

Increasing Highway Engineering Productivity

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One year ago at the A. R. B. A. convention, the four task forces reported on the ability and readiness of the engineering profession and the highway industry to plan, design and execute an expanded program over a period of ten years.

The excellent report of Task Force Number One on the ability and readiness of the engineering profession to plan and design such a program set forth some very pertinent facts. It was agreed that one of the major problems in expanding the highway program was the supply of engineering personnel. This problem, however, is by no means insurmountable. A survey showed that state highway departments used in the planning, design and supervision of construction, from three to 18 professional engineers per million dollars of construction work and that the average was about eight. It appears that in most states, substantial increases in engineering productivity could be accomplished by present personnel. Using an average of eight engineers, the \$4 billion current construction program requires 32,000 professional engineers. Now, if the engineering manpower requirements could be reduced to an average of four engineers per million dollars, double the work load, or \$8 billion per year, could be accomplished. About one fourth of the state highway departments indicated they can operate at or below this figure when the program level approaches its maximum. Through close supervision and through administrative planning and management, a properly organized highway department can effect such a reduction in professional engineer requirements.

Now I realize that you may very well exclaim, "It can't be done!" Well, I can now answer that by telling you—"That is exactly what we have done in Wisconsin" and it has been accomplished in two years' time!

Let me cite the figures. In 1954 we let \$42½ million of highway work to contract. In 1955 we let \$73 million to contract. Six months

ago we set up and approved and have underway a \$105-million program for 1956!

In 1954 we had 400 engineers for \$42½ million—10 engineers per million dollars of construction.

In 1955 we had 400 engineers for \$73 million—5½ engineers per million dollars of construction!

In 1956 we will have 400 engineers for \$100 million—4 engineers per million dollars of construction!!

New Techniques

To accomplish this, our department was reorganized on a staff and line plan. Engineers were relieved of all non-engineering work. We used to have engineers acquiring right of way, running surveying crews, acting as personnel directors, in charge of training programs, handling over-all policy and office procedure. Today our engineers do none of this. They are relieved of practically all administrative matters.

To accomplish this we developed and increased our non-engineering staff, sometimes mistakenly referred to as *subprofessionals*. In Wisconsin we prefer to call them nonprofessionals.

In many organizations such as ours, professional engineers are holding nonprofessional jobs. This we believe, is a waste of talent and manpower. They should be moved up to professional positions and given supervisory responsibilities.

It is in the nonprofessional group that the major expansion of engineering personnel will be made. At the present time, three or four nonprofessional men are being used for each professional employee. The expanded program would require a large number of additional nonprofessionals.

At present we operate two training programs, one for graduate engineers coming out of college, the other for the nonprofessionals currently recruited.

I must warn you, however, that it is not enough to simply attack this problem on a single front. It must be attacked on *all* fronts and we must employ the most modern developments and techniques known to the industry.

New types of equipment, new survey methods, photogrammetry, electronic computations, drafting short cuts, standardization of design, yes, even revised contract procedures are all prerequisites to the prompt execution of a modern highway construction program.

Recently I had the good fortune to participate in a nationwide conference of highway officials, representatives of the Bureau of Public Roads, aerial survey companies, and manufacturers of electronic com-

puter machines. At this meeting new techniques of highway work were explored. Engineering short cuts, photogrammetry and electronic computations, and possibilities of their combined use were thoroughly discussed.

The California highway department is now using electronic machines for earthwork problems. They state that recently they performed all such computations on a 10-mile segment of a four-lane divided highway in four days at a cost of \$50 per mile.

Electronics has moved in on highway construction. It is being used to increase the productivity of the resident construction engineer. His presence on the job is insurance that when unexpected situations arise, decisions will be made on sound engineering bases and construction can be continued without delay. But such situations arise only occasionally on most projects so that with the installation of a two-way radio on the site and in the resident engineer's car, he can assume responsibility for two, three, or even more projects in an area. Radio is also used to control the flow of materials between the central mixing plant and the pavement construction site.

On one of our highway projects we employed an aerial mapping company to fly the job and produce detailed topographic maps. We estimated it would take our own forces one year to do the job on the ground. Photogrammetry permitted completion in four months! We have now flown 350 miles of reconnaissance and route selection and 125 miles for completed topographic maps.

We too are using the services of consulting firms of engineers, and we have contracted a record amount of work to them. We have four nationally known firms of consultants under contract producing detailed plans for over 100 miles of our interstate system of highways. By the time Congress passes the next federal aid highway act and the Bureau of Public Roads informs us of our apportionment, we expect to be ready to let these contracts for freeway development on our interstate system. In this connection it should be mentioned that our use of consulting engineering services is merely complementary to and is not supplanting our engineering organization or production.

Great savings in engineering manpower and time are possible through the application of new techniques and the wider use of machinery and equipment in operations.

In plan preparation, more use of standard plans and specifications will save time and manpower. Nearly all plans can be simplified through reduction in the amount of detail without harm to the execution of the work. Undoubtedly many short cuts in plan production can be worked out and adopted. In Wisconsin, we have been experimenting

with the use of special typing equipment to do the voluminous and time-consuming lettering required in a standard set of plans. Our tentative conclusions are that if certain problems are overcome, a man with a machine can produce more than three and possibly as much as five men using the conventional hand methods.

