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Contents

OBSERVED MANPOWER REQUIREMENTS

C. E. Fritts 1

SIX-STATE CLASSIFICATION STUDY OF ENGINEERING PERSONNEL

Ralph S. Lewis 4

MICHIGAN ENGINEERING INVENTORY TREND STUDY

Merle J. Walker 14

LOCAL HIGHWAY ENGINEERING MANPOWER: APPRAISAL AND ACTION

Wayne H. Snowden 25

POTENTIAL SUPPLY OF MANPOWER FOR AN EXPANDED SECONDARY ROAD PROGRAM

John E. Stoner 35
Appendix 46

MINNESOTA'S ORGANIZATION AND METHODS SECTION

K. L. Bergstralh 54

TIME-SAVING IDEAS IN HIGHWAY ENGINEERING

M. Earl Campbell 57

INCREASING PRODUCTIVITY IN ENGINEERING

L. R. Schureman 62

UTILIZING BUSINESS MACHINES IN TRAVERSE AND EARTHWORK COMPUTATIONS

Sam Osofsky, R. K. Breece, John A. Haller, and Walker L. Ayres 68
Appendix A
Instructions for Calculation of Traverse Data by Punched Cards 76
Sample Traverse Sheets 80
Appendix B
Instructions for Calculation of Earthwork Data by Punched Cards 91
Sample Earthwork Data Sheets 96

Observed Manpower Requirements

C. E. FRITTS, Vice President in Charge of Engineering
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● THIS report deals with highway manpower requirements in two general ways; first, from the point of view of general national conditions, and second, from specific situations as witnessed in several states.

When we deal with the subject of manpower requirements, we all realize that we are working on a subject that has many facets and influences. It is not a subject that can be treated by application of engineering formula.

Economic influences, such as the lack of adequate long term highway programs or the general level of employment, have an important bearing. Changing situations in total scientific developments create imbalances in attractiveness of fields of endeavor. Currently the trend is toward atomic energy and electronics. Finally, government employment policies and management practices in many instances aggravate a situation that is already bad.

Throughout the nation we have a real problem in meeting the needs for engineering personnel, both professional and subprofessional. The situation may get worse before it can get better. It is now acute enough that we must take positive steps to solve the problem.

The shortage of highway engineers starts in college. Total enrollment in colleges continues to increase but the percentage of students taking engineering remains at 7½ percent, about the same as for the past five years. Out of an annual total of about 22,000 engineering graduates, about 4,000 are civil engineers. At the present rates of employment, only about 14 or 15 percent of the civils are going into highway engineering. And, to carry it a step farther, less than three percent of our total engineering graduates in all branches enter highway work.

It is difficult to accurately forecast the number needed. We do know that states generally have, up to now, been able to recruit less than one-third the number of graduates they were seeking. If the backlog of need for engineers could be met it would require induction of about 2,000 engineers annually in the highway field for the next few years.

This requirement calls for action on two fronts. First, more engineers must be attracted to the civil engineering branch in relation to other engineering fields. Second, highways must be made competitively attractive with other areas of employment for civil graduates.

Highway departments up to now have been able to subsist to a large degree because the first crop of engineers recruited in the road program of the 1920's are still in service. However, the age situation is becoming more critical and new blood must be injected at a faster rate. A few examples taken from recent studies serve to make the point.

In one state 15 of the 24 men in the top three grades were over 60 years old. In the same state, out of a total of 238 engineers in grade II, only 13 were under 40 years old. No one in grade III or higher was under 40 years old.

In another state over one-third of the personnel employed in engineering work are over 60 years of age and only 12 graduate engineers out of a total of 89 qualified engineers are under 45 years of age.

Another state has a total of 619 engineers with one-third over 50 years old. In the same state 182 employees are classified as junior engineers or instrumentmen. The average age of the 182 men is 40 and only 13 of them are college trained.

In another case, one-third of the entire engineering staff will be retired in 15 years and another one-fifth will follow in the next five years.

