPLING WILL BE EMPLOYED AS DESCRIBED IN SUBSECTION 405.15.

FINAL COMPLIANCE WILL BE DETERMINED AS SPECIFIED IN TABLE 914-7 AND SUBPARTS (G)(6) AND (G)(7) BELOW.

(6) PAY EQUATION.

THE PERCENT PAY FACTOR FOR EACH LOT OF CONCRETE SUR-FACE COURSE IS GIVEN BY EQUATION (5):

$$PPF = 100 + 15\ (THK - 10) + 0.01(STR - 5000) + SPA \qquad (5)$$

IN WHICH

PPF = PERCEMT PAY FACTOR

THK = AVERAGE THICKNESS (INCHES)

STR = AVERAGE COMPRESSIVE STRENGTH (PSI)

SPA = SMOOTHNESS PAY ADJUSTMENT, DEPENDS UPON CONFORMANCE WITH SUFACE REQUIREMENTS DE-FINED IN SUBSECTION 405.15 (PERCENT).

(7) PAYMENT ADJUSTMENT LIMITS.

THE PERCENT PAY FACTOR IS SUBJECT TO THE FOLLOWING LIMITATIONS, IN WHICH PDL IS THE AVERAGE PERCENT DEFEC-TIVE LENGTH DEFINED IN SUBSECTION 405.15 AND THK AND STR ARE DEFINED IN SUBPART (G)(6):

QUALITY MEASURE	MAXIMUM PERCENT PAY FACTOR
PDL: 0 TO 15	PPF(MAX) = 103 - 0.08 (PDL)(PDL)
OVER 15*	PPF(MAX = 85
THK: LESS THAN 9.5*	PPF(MAX) = 75
STR: LESS THAN 4000*	PPF(MAX) = 75

* REJECTABLE QUALITY LEVEL

FOR LOTS OF SUPERIOR STRENGTH OR THICKNESS, EQUATION (5) AWARDS BONUS PAY FACTORS UP TO 103 PERCENT, THE MAXIMUM BEING CONTROLLED BY THE LEVEL OF SURFACE SMOOTHNESS (PDL). FOR LOTS OF DEFICIENT QUALITY, BUT NOT EXCEEDING THE REJECTABLE QUALITY LEVEL, EQUATION (5) ASSIGNS REDUCED PAY FACTORS DOWN TO 85 PERCENT FOR SURFACE SMOOTHNESS OR 75 PERCENT FOR THICKNESS OR STRENGTH.

(8) PAY ADJUSTMENT.

THE BASE PRICE FOR CONCRETE SURFACE COURSE IS $40 PER SQUARE YARD.

THE AMOUNT OF PAY ADJUSTMENT IN DOLLARS IS THE PRODUCT OF THE BASE PRICE TIMES THE LOT QUANTITY TIMES THE PERCENT GIVEN BY EQUATION (6). THE SEQUENCE OF THE COMPUTATIONS ARE AS FOLLOWS:

USE THE MEASURED VALUES OF THK, STR, AND PDL TO COMPUTE THE PERCENT PAY FACTOR (PPF) USING EQUATION (5).

IF NECESSARY, REDUCE THE COMPUTED VALUE OF PPF TO THE MAXIMUM PERMITTED VALUE SPECIFIED IN SUBPART (G)(7).

COMPUTE THE PERCENT PAY ADJUSTMENT (PPA) USING EQUATION (6).

$$PPA = 100 - PPF \qquad (6)$$

FOR ANY LOT JUDGED REJECTABLE AFTER RETESTING OR REMEDIAL ACTION HAS BEEN PERFORMED, THE DEPARTMENT RESERVES THE OPTION TO REQUIRE REMOVAL AND REPLACEMENT (OR OTHER CORRECTIVE ACTION) AT THE CONTRACTOR'S EXPENSE. IF THIS OPTION IS NOT EXCERCISED, THE CONTRACTOR MAY ELECT TO LEAVE THE LOT IN PLACE AND RECEIVE THE COMPUTED PERCENT PAY ADJUSTMENT.