It is our experience that survey operations can be carried on almost entirely without engineering help. This, of course, requires some training, standardization of procedure, and the use of a manual for survey work. *In one of our district offices seven complete survey parties are in operation with only one engineer in the entire complement of personnel!*

Of particular note in our reorganization plan is the provision for a division of planning and research which is charged with the responsibility for long-range planning and programming. Traditionally this function has been directly associated with the engineering activities so that the engineering division controlled the development plan, the design of the component projects, as well as the supervision of their execution and completion. Under present arrangement, the engineering division is concerned principally with the design and construction aspects and merely provides advice and guidance on annual programs and the long-range plan.

This departure from traditional procedure has resulted in direct and substantial benefits. Improved programs, more rapidly executed, have been produced and approved more than a year in advance. *OUR GOAL IS TWO YEARS' ADVANCE APPROVAL!* Advance planning has made it possible to schedule the letting of projects for the entire ensuing year. Thus, we were able to control the work load instead of the work controlling us, and avoid many of the complications of haphazard letting of contracts to bid and construction. Planning has also permitted an earlier letting of contracts to construction so that we have been able to take full advantage of the short construction season, an important consideration in our part of the country. Also, as a result, project administration has been made easier and more effective. Because the district engineers knew in advance the probable work load and its incidence, they have been able to use and shift personnel more effectively, and thus extend the capabilities of our limited engineering and technical manpower.

A fruitful field for development is in the improvement of management processes. All highway administrators are probably willing to admit that, to some extent at least, their departments are still operating in accordance with procedures and practices established many years ago. Recently a far western state reported that unnecessary surveying, use

of inefficient methods, tedious plotting and replotting of cross sections, and endless calculations to the third decimal were collectively considered their number one "time thief." Unquestionably great savings in time and manpower could be effected by the elimination of much that is unnecessary.

There should be no "sacred cows" in highway administration. Too often the attitude that "we've always done it this way" stands in the way of progress. Also, the rather general willingness of administrators to leave things as they are and live with a situation which is admittedly tough to change, is a major obstacle to more effective administration.

It is incumbent upon administrators to plan, stimulate, and develop improvement in methods and techniques, and to keep abreast of the best available thoughts and practices. A searching examination of present operating methods is in order and all departments could profit from a plan of this kind. Such analysis will definitely disclose some unessential work and misapplication of manpower, and it will lead to the establishment of more efficient methods for performing operations and activities.

Personnel Policies

Although many technical improvements and organizational arrangements can be brought about to improve administrative efficiency, maximum results cannot be achieved without competent personnel. There are probably a number of ways in which the caliber and performance of personnel can be raised, but again the problem is one which requires a broad approach. The fact that highway departments are still having considerable difficulty in obtaining and retaining competent personnel indicates that we are not offering a very attractive package to prospective engineers and technical help.

Salary alone is not enough to attract personnel these days, although salaries dare not be much below the going rate. Many factors influence a graduate engineer's choice, some of which oftentimes outweigh salary considerations. Our experience indicates that the following are controlling factors:

1. Challenging work that will test the skill, imagination, and knowledge of the engineer.
2. Career opportunities including hiring based on merit, protection against arbitrary dismissal, and in-service training leading to advancement opportunities from within.
3. Training programs designed to further the engineer's knowledge and fit him into the organization as quickly as possible.
4. Adequate pay based on duties and responsibilities with periodic pay raises guaranteed if job performance is satisfactory.

5. Liberal sick leave and vacation privileges.
6. Retirement and other benefits, and finally—
7. Professional recognition. Prestige is an important consideration to an engineer, and departments should give it due recognition by insisting on higher educational and professional standards and by providing better chances for professional advancement and recognition.

Unless the salary offered is abnormally higher than the going rate, the graduate is more concerned with advancement opportunities than with any other single factor, if the recent survey which we made is of any significance. Promotion, salary, training, and location ranked in that order of importance. It is indicated, then, that highway departments should be selling advancement opportunities as their principal stock in trade. The time was never more ripe. Highway building and services are expanding rapidly. This rapid expansion and growing diversity in operations will provide many new opportunities in the highway service. As a counterpart to selling opportunity for advancement, however, more liberal and enlightened promotional policies will be required.

Engineering personnel should be pushed ahead as fast as possible. After some basic training a recruit should be given every opportunity to develop the confidence and abilities necessary for assuming increasing responsibilities. This is the time to discard the traditional concept that any individual must acquire a minimum, set amount of experience before he can be entrusted to perform a particular job. The artificial and unrealistic standards which have guided in the past can no longer be justified. Unless we adopt more progressive practices, it will not be possible to convince the graduate engineer of advancement opportunity, and the chances of attracting other than the mediocre will be slim indeed.

