

tential long-term societal values. Nevertheless, a decision to fund basic research is extremely difficult to defend, particularly under restricted budget conditions.

Closely related to the value concept of research is the risk factor. In our desire to quantify value, we often overlook that any research undertaking has a certain degree of risk. As well-known scientist A.B. Thomas, president of the Batelle Memorial Institute, once said, "If success is certain, there is no point in the experiment. Success often means the end of thought; failure may represent a fair beginning." If the problem being addressed by the research effort has a significant societal or economic impact, a more substantial research investment is justified, even though the probability of successfully solving the problem is relatively low. This is well illustrated by the large investment in cancer research, where a significant part of the total research effort is of a high-risk nature but, because of the potentially large benefit to society, the base of financial support is broad. In a similar vein, the potential impact of the world's dwindling petroleum supply on our nation's transportation system is beginning to be recognized by policymakers in both the public and private sectors and has resulted in substantial increases in energy-related research activities.

In summation, research is generally recognized as a valuable asset to federally funded programs administered by the U.S. Department of Transportation. However, since an applied research program can be more-effectively equated to near-term benefits, it is much easier to defend in the budget review and approval process. The result is that long-term research of a more basic nature generally receives only limited support and is usually the first item to be eliminated from an agency's research and development program.

Value is a many-faceted quantity that must be considered from the perspective of the basic objectives of individual research projects and the scale of the problem being addressed in terms of economic and societal impacts. As the magnitude of the problem increases, there is generally sufficient support for a larger research effort, even though the probability of success may be somewhat limited. Although the value of research is irrefutably accepted as a fact of life in the scientific community, this is not the case in the decision-making arena, where limited financial resources must be allocated on a priority basis. To ensure continued financial support for transportation-related research, we must continue to recognize the importance of quantifying its potential value, even though it may not be feasible to do so in absolute terms.

## Value of Research to the Researcher, Economy, and Society as Viewed at the Academic Level

HAROLD L. MICHAEL

The great value of research to the individual and to society as viewed by academia is presented as obvious. Further support is provided by factual data on the benefits that result to the Indiana State Highway Commission from 40 years of cooperative research with the Joint Highway Research Project at Purdue University. One of the most significant benefits noted is the production of the leaders and educators of the future from a university research program. The significant contributions of the Indiana experience in this area are reported and the challenge made that the opportunity, really the responsibility, for similar research-education programs exists for all transportation agencies and universities.

The basic question posed by the assigned topic is one that should never have to be asked, Is there value in research? Of course there is value, tremendous value. Research has given us almost everything we have. As an example, consider the next physical items you touch or use and think about how each of them came to be. If all people did that each time they used something, we would no longer take so much of what we enjoy for granted; we would know the value of research. There is great value in research. If there were not, we would not be spending \$51 billion/year on research and development in this country.

Another question about research that has been voiced often also bothers me. That question concerns the risk in research and especially that basic research has a higher risk. The fact is that there is no risk in research. Any research done competently produces new knowledge, even if it is not what was desired. That, too, is new knowledge, and

any knowledge has value. Since the real purpose of research is to produce new knowledge, research will always be successful. Risk only occurs if from a particular research project one wants a specific result and nothing else.

In the early years of this nation, Thomas Jefferson noted, "An enlightened citizenry is the only safe repository of control over the ultimate processes of society." Americans then, and for many years after, looked to science as the way to progress and strength. In the recent two decades or so, however, our fellow citizens have become skeptical of science, as they have of many other things. They appear to have forgotten that science and technology play an increasing role throughout our society. In business, in government, in the military, and in the professions, science is clearly an important key to success. The computer has revolutionized activity everywhere. Modern communications govern much of what we do. Travel and transportation find clearly that their futures, although heavily affected by resources available and environmental concerns, lie primarily with what we can do through science and technology.

Economists estimate that advances in knowledge have accounted for perhaps three-quarters of the economic growth of this country. But the economic impact is probably not as important as the impact on society, although I find it difficult to separate the two. Albert Einstein once said, "Concern for man himself and his fate must always form the chief

interest of all technical endeavors--in order that the creation of our minds shall be a blessing and not a curse." He knew that the pursuit of scientific truth was a good in itself but that the uses of those truths may be either good or bad, depending on the moral and political choices that determine those uses. This is where an enlightened citizenry must exercise its control--not in developing barriers to seeking knowledge but in determining uses of that knowledge.

