The Challenge of Highway Technology in Developing Countries

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•MUCH TIME and money has been put into the foreign aid effort since the adoption of the Point Four Program. Excellent advances have been made in the physical development of highway transportation in many of the new states with our help. Notwithstanding, there is a consensus that an accelerated and self-continuing evolution of highway administration and technology among the nationals is needed. And they need help in this evolution.

This conclusion was reached after visiting seven countries in various stages of development on three continents. Roads built and building were viewed and the status of technology and eminent problems in highway transportation in highway departments, universities and research institutes in these seven countries were discussed. In the light of perspective gained in two score years of work in many facets of highway administration and technology in the United States, and in travel in all of our United States, it was clear that a gigantic job remains in every developing country visited, and that each country must progress to the point that it can handle its own highway programs. This is the broad challenge.

This report derives specifically from visits made to Nigeria, the Philippines, Thailand, India, Iran, Lebanon and Brazil. The suggestions made evolved from discussions with 117 people in these seven countries. This report can provide the foundation and framework for working plans to serve the present need and to prepare the special competence needed in countries abroad. Therefore, this report is addressed to two audiences: the highway administrator and technologist in the United States, and the highway administrator and technologist abroad.

PURPOSE OF TRIP AND PREPARATION

The trip to Asia was sponsored by the Agency for International Development. The National Academy of Sciences recognized the potential benefits to the Academy as well as to the institutions in the countries visited and gave its full cooperation in support of the trip. Dr. Robinson Newcomb, coauthor of the paper, Deputy Director for Transportation, Technical Cooperation and Research, Agency for International Development, arranged the trip and has assisted with the preparation of this paper.

The trip was planned to enable the principal author to talk with key people in the highway departments, universities and research agencies in developing countries, to explore their technological needs and to learn how AID might appropriately employ the resources of the Highway Research Board in providing assistance in highway technology to them. The trip was made to find also how these countries in turn could assist the highway profession in the United States by providing information from their research and practice for our Highway Research Information Service.

A great deal of planning was necessary to outline a framework for discussions, including check lists of discussion topics and enunciation of questions formulated in conferences with the staff of eight departments in the Board. Pertinent things to look for on field trips were also reviewed and listed.

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Though not sponsored by AID, similar explorations were carried out during visits in Brazil and Nigeria.

FUNCTIONS OF HIGHWAYS

Inasmuch as the exploration concerned highway administration and technology it was desired first of all to consider the function of highways in the developing areas. The fundamental function of the highway is more clearly discernible in countries where life and life's activities outwardly appear simpler than in the United States. Here we have had the basic road systems for many years and our accumulated road needs are expressed in terms of lower transportation costs, comfort, and time saving. One may lose sight of the original purpose of highways in the United States, which was for communication and cohesion.

In many countries the prime concern is still communication and cohesion. In a country where many dialects are spoken, where many cultures exist side by side, where many separate and individualistic tribes remain, where mountain ranges, rivers and deserts isolate communities, the tie that binds the people together physically is the highway that crosses all of these erstwhile barriers. There is a need for roads in deserts, for there is a need for pure connectors—connectors for cohesion, for communication, and for commerce between producer and consumer. Such connectors are needed in many developing areas. Their need is seen most easily, however, in countries such as Iran, where mountains and deserts separate communities that must be linked to preserve the country as a nation.

THE GATEWAY TO DEVELOPMENT

The obvious is often overlooked because we seek some new magic gateway to development. The proven gateway is made up of the doorposts of research and education, capped with the lintel of practice. In the context of highway development each part of the gateway needs examination.

Highway Research

As highway engineers we are concerned with the mathematics of performance. To understand this we need scientific research because it determines the criteria for action within the norms of the economy, and it shows how to put forces to work most effectively (through orientation, combination, opposition, etc.) to provide the maximum service at minimum cost. It gives us the optimum measures and scale of values for policies, procedures, practices, specifications, standards and warrants.

Research has shown that costs are reducible. Cost of research compared to savings produced therefrom in one statewide study showed a 1 to 10 ratio from one year's use of findings. Controlled investigation stands first because we need to know the interrelations of energy, matter and mind before we can anticipate the consequence of choices or predict the performance of designs.

Education

Education involves stimulation and access to information—it involves method and content. Content naturally proceeds from research and from tested practice.

What are the processes for updating knowledge?