FOR ANY OVERALL BONUS FOR THR ENTIRE PROJECT TO BE PAID, THE OVERALL AVERAGE PDL (WEIGHTED BY INDIVIDUAL LOT SIZES) SHALL BE NO MORE THAN 8.0 PERCENT. REMEDIAL MEASURES TO ACHIEVE THE PDL REQUIREMENTS WILL BE PERMITTED PROVIDED THEY CAN BE ACCOMPLISHED IN ACCORDANCE WITH SUBSECTION 405.15, SUBPART (D).

914.03 MORTAR AND GROUT DESIGN AND ACCEPTANCE REQUIREMENTS.

MORTAR AND GROUT SHALL CONSIST OF ONE PART PORTLAND CEMENT TO TWO PARTS FINE AGGREGATE. WATER SHALL BE ADDED TO FORM THE PROPER CONSISTENCY. MORTAR AND GROUT SHALL NOT BE RETEMPERED OR USED AFTER IT HAS BEGUN TO SET.

WHERE NONMETALLIC OR NONSHRINK GROUT IS SPECIFIED, THE GROUT SHALL CONFORM TO THE CORPS OF ENGINEERS CRD-C 621 WITH THE FOLLOWING AMENDMENTS:

THE GROUT SHALL BE OF A PLASTIC CONSISTENCY.

THE COLOR OF THE HARDENED GROUT, WHERE VISIBLE, SHALL MATCH THE COLOR OF THE ADJACENT HARDENED CONCRETE.

THE MINIMUM COMPRESSIVE STRENGTH OF 2-INCH CUBES WHEN CURED SHALL BE AS FOLLOWS:

CURING PROCEDURE	STRENGTH (PSI)
24 HOUR AIR CURE AT 75 DEG F	2500
7 DAY AIR CURE AT 75 DEG F	6000
7 DAY AIR CURE, 10 DAY WATER SUBMERSION	6000
7 DAY AIR CURE, 24 HOUR WATER SUBMERSION, 25 CYCLES FREEZE-THAW	6000

THE GROUT SHALL HAVE A MINIMUM WORKING LIFE OF 30 MINUTES FROM THE TIME THE WATER IS ADDED AND SHALL CONTAIN NOT MORE THAN 0.05 PERCENT CHLORIDES OR 5.0 PERCENT SULFATES BY WEIGHT.

THE GROUT SHALL NOT CONTAIN ANY CORROSION-PROMOTING AGENTS.

EPOXY AND OTHER TYPES OF NONMETALLIC OR NONSHRINK GROUT MAY BE USED IF APPROVED.

914.04 SAMPLING AND TESTING METHODS.

SAMPLING AND TESTING SHALL BE PERFORMED IN ACCORDANCE WITH THE FOLLOWING:

AASHTO	
T 22	COMPRESSIVE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS (INCLUDING THE ANNEX PROVIDING FOR USE OF NEOPRENE CAPS)

T 23	MAKING AND CURING CONCRETE TEST SPECIMENS IN THE FIELD
T 24	OBTAINING AND TESTING DRILLED CORES AND SAWED BEAMS OF CONCRETE
T 119	SLUMP OF PORTLAND CEMENT CONCRETE
T 121	WEIGHT PER CUBIC FOOT, YIELD AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE
T 126	MAKING AND CURING CONCRETE TEST SPECIMENS IN THE LABORATORY
T 141	SAMPLING FRESH CONCRETE
T 152	AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD
T 196	AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE VOLUMETRIC METHOD

<u>ASTM</u>

C 567	UNIT WEIGHT OF STRUCTURAL LIGHTWEIGHT CONCRETE
C 311	SAMPLING AND TESTING FLY ASH OR NATURAL POZZOLANS FOR USE AS A MINERAL ADMIXTURE IN PORTLAND CEMENT CONCRETE

NOTE - THE DEPARTMENT MAY MODIFY THE SAMPLING RATE, AS PROVIDED IN ASTM C 311, FOR INDIVIDUAL AND COMPOSITE SAMPLES.

APPENDIX D

PENNDOT VALUE ENGINEERING IN HIGHWAY CONSTRUCTION PROGRAM

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

CIRCULAR LETTER

SUBJECT	DATE
CONSTRUCTION VALUE ENGINEERING	JUNE 26, 1985
EXPIRES: JUNE 26, 1987	RESCINDS: C-2895 and C2895-1

TO:
CENTRAL OFFICE
ENGINEERING DISTRICT

Value Engineering (VE) is a systematic, organized approach to obtain the optimum value for each dollar spent. It is the application of recognized techniques to identify the function of a product or service, establish the value of that function, and then to provide that function at the lowest actual cost. Ideas which merely cost less initially, but add to the future costs of maintenance and operation, are usually unacceptable.