In one of the smaller states with only 71 engineers, 17 are now eligible for retirement and only six men are under the age of 40.

Those individual cases do not necessarily represent a national average condition, but they do illustrate the fact that many states thus far have fallen far short of laying the groundwork which will build strong engineering forces for the future.

On the other hand, we can point to a few states that have recognized the problem and have adopted aggressive courses of action which are producing results.

Now let us turn to a discussion of the things that can and must be done to meet the problem.

To get more engineers into the colleges and in turn to get more of them into highways, we must have a sound sales argument.

First, engineers must be convinced that there is a rewarding future in highways. That means that for one thing the highway program at all levels of government must be adequate and firmly committed as a continuing program. Opportunity for an engineering career cannot be easily sold when it is of a fluctuating or unstable character.

Second, it must be demonstrated that the rewards are substantial. By that we mean that salaries and other benefits are competitive with other fields and that meritorious effort will bring recognition and advancement.

With regard to the influence of a stable long range program, it can be concluded that the current national interest in highways will bring forth a stepped-up program. Such a program on a nation-wide basis should serve well to convince students that there is a big job to be done in highway development. It should lead to a greater proportion of students choosing civil engineering. It should also provide the incentive for the highway agencies to reorganize their personnel policies and practices in such a manner as is required to be competitive for engineering talent.

It is significant to note that those states which have been most aggressive in the post-war years in the adoption of long range plans with accelerated financing have been most successful in meeting the personnel problems.

The salaries of civil engineers on a national basis for the first ten years of service are generally competitive with other branches of engineering. However, as engineers progress beyond the ten year period of service, median salaries of civils are falling below other major branches. Highway salaries generally are below that of civil engineers in non-governmental employment but it is most noticeable in the upper grades. The situation varies greatly between agencies of government and regions of the nation.

If highway agencies are to be made fully salable to young engineers, it will be necessary not only to make beginning salaries attractive, but rates must be materially increased in the higher positions. The young engineer of today is being solicited by many agencies. He cannot afford to choose one that does not give a reasonable opportunity for an ultimate economic status equivalent to his fellow engineers in other fields.

The salary studies made by several engineering societies provide the basis for the above observations.

Attraction of engineers to highways will require more than adequate salaries and a challenging long term program. One requirement is the production of evidence that careers are not subject to the whims of political manipulation of management. This can be brought about, as far as most personnel are concerned, by good systems of civil service or merit rating. Such systems are not without their disadvantages but by and large they serve to attract men to careers in government. Such systems must be administered with sympathetic understanding of the management needs of the highway agencies. By that I mean they must be flexible enough to permit active recruitment on a competitive basis. It must be recognized that engineering is a technical profession requiring education and demonstrated qualification. It cannot be put in the same category as non-technical government service where comparable pre-qualification is not required.

At the end of the line, men today, as in nearly all walks of life, hope to look forward to a retirement that is commensurate with the cost of living. Many highway department retirement plans are now inadequate to meet those objectives.

Another need in order to compete for talent and simultaneously provide the best results from talent obtained is that of in-service training. This activity should be designed to fully acquaint the new employee with all the varied functions that are required in highway engineering and operation. It provides a period when the new employee may convert his academic training into practical application in a highway career. It gives the employee a chance to demonstrate the area of greatest interest to him and the area of greatest capability to the employer. Both employer and employee benefit from the process. The value of the process has been fully demonstrated in too few departments.

Perhaps another area should not be overlooked in creating an atmosphere of salability with respect to highway engineering. Highway engineering today is a real challenge. It is tremendously diversified in its requirements. Traffic movement is one of the more complex domestic problems. If we are to plan, build and operate highways for the future, we must have men with a great variety of skills, imagination and courage.

We must have men with foresight for planning and design. We must devise new ways of performing routine engineering calculations. We must devise new and better ways of operating and maintaining facilities. We must find better ways of getting the most from the men we have and those we will get in the future. We need to apply as much science to personnel engineering as we do to the basic sciences of engineering. When we do, we will then begin to meet our manpower requirements. Then I think we will be able to approach the young engineer with an argument that will be convincing and salable.