A minister of public works in Asia put this question: "How can we keep our engineers updated, recognizing that we can't require them to study at night and also recognizing that most of the developing information is printed in a foreign language?" The question is pertinent not only in the country where asked but really around the world. His key men had been well educated, many having masters degrees in some phase of highway technology, but few new graduates had been added to his staff in the past decade. Apparently, the engineer in a far-off country and out of the mainstream of advancing technology senses more than we do in America that advances in technology during the past ten years are so far-reaching and significant that without self-renewal and continuing evolution an engineer is soon left behind. How would you answer this question?

Our answer was to suggest programming short courses for each division of the department directed toward its continuing evolution in terms of advances being made in each field—and the establishment of two-way avenues of communication with the highway information centers.

But in the final analysis an engineer cannot escape his need for self-involvement in evolution and renewal through reading. The Highway Research Board publishes annually enough reports vital to highway development to fill 15 inches on a bookshelf. These publications can and do bring about changes in policies and practices that provide better services and greater economies. Other organizations are likewise adding vital information to the storehouse. But the potential rewards from these depend upon the publications being disseminated to the engineer and the necessary stimulus provided to get him to read. There is need for programmed short courses.

Incidentally, the Highway Research Board has begun its initial operation of the Highway Research Information Service (HRIS), which provides for the exchange of information among participating countries on research findings and tested practices. This will provide an invaluable service to the developing technology of all 148± countries, especially to those in their dawn of motorized transportation.

There is no intent to overlook the need for translations in the field of education. Although English is the second language in nearly every country of another tongue, many highway engineers cannot read it, and few American engineers speak a second language. Any two-way avenue for communication has this barrier to free flow—and the flow towards the United States has seven or more major language barriers.

Practice

Education is not enough. New knowledge must be applied. One question that comes to the Board as often as any other is this: "How can we get findings put into practice?" This is the crux of the matter—the lintel of the gateway. This requires putting newly learned principles into context, securing any necessary changes in legislation, modernization of manuals, standards, specifications and warrants, and finally, the understanding and use of these new laws and manuals by those at the respective working levels. This requires rapport between research engineer and operations engineer.

Does the challenge to accelerated evolution include the development of coordinated or linked programs in research-education-practice?

COMPARABILITY OF GLOBAL HIGHWAY PROBLEMS

Similar forces, animate and inanimate, are at work the world around, but they are focused at different intensities and have different durations. The tropics intensify and prolong certain forces. The temperate zone provides greater cyclic frequency and emphasizes forces differently. Materials differ. People belong to different cultures, and hold to traditions exerting subtle and powerful influence on behavior.

But research discovers and measures intensities, frequencies, combinations and orientation of forces, in both the physical and socioeconomic realms in terms of effects and consequences. Physical forces, whether in the Congo or on Manhatten Island, are measured in the same units and by the same instruments. Properties of materials are determined by the same physical and chemical tests. People have the same inherent drives and desires and basic motivations. Diversities are basically of degree, not of uniqueness. Tests are the same the world around and findings from Britain, Brazil, India and Japan can be traded for findings in the United States.

PROBLEMS OBSERVED

Some of the problems observed abroad from which technological challenges come are these:

1. Extreme mixtures in traffic (animals, pedestrians, cycles, carts and cars),
2. Inadequate lane discipline,
3. High accident involvement,
4. Low average speed,

5. Inadequate signing and marking,
6. Inadequate management skills,
7. Much hand labor,
8. Maintenance needs,
9. Stabilization of fills by settlement,
10. Many rough surfaces and uncomfortable riding,
11. Library needs—basic reference literature,
12. Lag in use of research findings,
13. Updating needs in technology, and
14. Great areas without adequate road development.

A similar list of problems might have been written after a trip across the United States—the problems are mostly of degree, not of uniqueness.

TWO COMMON OVERALL PROBLEMS

In every country two problems were stressed. Actually these two grew out of the others and were a part of the other problems. Therefore, these—traffic safety and economy—are ranked first for discussion.

Highway Traffic Safety

When we are insisting here in the United States that we must cut our fatal accidents to a figure much lower than the present 5.7 fatalities per 100 million vehicle-miles, it is appalling to find that the fatal accident rates in the countries visited are from 3 to 15 times that of the rate in the United States. "We surely pay for safety whether we have it or not and we pay more when we do not have it."

With quick expansion of paved mileage, registrations doubling each four or five years, the introduction of so many new, untrained drivers, and with extremes of slow and fast traffic mixed together, naturally a high accident rate results. As in the United States the causes are complex, and there is a paucity of accident statistics on which to premise an action program. Reliable accident records are sorely needed. And the development of records must be followed by an action program supported by the heads of government. If accidents cost 1 cent per vehicle-mile in the United States they may cost 10 cents per mile of travel in some of the countries visited. These countries can far less afford such costs than can the United States.