VE is a provision of the Department's Specifications (Pub. 408, Section 1104.04) which provides contractors with a monetary incentive to participate in these cost saving techniques. Department personnel should be knowledgeable of this provision and should encourage contractor participation. All VE submissions must be processed as quickly as possible in order to prevent construction delays and provide the greatest savings.

The following are the steps needed for evaluation of contractors' VE proposals: (See Flowchart, page 4)

1. The contractor may submit a Concept Proposal to the Inspector-in-Charge. Although this is optional, the Concept Proposal will allow the contractor to determine whether the concept is acceptable before he commits a large design effort to developing specifics of the Proposal.

This Concept Proposal should be evaluated by the Inspector-in-Charge and forwarded to the District Construction Division (DCD) with recommendations within 2 working days.

2. The Assistant District Engineer (Construction) may approve the Concept Proposal for the District Engineer (DE). If the DCD recommends rejection of the Concept Proposal it must be sent to the Chief Engineer for his concurrence prior to notifying the contracter. The contractor must be notified promptly in writing so he can start work on the actual detailed Proposal if the Concept is approved. The District Value Engineering Coordinator (DVEC) and the Bureau of Bridge and Roadway Technology - Value Engineering Coordinator (COVE) will be sent copies of this notification.

Since time is of the essence, DCD evaluations should be completed and the contractor notified within 7 working days of the original submission.

3. The DVEC should make all the arrangements for review of the actual Proposal if the Concept Proposal is approved. He should contact the contractor to determine when the Proposal will be submitted. He should then arrange for a VE Team, appoint a chairperson and find a suitable place for them to work.

OS-90 (1-74)

4. When the contractor submits his Proposal, it must include all the items required by Pub. 408. It should be submitted to the DE "to the attention of the DVEC." Permission may be granted for the contractor to present the Proposal orally, but all the data needed for evaluation must be submitted in writing. Copies of the Proposal must be sent to the Bureau of Construction & Materials (BCM), and the Bureau of Design (BD), for information and comments on Certification Acceptance (CA) projects. Comments from BCM and BD will be sent to COVE for coordination with the Districts and file. Proposals on projects which require FHWA approval should be coordinated directly between the BCM Work Order Review Section and the DVEC with copies of correspondence to COVE.

5. The VE Team will evaluate the Proposal and recommend approval/rejection to the DE within 3 working days. Comments received by COVE from BCM and BD will be forwarded to the District. All recommendations for rejection must be sent to the Chief Engineer for his concurrence.

6. The DE will review the Proposal, recommendations of the VE Team, and information from the Chief Engineer, BCM and BD, if necessary. He may approve all Construction VE Proposals on CA projects. On non-CA projects he will need BCM and FHWA concurrence.

If approved, he should notify the contractor within 7 working days after the Proposal has been received on CA projects and, as expeditiously as possible, on the projects where BCM and FHWA concurrence is required. He must prepare and submit the necessary work orders. If the Proposal is rejected by the Chief Engineer, the DE's notification to the contractor must include the reasons for rejection and copies must be sent to COVE.

7. Acceptable Construction VE Proposals will be utilized in the design of future applicable projects, and applicable design standards. It will be the responsibility of the COVE to initiate applicable specification and design standard changes.

8. Payment will be in accordance with Publication 408, Section 110.08 - Value Engineering.

David C. Sims

David C. Sims, P.E.
Deputy Secretary for
Highway Administration

450/RDH/pad 3-9673

APPENDIX E

MICHIGAN DOT TOTAL COST BID PROCESS

TOTAL COST BID PURCHASE AGREEMENT

It is hereby agreed that the State of Michigan and ______________________, the bidder have entered into a TOTAL COST BID agreement the terms of which are described herein. This agreement refers specifically to the purchase of equipment identified as Tractor loader ______________________ by the State of Michigan, Purchasing Division.