Six-State Classification Study of Engineering Personnel

RALPH S. LEWIS, Bureau of Public Roads

A study made by the Highway Research Board late in 1954 indicated that the number of engineers employed per million dollars of capital outlay varied from 2.0 to 28.2 in the several state highway departments. It was realized, of course, that differences among the states in classifying and reporting engineering personnel might account to a considerable extent for the variations, but the possibility that the variations might be indicative of relative operating efficiency was also considered. In an effort to explain the variations, studies of engineering classification and related matters were conducted during the summer and fall of 1955 in Mississippi, Nebraska, Oregon, Vermont, Washington and Wisconsin.

It was found that classification prodecures and reporting methods definitely affect the results reported by the earlier study. Two of the six states studied, for example, had reported only registered engineers, while the other four states had reported all personnel classified as engineers by civil service or merit system provisions, regardless of professional qualifications. Only 31 percent of the personnel classified as engineers were registered, and only 35 percent were civil engineering graduates; 52 percent were neither civil engineering graduates nor registered.

The six-state study also related the number of engineers employed to the number of subprofessional employees, to program characteristics, and to management practices and procedures. The resultant findings are not conclusive, because of the many intangibles involved and the relatively few states included in the study. It is established, however, that the combination of engineers and engineering aids reduces considerably the extreme variations in the number of engineering employees per million dollars of capital outlay.

LATE in 1954 the Highway Research Board requested from all state highway departments information as to the number of professional engineers employed, the number of engineering positions it would be necessary to create in order to handle the work then being handled by consulting firms, and the number of additional engineers needed in order to work at the highest level of effectiveness. The states reported a total of 18,034 engineers employed, consulting work equivalent to another 4,192 engineering positions, and a need for 3,990 additional engineers for fully effective work.[1]

Subsequent analysis indicated that the number of engineers reported per million dollars of capital outlay varied from 2.0 to 28.2 in the individual states. These wide variations were somewhat of a surprise, and their possible significance appeared to justify further study, although it was realized that differences among the states in classifying and reporting engineering personnel might account to a considerable extent for the variations.

There was also the possibility, however, that the variations might be indicative of relative operating efficiency. If so, it seemed likely that those states with a low number of engineers per million dollars of capital outlay might furnish ideas for the utilization of engineering manpower which would be of value to other states. In any event, no conclusions could be reached without a much more detailed analysis.

Accordingly, it was decided to make detailed studies of engineering classification and related matters in six selected states — Mississippi, Nebraska, Oregon, Vermont, Washington and Wisconsin. In selecting these states, consideration was given to the relative number of engineers per million dollars of work, geographic location, rural-urban characteristics, total amount of program, amount of work done by consultants,

[1] See Highway Research Board Bulletin 106, "Manpower Needs in Highway Engineering," 1955.

and number of additional engineers needed for fully effective work. Information on the number of engineers employed per million dollars of capital outlay for the six states selected is presented in Table 1, on the basis of data reported in the 1954 study.

TABLE 1

NUMBER OF ENGINEERS EMPLOYED PER MILLION DOLLARS OF CAPITAL OUTLAY IN SIX SELECTED STATES

State	Engineers employed[a]			Capital outlay[b]	Engineers employed per million dollars of capital outlay[c]
	Total	Assigned to maintenance	Total, exclusive of maintenance		
				Million dollars	
Mississippi	111	11	100	26.3	3.8
Nebraska	245	20	225	16.5	13.6
Oregon	452	26	426	40.1	10.6
Vermont	153	25	128	5.2	24.6
Washington	206	12	194	46.3	4.2
Wisconsin	422	34	388	33.4	11.6
Totals	1,589	128	1,461	167.8	8.7

[a] As reported by the 1954 study.
[b] Bureau of Public Roads Table SF-4, 1954.
[c] Excluding those assigned to maintenance.