Socioeconomic Problems

In many of the developing countries the basic highway systems are being developed. This is raising many fundamental questions. What is the best technique for making feasibility studies? How much, how fast and where should we build? Should existing rail systems be replaced with highways? What impact will the program have on resource development? . . . on exports? . . . on the overall economy? . . . on sociology? How can the roads be financed? Should costs be allocated to user? How? Roads are not built for the sole purpose of moving goods and people. This is what we see, but the larger implications are not so easily seen. What is the mission of roads in developing countries?

SUMMARY OF TOP PROBLEMS

What appeared as obvious challenges might or might not be relevant. We wanted to learn their needs. Needs are relative. They are related to some norm, and the norm is based broadly on economy and culture. So we asked the key people concerned with needs in each of the countries visited to name their top problems.

Twenty-five problems were named. In nearly every case the person asked considered the question several days, reviewed it with associates and then gave a listing as representing not his individual opinion but as the consensus of his organization or division. These were elicited from highway departments, universities and research institutes. They are grouped by the frequency of times noted and by number of countries

including the problem in their listing. In this listing the challenge to highway technology is expressed.

Inasmuch as the problems of highway safety and economic analysis ranked at the top in all countries, and inasmuch as safety and economy of transportation are related to nearly all of the other problems, they were given first place in this discussion by way of special emphasis. Hence, they are not included again as separate problems among those now listed.

FIRST RANK (Listed by all countries)

Management of Construction
Compaction and Stabilization
Selection of Suitable Materials
Maintenance, Management and Methods
Traffic Operations and Capacity (for mixed components)

SECOND RANK (Listed by 5 or 6 countries)

Construction Practices
Testing Techniques
Research Organization and Administration
Stage Construction, Methods and Economy
Signs, Signals and Markings

THIRD RANK (Listed by 3 or 4 countries)

Highway Laws
Low Cost Roads
Maintenance Budget and Construction Budget
Needs Inventory, Methods and Feasibility
Financing

FOURTH RANK (Listed by 1 or 2 countries)

Resource and Revenue Apportionment
Snow and Ice Control
Materials Mapping
Highway Organization and Administration
Asphalt Mix Design

FIFTH RANK (One country)

Drainage and Hydrology
Equipment Maintenance
Weed Control
Computer Technology
Secondary Road Design

THE ACTION PROGRAM

In light of the listing of top problems enunciated by the people most concerned and most involved in their challenge, certain areas of activity are seen as specific and important and universal.

Administrative Planning

The challenge of planning lies in the collection, selection and interpretation of facts. Planning must show the consequences of decisions, show trends, point the way, and provide guidance in the choice of alternatives. Planning must also assist in the establishment of norms—or standards—compatible with current socioeconomic conditions.

Planning should be both the steering wheel and the fuel for the action program. Planning should help set goals and objectives for highway administration. It must use

the scientific method in the controlled design of research, investigation, analysis, interpretation and use of findings. It is the planner's business to see that the findings from the $60 million annual expenditures on research around the world which are pertinent to the problems of his country are made available.

The planning division gathers facts as a means, not as an end.

Research

One of the most elementary yet most significant considerations in highway research is simply: How does the design perform?—not in the laboratory alone but particularly in the field. Research may determine the properties of materials—physical and chemical—in component parts and in combinations by testing in the laboratory under controlled conditions for effects under all the recognized significant field forces that will be brought to bear. But this gives only indications of field performance. It is not the final answer. The research must now be applied in the field and be carried out without control of ambient forces. It is important that test sections be rigidly controlled and observation be carefully planned and precisely measured—and finally that the analysis and interpretation be subjected to rigid scientific methods. This may be difficult for developing countries. And unless there is adequate engineering control of construction, the performance of the projects thence built will hardly parallel the performance of the researchers' test sections.

Performance goes beyond structural requirements. "How does it perform?" is asked with just as much validity by the traffic engineer as by any other engineer. In some cases the annual cost of accidents has exceeded the annual costs of the plant. In the United States it is estimated that accidents cost about 1 cent per vehicle-mile, plant costs are but slightly higher on a vehicle-mile basis, and average shipping costs are about 6 cents per ton-mile. In some of the pioneering countries the cost of transportation may exceed 10 cents per ton-mile and the accident costs approach 10 cents per vehicle-mile.