TERMS OF AGREEMENT

1. DEFINITIONS

   A. Term equipment as used in this agreement referes to the equipment identified above.

   B. The term state refers to the State of Michigan.

   C. The term Department refers to the Michigan Department of Transportation.

   D. The term bidder refers to the successful bidder from whom the equipment is purchased.

   E. Total Cost Bid refers to total equipment costs guaranteed by the bidder which define maximum expenses to be borne by the (Department) State for scheduled maintenance and major repair, and, further, which include a guaranteed repurchase price by the bidder.

2. MULTIPLE EQUIPMENT PURCHASE

   In the event that more than one piece of equipment is purchased, the bidder's guaranteed costs described in this agreement will apply individually to each and the terms of this agreement wil extend individually to each.

3. METHOD OF DETERMINATION OF TOTAL COST BID

   To the bidder's base purchase price will be added to the bidder's guaranteed scheduled maintenance cost and guaranteed repair cost to determine the total lifetime equipment costs to be borne by the State. From this total lifetime equipment expense will be subtracted the bidder's guaranteed repurchase price to determine the bidder's TOTAL COST BID. The successful bidder will be that whose TOTAL COST BID is the lowest of all TOTAL COST BIDS offered on the equipment.

4. ORIGINAL PURCHASE PRICE

   The bidder has read and noted the State equipment Specification forwarded with the invitation to bid No. 84-Q05743 dated 8-1-84 and agrees to provide equipment meeting said specifications for a price for each identical machine with and without a trade-in as submitted with the bid.

5. GUARANTEED SCHEDULED MAINTENANCE COST

   A. The Department agrees to provide labor and materials to maintain and perform all routine maintenance in accordance with manufacturer's standard recommended guidelines to be provided by the bidder. Such materials shall include, but need not be limited to oils, fluids, filters and lubricants.

B. The Department agrees to keep and maintain records for the bidder's inspection to document that maintenance has been performed as recommended and on schedule.

C. The Department's labor will be provided at the State of Michigan classification level of Mechanic IVB or lower to which will be added normal fringe benefits associated with labor cost. For the purpose of this agreement, the estimated aggregate of labor and fringe benefits will not exceed $25.00 per hour during the life of the agreement.

D. The Department agrees that the time required to perform the services specified in the manufacturer's recommended maintenance guidelines will not exceed generally accepted industry flat rate schedules for the service.

E. Under the conditions noted in A through D above, the bidder guarantees that for a period of 6,000 hours of usage as recorded on the engine hourmeter of five (5) years, whichever occurs first, the cost of scheduled maintenance, herein known as the GUARANTEED SCHEDULED MAINTENANCE COST, will not exceed $ 900.00 . This amount shall be added to the bidder's base bid price in determining the bidder's TOTAL COST BID.

F. All costs in excess of the bidder's guaranteed amount shall be reimbursed to the Department by the bidder no less often than at the end of each equipment operating year.

6. GUARANTEED REPAIR COST

A. The bidder guarantees under the terms further stipulated below that for a period of 6,000 hours of usage as recorded on the engine hourmeter or five (5) years, whichever occurs first, the cost of labor and parts for major repairs, herein known as the GUARANTEED REPAIR COST, will not exceed $ 2750.00 . This amount shall be added to the bidder's base bid price in determining the bidder's TOTAL COST BID.

B. All costs in excess of the bidder's guaranteed amount shall be reimbursed to the Department by the bidder no less often than at the end of each equipment year.

C. The Department agrees to provide labor and parts for major repairs at the rate stipulated in paragraph 5.C except that, when the total cost of such labor and material for any single repair exceeds $400.00, the Department will notify the bidder of the details of the work to be performed prior to beginning the work. Such notification may be by telephone or in writing. The bidder may elect to perform the repair in the bidders shop, however, all costs of transporting the equipment shall be at the bidders expense if transported by the bidder, or shall be added to the GUARANTEED REPAIR COST if transported by the Department.

D. Repairs may be made in service shops other than the Department or bidder if the shop selection is agreeable to both parties. The cost of transporting the equipment to other shops will be added to the guaranteed repair cost.

E. All parts purchased for major repairs shall be purchased from the successful bidder of the original equipment at a competitive price considered to be reasonable as determined by the State.