That study, in asking for information on the number of "professional" engineers employed, defined a professional engineer as a "registered professional engineer, or one qualified to register." Since this definition was subject to interpretation by the states, it was decided that one of the primary concerns of the new studies should be the professional qualifications of employees classified by the states as engineers. Also, it was decided to extend the studies to include engineering aids, as well as engineers, and to relate the number of engineers and engineering aids employed to both program characteristics and management practices and procedures. Such studies were conducted in each of the selected states during the summer and early fall of 1955.

CLASSIFICATION PLANS OF THE SEVERAL STATES

Since these studies are concerned primarily with classification, it is desirable at this point to comment briefly on the classification plans of the states included in the studies. The highway departments of Oregon, Vermont, Washington and Wisconsin all operate under formal civil service systems and have classification plans of the graded type, i.e., Engineer I, II, III, IV, V, etc., and Engineering Aid I, II, III, etc. or A, B, C, etc. The Nebraska Department of Roads and Irrigation has for years maintained an informal merit system for its technical employees, and also has a graded classification plan. In Mississippi, on the other hand, job titles are related to specific duties, i.e., junior engineer of final plans, senior instrumentman, junior draftsman, rodman, etc., and are difficult to correlate with the several classes of a graded classification plan.

Moreover, even in the five states with graded classification plans, correlation is not a simple matter. There are several reasons for this. In the first place, a graded classification plan, in addition to engineers and engineering aids, usually includes several miscellaneous classes, such as draftsman, radio technician, traffic recorder, and on occasion even laborer, which can be included in either the engineer or engineering aid categories, and sometimes in both. Also, the duties performed by an Engineer I in some states are preformed by high-grade engineering aids in other states. Finally, although in most states a civil engineering graduate can be hired as an Engineer I, in other states he must be hired as an engineering aid and cannot be classified as an engineer until certain service requirements have been met.

The matter of registration is a confusing one, too. Some states require that engineers in a particular classification or salary scale be registered, but others require registration only in connection with certain duties. Also, some states require registration for particular grades, while others require only eligibility for registration. In Wisconsin, for example, an Engineer IV must be eligible for registration, while an Engineer V or higher must be registered. In Oregon, classification as a Civil Engineer IV or higher requires registration. Washington likes to have registration at the Associate Engineer level, and requires it at the Senior and higher levels. In Mississippi, only field engineers at the project level and higher are required to be registered.

All of this discussion indicates, of course, that there are wide differences in the qualifications of the engineers classified as such by the several states. It also suggests that there may be some variation among the states in the relation of classification to duties. Both are important matters in determining the number of engineers employed by the state highway departments, but because of time limitations it was impossible to conduct the interviews necessary to determine the relationship of classification to duties. The number of civil engineering graduates and registered professional engineers included among the classified engineers in each state was tabulated, however.

Although the 1954 study reported engineers employed, those equivalent to consulting work, and additional engineers desired, the six-state studies are concerned only with engineers employed, because of the intangibles involved in studying the other two categories. Also, while the 1954 study reported engineers by function to which assigned, i. e., construction, design, maintenance, etc., this functional distribution is not carried forward here because of the relatively few engineers assigned to other than a few major functions. In computing the number of engineers employed per million dollars of capital outlay, however, those assigned to maintenance are omitted in all cases, because their efforts do not affect the capital-outlay accomplishment.

It should also be pointed out that in most cases the number of engineers employed in a particular state does not change much from year to year, nor at different times during a given year. Neither does the number of engineering aids change much from year to year, although this number may change substantially at different seasons of the year. Program amounts in a particular state, however, may vary widely from year to year, with a corresponding pronounced effect on the number of engineering employees per million dollars of capital outlay.

Generally, then, the findings of the six-state study are relative, rather than absolute or final. The fact that only six states are included is itself a limiting factor. For any particular state, the information reported here might have been widely different a year ago, or might change radically during the course of the next year. Whether the six states selected for study are representative of the other states is not known. Nevertheless, it is believed that the studies contribute materially to the over-all engineering manpower problem, if only because of the questions they raise.