The major functions of a university are three in number:

1. To distribute knowledge through educational means,
2. To create knowledge through research, and
3. To store knowledge.

All are important and, certainly, the creation of new knowledge is an important one. We in academia do not do research just to get promoted or for the sake of more publications. Educators do research because that is their function, because development of new knowledge is fundamental to development as a good distributor (teacher) of knowledge, because creation of new knowledge is more likely to occur by someone who has a thorough understanding of existing knowledge in related areas and where intellectual freedom for the pursuit of scientific truth exists. Our founding fathers established the United States as a place where scientific endeavor would be encouraged and honored. The wisdom of that decision is not questioned, for as a nation we have prospered.

As President Carter said in a 1980 address to the National Academy of Sciences, "We still look to our scientists and to our engineers, our military researchers and to our doctors, to our inventors, and to our thinkers, to improve our lives and to improve the lives of our children." President John F. Kennedy noted years earlier to another meeting of the Academy, "Progress in technology depends on progress in theory; the most abstract investigations can lead to the most concrete results; the vitality of a scientific community springs from its passion to answer science's most fundamental questions."

I have said that the value of research is viewed at the academic level. The proof, of course, is if such high-sounding expectations have been met over the years through research in the universities. Let me now summarize briefly some major benefits that resulted from the research financed over the last 45 years by the Indiana State Highway Commission through the Joint Highway Research Project at Purdue University, the organization with which I have been associated for 30 years.

During the 45 years, about 600 research studies have been completed. They were a mixture of basic and applied research. The results of these studies have been reported in many technical publications, especially those of the Transportation Research Board. The technical results of these studies have influenced highway development in Indiana, throughout the United States, and in many foreign countries. Our researchers work closely with personnel of the Highway Commission and develop new projects from problems that are encountered by them in the planning, design, construction, maintenance, and operation of the highway system. Our researchers use highway department personnel as advisors on the research as it progresses. They keep them informed of progress, of findings as they occur, of results as quickly as possible, and of the possible impact on highway activities.

The staff of the Joint Highway Research Project and I are confident that the Indiana State Highway Commission can document that the cost savings to the

Commission from the research conducted over the years have been greater than the dollars expended. Perhaps the best argument that this is a true statement is that we operate on the basis of mutual respect for the value of research to the Indiana State Highway Commission. The university is provided funds for the research as a free grant each three months. This provides for the freedom of intellectual endeavor so necessary to pursue good research while at the same time using wise management by the university and the highway department of the research conducted--management based on performance, support, appreciation, and respect rather than on legalism and suspicion.

The direct benefits of the research have been sufficient to justify the continued investment of the highway department. But I am certain there have been and continue to be even greater benefits. Obviously, involvement in current activities of the highway department assists our faculty in maintaining technical competence and knowledge of current events. The opportunities of discourse with other experts expand the continued development of our faculty and permit them to be better distributors of their knowledge to students at all levels--undergraduate, graduate, and continuing. The program permits us to attract a highly competent faculty because the opportunities for teaching, research, and national participation are great. This also improves our capability to provide quality educational programs, enhances our reputation as a university, and expands the loyalty of our alumni.

Perhaps the greatest benefit of such a research activity is the number of educated people in transportation that such a program produces. The young men and women who will be the leaders in transportation are attracted to the profession, educated in the profession, and retained in the profession through transportation research in the universities.

Our highway research project at Purdue has graduated more than 500 such young men and women. They were educated at the graduate level in the best possible way, through involvement not only in academic courses but also in a transportation research project. Anyone who conducts such a project becomes an expert on completion in some small area of transport. He or she is probably as good an expert in their area of study as anyone anywhere. Such graduates are confident in their field. They are enthusiastic to continue work where they are the best. It is very likely they will continue their career in an area closely associated with the subject of that initial research. If they cap their formal education by attaining a doctorate, they are likely to teach and do research in transportation or go into the research and development field in transportation.