Soils and Materials

The soils problem is one of relating their properties to manipulation and to performance. There is much to be done in developing countries to determine performance characteristics of soils. Laterites and lateritic soils of "a thousand varieties," for instance, are abundant in many areas. But their performance is diversified and unpredictable today.

The economics of stabilization and of compaction provide challenges to highway technology. Compaction by settlement may be an economic answer on lightly traveled roads.

Construction

Standards and specifications for construction in the new states must be in the form of putting new wine in new bottles. The new knowledge should be made available for application to local conditions in developing countries. This goes far beyond the adoption of our old county standards of 1925 simply to match an economy perhaps comparable to our 1925 county economy. Technology has advanced on all fronts in an amazing way since 1925. The problem is adaption, not adoption; it is the application of new methods, materials, and practices to road problems for maximum service at minimum annual cost. It is the adaption of new knowledge of soils, steels, cement, asphalt, and traffic. It involves the extension of machine work to appropriate elements of construction, and the limiting of manual work to the elements most appropriate for it. It involves a continuing rearrangement of science and engineering, of man and machine for economic balance.

Project management is very important in developing countries. This is why it was mentioned by so many people. Work quantities and operations need to be blended into an optimum balance of men, machines and materials. This requires scheduling of operations through an activity analysis comparable in theory, though not in detail, to

PERT or CPM, so that all components of the work flow will merge in a continuous stream of desired volume. It will lead in time to a coordination among contractor, engineer, and public service officials, a goal hard to realize in a hurry. Efficient construction in developing countries needs analyses of the relative costs of stage construction versus "turn-key" construction as related to traffic volume for each project. This is rarely done in developing countries. And it needs better relationships between construction tolerances and maintenance standards. This, too, is often ignored abroad.

A pencil can be more potent than a pick.

Maintenance

In general terms: "The greater the investment, the greater the upkeep." Even if it should cost the highway department less to neglect maintenance, the cost to the user is increased. Such costs include the effect on motor-vehicle operating costs and accident costs of potholes; pumping and faulted slabs; low, unstable, narrow shoulders; loose gravel; and wavy, rutted, or slick surfaces.

A proper balance between well-handled construction expenditures and well-managed maintenance expenditures can make the maintenance dollar go much farther. This requires equitable allocation of funds and trained management in both fields.

Traffic

Although the traffic problems could be recited at some length, the greatest of these include (a) a way to segregate the dissimilar components of mixed traffic for safety, greater capacity and accelerated flow; and (b) a lane discipline assisted by signs and markings, and, for camel and donkey traffic, by roadway design.

Design

In this discipline the standards and specifications and warrants provide the guidelines for merging the data from the specific locale into plans. Within the tolerances allowed, the design engineer fashions out of the information provided from the field by topographical, soils and materials surveys the finished action plan. He balances safety and convenience with economy. He balances construction economy with maintenance economy. In short he merges field data often supplied by other divisions into a plan balanced for safety, economy, convenience, and other pertinent qualities of transportation. His watchword is "optimization"—maximum service at lowest cost.

Legal Studies

The framework for nearly every activity of the highway department is established in law. The body of law pertaining to these activities can provide guidelines to safety, to economy and to convenience in highway administration through constraint. It finds its greatest effectiveness in its paralleling and interpretation of the ethical and physical laws in the highway field. Highway accident prevention, for example, rests in large measure in the legal provisions for driver licensing and motor-vehicle operation.

IN PERSPECTIVE: PRIORITY AND IMPLICATION

The summary of top highway problems provides a subjective popularity ranking or indicator of universal need rather than an objective priority rating. Popularity may reveal importance but not necessarily the greatest promise, whereas priority stems from a significant difference in the benefits. Priority also considers the scheduling of sequential operations. Priority guidelines offer the maximum return on investment for the state and the maximum service at lowest cost for the highway user. In light of this definition the problem areas were reviewed for priority. All are of importance. All are not of the same urgency in accomplishment. Cost effectiveness is a determinant.

The sequential staging of activities is arranged as follows (through three levels):

I. ADMINISTRATIVE FRAMEWORK

1. Highway Organization and Administration
2. Research-Education-Application (programming)
3. Resource and Revenue Apportionment
4. Highway Needs Study (including socioeconomic analyses)
5. Highway Law (formulation)

II. OPERATIONS PLANNING

1. Maintenance Budget vs Construction Budget
2. Construction Management (planning)
3. Maintenance Management (planning)
4. Traffic Operations and Capacity (planning)
5. Stage Construction, Methods and Economy

III. OPERATIONS PRACTICE (manuals)

1. Signs, Signals, Markings
2. Construction Practices
3. Maintenance Methods
4. Selection of Suitable Materials
5. Compaction and Stabilization (and other operational functions)

The reason for the sequential staging is self evident. But for the significant return from investment the accent should be placed on certain of these activities. The following listing suggests the activities for special priority:

a. Research-Education-Application
b. Socioeconomic Analyses of Highway Needs
c. Construction Management
d. Maintenance Management
e. Traffic Operations and Control
f. Manuals of Practice (in native tongue)

A coordinated program of research-education-application, as noted elsewhere in this report, can provide benefits related to costs of the order of 10 to 1 for one year's use of findings. Skill is needed, however, in the blending of sophistication and pragmatism.