ENGINEERS — PROFESSIONAL AND OTHERWISE

Turning now to the findings of the study, Table 2 shows the number and qualifications of highway department employees classified as engineers in each of the six states selected for further study. The "classification" concept used here is of course different from the "professional engineer" concept of the 1954 study, and is quite revealing. It is first noted that the difference between the 2,114 total engineers of Table 2 and the 1,589 total of Table 1 is accounted for largely by two states, Mississippi and Washington. After some discussion with the appropriate state personnel, it was discovered that for the 1954 study Mississippi had reported only registered engineers, while Washington had reported only engineers of the associate or higher grades, omitting the junior and assistant grades. Each of the other states had reported all engineers classified as such,

TABLE 2

NUMBER AND QUALIFICATIONS OF STATE HIGHWAY DEPARTMENT EMPLOYEES CLASSIFIED AS ENGINEERS IN SIX SELECTED STATES

State	Both C.E. graduate and registered		C.E. graduate only		Registered only		Neither C.E. graduate nor registered		Total employees classified as engineers		Total C.E. graduates		Total registered engineers	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Mississippi	82	38	4	2	34	16	96	44	216	100	86	40	116	54
Nebraska	28	12	25	11	71	30	111	47	235	100	53	23	99	42
Oregon	63	13	77	16	39	8	302	63	481	100	140	29	102	21
Vermont	32	21	33	22	20	13	67	44	152	100	65	43	52	34
Washington	63	10	124	20	56	9	384	61	627	100	187	30	119	19
Wisconsin	115	29	98	24	55	13	135	34	403	100	213	53	170	42
Totals	383	18	361	17	275	13	1,095	52	2,114	100	744	35	658	31

TABLE 3

NUMBER OF EMPLOYEES CLASSIFIED AS ENGINEERS[a] PER MILLION DOLLARS OF CAPITAL OUTLAY, ACCORDING TO QUALIFICATIONS, IN SIX SELECTED STATES

State	Both C. E. graduate and regis- tered	C. E. graduate only	Regis- tered only	Neither C. E. graduate nor regis- tered	Total employees classified as engineers	Total C. E. graduates	Total regis- tered engi- neers
Mississippi	3.0	0.2	1.3	3.6	8.1	3.2	4.3
Nebraska	1.5	1.4	3.8	6.2	12.9	2.9	5.3
Oregon	1.3	1.9	0.8	7.1	11.1	3.2	2.1
Vermont	6.0	6.3	3.8	12.9	29.0	12.3	9.8
Washington	1.3	2.7	1.1	8.3	13.4	4.0	2.4
Wisconsin	3.3	2.9	1.2	3.8	11.2	6.2	4.5
Totals	2.2	2.1	1.4	6.3	12.0	4.3	3.6

[a] Excluding those assigned to maintenance.

regardless of their professional qualifications or grades.

Thus, the reported total of 18,034 engineers employed by all state highway departments may be either high or low, depending on what is wanted. If the ratio which exists between Tables 1 and 2 is applied to all states, the figure becomes approximately 24,000 on a classification basis. If, on the other hand, the "professional engineer" concept is adhered to, the 18,034 figure is probably much too high; its actual amount will depend on how the term "professional engineer" is defined.

This matter of definition is obviously an important one. Referring again to Table 2, it is noted that 52 percent of the employees classified as engineers are neither civil engineering graduates nor registered professional engineers, the percentage varying from 34 to 63 in individual states. Also, only 35 percent of such employees are civil engineering graduates, and only 31 percent are registered professional engineers; only 18 percent are both civil engineering graduates and also registered professional engineers.

If an engineer is defined as a civil engineering graduate and/or a registered professional engineer, only 48 percent of those employees now classified as engineers could qualify, according to Table 2. Is this a reasonable definition, or does it do an injustice to the other 52 percent of the employees? Should these employees continue to be classified as engineers, or should they be reclassified and placed in high-grade engineering-aid classifications, which may not even exist at present? Granted, some of them may eventually attain registration, but are we interested in potential or in present qualifications?