F. If needed repair parts for the repair to be performed are not supplied to the Department within five (5) working days from the date of notification to the bidder, a daily charge of $200.00 shall be added to the cumulative cost of repairs for each work day in excess of five that the part is not available. The successful bidder may elect to temporarily provide the Department with an equivalent or identical machine at the bidder's expense until repair parts are available. If the bidder elects to provide a temporary machine, the daily $200.00 charge shall not be applied to the cumulative cost of repairs.

G. In computing the cost of repairs, the successful bidder will be fully responsible for all costs normally associated with the manufacturer's standard warranty for new equipment. Such repairs, when performed under warranty, will not be added to the GUARANTEED REPAIR COST.

H. The Department will be responsible for cost of repair necessitated from damage due to fire, vandalism, windstorm, theft and pilferage, flood and rising water, accidents, and operator and mechanic negligence or misuse. Such costs shall not be added to the GUARANTEED REPAIR COST.

I. The Department will be responsible for cost of repairs associated with normal day to day operations such as tires, tubes, cutting edges, teeth, batteries, headlights, glass breakage, cleaning and painting. This paragraph will not supersede guarantees usually provided with new equipment, such as tires and batteries, or for defects due to workmanship and materials that show up under normal working conditions.

J. All repairs performed under this paragraph shall have the labor and parts costs substantiated by a detailed invoice.

K. The bidder may examine the Department's cost records at any reasonable time at the bidder's request. At the end of each equipment operating year the bidder will have ninety (90) days to contest the preceding year's repair costs, both for labor and parts. If no action is taken by the bidder in the ninety (90) day period, the records for that year will be considered acceptable to both parties. Settlement of any challenged items may exceed the ninety (90) day period. Notice of contested items shall be delivered in writing to the Department at its equipment office at 2522 W. Main Street, Lansing, Michigan.

L. If the bidder and the Department are unable to agree on costs contested by the bidder, the matter will be resolved in arbitration as noted in the ARBITRATION paragraph.

M. Department records will be kept complete and current as measured by the engine hour meter, not to exceed sixty (60) days.

7. GUARANTEED REPURCHASE PRICE

A. The bidder guarantees to repurchase the equipment at the end of 6,000 hours of usage as recorded on the engine hourmeter or five (5) years from the date of delivery, whichever occurs first, for a GUARANTEED REPURCHASE PRICE OF $ 12,000.00 ______________. Such GUARANTEED REPURCHASE PRICE will be subtracted from the sum of the bidders (1) base purchase price, (2) guaranteed scheduled maintenance cost and (3) guaranteed repair cost to determine the bidder's TOTAL COST BID.

B. The Department may elect to sell the equipment at a higher price to someone other than the bidder at the end of the guarantee period.

C. The Department may elect to not sell the equipment at the end of the guarantee period if it chooses. In so doing, the repurchase portion of this agreement will be considered null and void and the bidder will be under no further obligation to repurchase the equipment. Any costs due the Department under paragraphs 5 and 6 will be due and payable by the bidder after which the bidder is relieved of any further maintenance and repair obligations.

8. ARBITRATION

In the event of a disagreement as to the interpretation or application of this agreement, an arbitration panel shall be established to resolve the disagreement. The panel shall have one person appointed by the State, one person appointed by the bidder, and these two appointees shall select a third person who shall serve as chairman. The ruling of any two members of the arbitration panel shall be binding on both parties.

9. PERFORMANCE BOND AND BID DEPOSIT

The bidder will be required to provide the State with a performance bond equal to the sum total of (1) 100% of the guaranteed repurchase price, plus (2) 50% of the guaranteed scheduled maintenance cost, plus (3) 50% of the guaranteed repair cost. A bid deposit equal to 5% of the performance bond will be required with the bid. The bidder further agrees to deliver the bond prior to delivery of the equipment but not later than thirty (30) days after notification of award. Failure to produce the bond will result in forfeiture of the bid deposit, and cancellation of the contract.

10. Other equipment may be traded in to apply toward this purchase of new equipment. Such notice of trade-in will be given on the request for quotation along with a description of the equipment and a location where the equipment may be inspected during normal working hours. Bidders may be asked to quote the new equipment with and without a trade-in. The State reserves the right to not trade-in.

______________________	______________________
Bidder	Director, State of Michigan Purchasing
Date 8-1-84	Date ______________________

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