Of our more than 500 graduates over the last 45 years, about 150 obtained their doctorates. More than 100 of these are teaching transportation in universities throughout the world. Recently I attended a meeting of university professors involved with transportation. Thirty-nine such individuals from 31 universities were present. Ten of those individuals, now at 9 universities, were graduates of our program. All did research in highway transportation funded by the Indiana State Highway Commission through the Joint Highway Research Project. There is no better way to provide value to society, to the economy, and to the researcher than to be involved in the development of a nation's greatest resource, development of human minds. Research in the universities can be of great assistance in such development and in attracting the best men and women to the areas of the research. This development of the leaders and teachers in transportation of the future is the greatest value that can be provided.

The Indiana State Highway Commission, through its continuing practice of funding research at Purdue University, provides such benefits to the researcher, to the economy, and to society. The op-

portunity to do likewise exists for every state transportation agency and for all federal transport agencies. In fact, it is a responsibility.

## Past and Future Value Systems in Research: An Industrial Perspective

C. F. COOK

**The value of research to an industrial researcher is intrinsically related to the researcher's value system and the judgment of the free market system in this nation. The researcher's value system is shaped by his or her formative professional years and the market acceptance or rejection of his or her developments. In the United States, the free enterprise market system has historically provided the judgment of developments and selected only those that successfully benefit society and thus the economy and the researcher.**

Although there are many value systems that can be considered, one of the keys is the value system held by the individual researcher. It is not always clear whether one is dealing with value systems or motivational systems when one relates to individual researchers.

If one can obtain just a little insight into the value and motivational systems of a researcher, the first step has been identified to enhance the creative and constructive environment so important in the technological community.

One measure of our nation's strength is the technological value of research done in our nation's three major professional segments--university, government, and industry. If our nation is to move to new thresholds, as measured by any set of values, then the three segments of our research society must extend the cooperative spirit that has brought America to this point in history.

The importance of cooperative spirit to the value of research cannot be overstressed. Other nations may cooperate by edict and may be controlled by monolithic governments, industrial cartels, or university extremists. Our nation cooperates through the free enterprise system. As long as free enterprise and free choice of research remain the cornerstones of our triangular research society, America will continue to provide technological improvements to better mankind and give each of us time in our lives to reach our personal goals.

### HISTORICAL VIEW

To talk about the value of research, it is interesting to look at a perspective of mankind. If we look at the short-term history of the United States, we realize that the settlers of this nation worked from sunup to sundown to survive. It was hard, physical, and sometimes death-dealing work to just survive. The selection of what research to do and the value to these individuals of a research improvement are easy to measure in retrospect. In most cases the improvement grew out of urgent needs for a better plow, better ax, or better home and the strong desire to have some free time.

As the frontier of this country moved westward,

needs appeared, solutions occurred, industries grew, cities evolved, and man became civilized. Research made contributions of significant value to the individual, to the economy, and to society.

As one traces the American history of industrial research, significant events that have occurred affected the lives of our forefathers and continue to affect our lives today. The most significant areas in this respect are transportation, electricity, communications, medicine, agriculture, and energy. An analysis of these six areas reveals one commonality: The end result of these developments benefited individual man so that life was better and he could reach out to his fellow man. This broad perspective leads one to conclude that the frank judgment of history on research value is intrinsically tied to societal benefits.

The research history of the United States has brought this nation to the threshold of a golden opportunity. This nation can provide the population of the world with significantly better living through the technological developments from our research community.

Whether this nation accepts the challenge or not will define what historians will record about the United States. We live in a different era. For the first time in recorded history a large fraction of mankind has time to think, plan, and spend more than half a lifetime on activities other than those required to survive. What is done in the next few decades will determine whether this nation is the beginning of attempts to reach new heights of civilization.

This time element may be the major underlying factor today that drives many industrial researchers. It is interesting to speculate how our forefathers would look at this phase of America in the stream of history.

The question before the individual industrial researcher encompasses all three subjects discussed in this symposium: What is the value to me, to the economy, and to society?

### VALUE TO SOCIETY

The value of industrial research to society could be measured in charts and graphs by comparing gross national product to industrial research expenditures, basic to applied research, ratio of the number of engineers trained, or any number of other solid technical pieces of information. However significant these correlations may turn out to be, they would speak primarily to the technical community and, no doubt, be argumentative. It seems important to step back from the maze of detailed technical