In any event, Table 2 presents some of the most important findings of the six-state study. It indicates that the engineers reported by the states in the 1954 study were not reported on a uniform basis, and therefore raises a question as to the significance of any previously reported figure for the total number of engineers employed by the state highway departments. Also, by pointing out variations in the qualifications of employees classified as engineers, it demonstrates the need for a more exact definition of the term "engineer" and suggests a definition which might be usable, i. e., a civil engineering degree and/or registration. Possibly this definition should be broadened to include the small number of mechanical, electrical and other engineers engaged in state highway work.

Now, what about the number of engineers employed per million dollars of capital outlay, on the basis of the information reported in the six-state study? Table 3 presents these figures, according to the qualifications of the employees classified as engineers. This table was prepared by using the information presented in Table 2, but excluding employees assigned to maintenance, with the capital outlays shown in Table 1. The last column of Table 1, then, is based on the 1954 study, while Table 3 is based on the later six-state study.

According to Table 3, the total number of employees classified as engineers per million dollars of capital outlay varies from 8. 1 in Mississippi to 29. 0 in Vermont. This is still a wide range, although not so extreme as that indicated by Table 1. The principal differences are in the cases of Mississippi and Washington, and are due to the substantially higher number of engineers reported for those states in Table 2. Again referring to Table 3, it should be noted that for the four states other than Mississippi and Vermont the total number of engineers per million dollars of capital outlay varies only from 11. 1 to 13. 4

Similar variations exist for each of the several categories of engineers included in Table 3. For those who are both civil engineering graduates and registered, for example, the range is from 1. 3 to 6. 0; for all civil engineering graduates, the range is from 2. 9 to 12. 3. Although these ranges for the separate categories are less extreme on an absolute basis than is the range for total engineering employees, they are in most cases more extreme on a percentage basis. In all cases the upper extreme is represented by the figure for Vermont.

Since these rather wide variations still exist, after the figures reported by the several states have been put on a comparable basis, it is necessary to look further for an explanation. The next point of inquiry, then, is the number of engineering aids employed by the several state highway departments. Does the number of such aids vary directly, or inversely, with the number of engineers? If the latter, there is a possible explanation for the variations which exist with respect to the number of engineers employed per million dollars of capital outlay.

RELATION OF ENGINEERING AIDS TO ENGINEERS

There is no particular problem with respect to definition in connection with engineering aids, because the number of civil engineering graduates and/or registered engineers classified as engineering aids is insignificant. There is a problem of nomenclature, however, as to whether those employees who complement the engineers shall be called engineering aids, sub-professional employees, technicians, or something else. Since there is no obvious answer, they are called engineering aids here.

Table 4 shows the total number of engineering aids employed and the number employed per engineer employed for each of the states included in the six-state study. It is noted first, that the total number of engineering aids employed in all six states (2,099) is approximately the same as the number of engineers employed (2,114), so that the ratio of engineering aids to engineers is 1.0. Incidentally, this ratio can be compared with a published over-all ratio of one technician to 2. 5 engineers for all fields of engineering and for all types of engineering endeavor.[2]

In the individual states, however, the ratio of engineering aids to engineers varies from 0. 2 in Vermont to 2. 1 in Mississippi. The significant fact here is that the low ratio exists in the state with the highest number of engineers per million dollars of capital outlay, Vermont, while the high ratio exists in the state with the lowest number of engineers per million dollars of capital outlay, Mississippi. Apparently, then, there is some sort of an inverse relation between engineering aids and engineers.