Since the hiring of competent personnel in the numbers required is virtually impossible, training of employees is the only alternative. In any event, training is necessary to staff any department with men well-trained for increased responsibilities which lie ahead of them. Our engineer training program is designed to accomplish this purpose. It is our experience that well-organized and specific training shortens the time required for personnel to become really effective and productive. A training program of some kind is desirable if for no other reason than the fact that the graduate engineer rates training next to salary and advancement opportunities in importance. Furthermore, a training

program is one of the better ways of attracting and holding engineering personnel, as our experience in Wisconsin will bear out.

Training is perhaps the only way in which it will be possible to acquire the great numbers of technical personnel required for the expanding highway programs.

Contract Procedures

In contract and project supervision, manpower can be saved and utilized more effectively if contracts are let and contractors start working as early in the year as possible. An analysis of the projects completed this season in one district disclosed that about 80 percent of them could be completed within the normal construction season. Because of the short season in our part of the country, it is imperative that projects are scheduled properly and started early in the season. It is also important to keep the contractor on schedule. Everyone is familiar with the disturbance which is caused when contractors get behind schedule. Each delinquent operation puts an added strain on limited supervisory personnel, upsets any plans for orderly administration, and often delays the scheduled starting of other projects. Contractors also benefit in much the same manner from early lettings which permit setting up requirements for supplies and equipment in advance, and thus avoiding delays which are frequently caused by temporary shortages. A precautionary consideration is to avoid loading contractors beyond their capacity of supervision and equipment. Geographical distribution of the jobs of a contractor may also be an important item to consider.

In the construction phase, it has long been known that the award of larger contracts would require fewer engineers in the planning stage as well as in the supervision of the projects. Possibilities in this area should be explored further. During the past two seasons we have been attempting to discover how to spread the limited number of engineers over larger programs and a greater number of projects. We have been pleasantly surprised to find that not only is it feasible but it may be possible to extend the engineering staff more than we had anticipated.

In Wisconsin we have worked closely with our contractors. Joint meetings are held between the Highway Commission and the Board of Directors of the Wisconsin Road Builders' Association. Such a joint meeting was held this last December. We are now revising our specifications and in rewriting them we are giving consideration to the new procedures and to the suggestions offered by the contractors. We are revising contract procedures—and are providing for lump sum bids, package deals and elimination of some final measurements. We have

invited the W. R. B. A. to submit recommendations for any changes in specifications which they may deem helpful to their industry and the efficient prosecution of the work.

Legislative Support

We have worked closely with the Highway Study Committee of our state legislature. Our Governor, who is Chairman of the Highway Committee of the Governors' Conference, has a keen insight into the highway problem. This past session saw enactment of the greatest highway program in the history of our state. A few of the laws enacted are:

1. A driver licensing program.
2. A great increase in the State Highway Patrol.
3. An increase of 2c in our state gasoline tax, from 4c to 6c—producing an additional \$20 million for highway construction.
4. Establishment of a 2,100-mile state arterial system of highways, with a program for building this heaviest traffic system up to standard in 10 years.
5. Increase in mileage of controlled access from 500 to 1,500 miles.
6. An enabling act authorizing our participation in any legislation or program passed by Congress affecting the Interstate System.

Enactment of this program was greatly facilitated because our legislature was not only convinced of the need for an expanded highway program, but they were convinced that our highway department was capable of planning, designing and supervising the construction of double the amount of work heretofore accomplished.

Conclusion

In this discussion, a number of ways have been suggested to improve highway administration and increase our engineering productivity. An exchange of ideas would undoubtedly disclose many additional ways to bring about more effective methods and procedures that would conserve time, money, resources, and life itself. Such an exchange of ideas is contemplated through meetings of the Highway Research Board. The labor saving devices and new methods already uncovered are impressive and lead us to believe that we are merely scratching the surface of possibilities for improvement.

A highway plan for years to come is in the making. The very magnitude of this plan is both a challenge and an opportunity for all of us.

It not only implies some 10 to 15 years of expanded activity; it will also afford contractors in particular a sound long-term opportunity to buy equipment and enlarge and train their staffs. It will permit manufacturers of equipment and producers of highway materials to plan sound expansion programs. And it goes without saying that a long-range program lends itself to more efficient methods of operation.

Recently, at a conference of our district engineers, I made this statement: "If you are doing things today the way you did them 10 years ago, you are doing them wrong." I say to you men of the gigantic road building industry today: "If you are doing things the way you did 10 years ago you are not only doing them the wrong way, but you are wasting time, money, talent, and profits."

In Wisconsin we have adopted a number of the tested techniques and are experimenting with a number of others because it is our belief that under the existing situation highway departments are not likely to obtain engineering manpower in the numbers presumably needed. We know also from experience that engineering talent can be stretched considerably more than anticipated, because this year we have been able to manage successfully almost double the amount of work—with no appreciable increase in the number of engineers on the staff. In the face of such encouraging results, further experimentation will be the keynote of our administration.

We are greatly inspired by the fine idealistic thoughts of Daniel H. Burnham, Architect and Planner of Cities—

"Make no little plans; they have no magic to stir man's blood and probably themselves will not be realized. Make big plans, aim high in hope and work, remembering that a noble, logical diagram once recorded will never die, but long after we are gone, will be a living thing, asserting itself with ever increasing insistency. Remember that our sons and grandsons are going to do things that would stagger us."