The socioeconomic analyses of highway needs will reveal the benefit-cost of the system and its component parts and the alternatives, thus providing the administrator a device for investing the dollar for its greatest effectiveness.

Construction management and maintenance management by system analysis and stratagem has shown marked reduction in costs in the United States at insignificant costs in providing management skills.

Traffic operations and control has proved itself by providing very substantial reductions in congestion and in accidents at relatively small cost. It is the first must in traffic engineering.

Manuals of Practice provided at little cost can provide the means for "accomplishing with a penny what anyone can accomplish with a dollar."

To whom is the challenge? Certainly to the responsible officials of the developing country. Certainly to all who have any interest in the preservation of democratic principles in free countries. Certainly to all who will benefit by a substantial reduction in costs of transportation in the developing countries (both in ton-mile cost and distance hauled), and certainly to all who will benefit from the greater socioeconomic activity awaiting reduced transportation costs, and finally to those who have a genuine compassion for the world's underprivileged.

When we look at the problems of developing countries we see a reflection of our own problems. When we state their problems we crystallize our thinking about our own. When we help them solve their problems we learn things that will help us. We learn by sharing knowledge. And we may ask ourselves, "Are we truly learned if we remain unacquainted with the viewpoints and practices of other countries?"

SOME DIMENSIONS OF THE PROBLEM

The problem could more easily be seen if we could give finite dimensions to it. These we have not been able to obtain. But we do have evidence that the present hard-surfaced roads are just the "first easy increment" of needed road mileage. We have suggestions that there are needs now for up to 20 times the surfaced mileage already completed. We also know that the demand is related to motor-vehicle registration, which is doubling in some countries every four or five years. We know too that the potential demand is related to population growth, which may double by the year 2000 A.D. in the less developed countries. And we know that economic activity and transportation facilities go forward hand in hand. This pressing need gives some perspective to the problem.

The first need without doubt is seed money for research-education-application. Bootstrap escalation is inadequate. Many more technologists and technicians are needed now because at the present time large segments of work are being done by consultants from more advanced countries. Finally, we know that there are about 150 countries in the world and half of these need fiscal and technological help in some measure—especially in the form of technological information. The challenge is to match the resource capabilities of more advanced countries with the priority needs of the less developed countries. Many of the developing countries have reached the stage where they can lend a helping hand in numerous fields to the neighboring, comparatively less developed countries, and this help can be realistically applied in the lesser developed countries, or in lesser developed technologies. Technical assistance from abroad can reach its greatest potential if it is used to supplement or complement the resources already available locally and to the extent that it cannot be provided locally.

WHAT THE UNITED STATES CAN DO

We have built more than two million miles of roads to a variety of standards in the past 50 years in the United States. We have maintained highway courses in our undergraduate curricula and advanced courses in highway administration and technology in our graduate curricula in many universities. We are conducting more than $25 million worth of research in the highway field annually and we are publishing more than 10,000 pages a year on highway technology.

Out of this historical and current experience the United States has gained competence to aid in the priority areas noted, and in terms of research, education and application can provide various helps, including:

1. Exploration of needs in technology in specific countries;
2. Special courses in subjects relevant to highway management and technology;
3. Manuals of practice;
4. Highway literature (including translations);
5. Information service on research and practice;
6. Research on local soils and materials—their use in highways; and
7. Assistance in establishment of highway research units and their priority programs.

CONCLUSION

Let me say in closing that the words "developing country" have no absolute meaning. We usually think of the newer or less industrialized states as developing countries, but the United States is still a developing country, certainly in transportation administration and technology, for we still have a long way to go. Our own top problems tell us so: congestion, parking problems, traffic accidents, soil problems,

pavement-design problems, travel costs, etc. Our problems, too, can be reduced to a substantial degree.

These observations, therefore, do not apply exclusively to the seven countries I visited. Years of travel in the United States and travel in other countries have made this amply clear.