This relation is demonstrated further by Table 5, which shows the number of

TABLE 4

TOTAL NUMBER OF ENGINEERING AIDS EMPLOYED AND NUMBER OF ENGINEERING AIDS EMPLOYED PER ENGINEER EMPLOYED IN SIX SELECTED STATES

State	Engineering aids employed	Engineering aids per engineer employed
Mississippi	459	2. 1
Nebraska	237	1. 0
Oregon	394	0. 8
Vermont	27	0. 2
Washington	376	0. 6
Wisconsin	606	1. 5
Totals	2,099	1. 0

[2] Engineering News-Record, November 24, 1955, p. 164.

TABLE 5

NUMBER OF ENGINEERS AND ENGINEERING AIDS EMPLOYED PER MILLION DOLLARS OF CAPITAL OUTLAY IN SIX SELECTED STATES

State	Engineering employees per million dollars of capital outlay		
	Engineers	Engineering aids	Total
Mississippi	8.1	17.5	25.6
Nebraska	12.9	14.4	27.3
Oregon	11.1	9.8	20.9
Vermont	29.0	5.2	34.2
Washington	13.4	8.1	21.5
Wisconsin	11.2	18.1	29.3
Totals	12.0	12.5	24.5

engineers and engineering aids employed per million dollars of capital outlay. Column 1 of this table is taken directly from Table 3. Column 2 was obtained by combining data from Tables 4 and 1; no correction was made for maintenance employees, because very few engineering aids are engaged in maintenance activites. Column 3 is simply the sum of columns 1 and 2.

It is evident from Table 5 that combining engineers and engineering aids reduces considerably the extreme variations in the number of engineering employees per million dollars of capital outlay. For engineers, the high figure is 358 percent of the low figure; for engineering aids, the high figure is 348 percent of the low. When the two are combined, however, the high figure is only 164 percent of the low figure.

It has been mentioned previously that program or capital outlay amounts may vary widely from year to year in a particular state, and in some states the number of engineering aids employed increases greatly during the construction season. In Nebraska, for example, the 1953 capital outlay was only $9.9 million, as compared with the 1954 figure of $16.5 million reported in Table 1. In Wisconsin, the number of engineering aids employed practically doubles during the summer months. Thus, the ratios established above cannot be considered as final or conclusive in any one instance, but do indicate a definite inverse relation between engineering aids and engineers.

This inverse relation explains at least partially the wide variations among the states with respect to the number of engineering employees per million dollars of capital outlay. Since the states use engineers and engineering aids in different proportions, a combination of the two is the best indication of engineering effort for a particular state. As shown above, when states are compared on this combination basis, some of the extreme variations are eliminated.

It remains, then, to relate the number of engineers and engineering aids employed to both program characteristics and to management practices and procedures. Perhaps this analysis will explain further the variations among the states as to number of engineering employees per million dollars of capital outlay. In any event, it would be unrealistic to expect that these variations could be explained away entirely.

PROGRAM CHARACTERISTICS

In relating the number of engineering employees to program characteristics, perhaps the most obvious characteristic to be considered is that of program amount. Other characteristics which can be analyzed include the relative amounts of rural and urban work, the relative amounts of "surfacing only" and all other work, and the average length of projects in each of the several work categories.

Table 6 shows the relative rankings of the six states selected for study with respect to program amounts and number of engineering employees. The rankings indicated in the first column are based on the program amounts reported in Table 1, while those in the remaining columns are based on data in Tables 2, 3, 4 and 5. Although not apparent at first glance, certain relations between program amounts and number of engineering employees are evident after some study of Table 6.

The most direct relation is that between program amounts and total number of engineers; Washington, Oregon, Wisconsin and Vermont rank 1, 2, 3 and 6, respectively, in each case, while Mississippi and Nebraska rank 4 and 5 in one case and 5 and 4 in the other. Similar, but less direct, relations exist between program amounts and total number of engineering aids and between program amounts and total number of engineers and engineering aids combined. These relations are not surprising, of course, since it is only reasonable that the number of engineering employees should increase with the size of the program.

As to relations between program amounts and number of engineering employees per million dollars of capital outlay, none is clearly evident from Table 6. Apparently,

TABLE 6

RELATIVE RANK OF SIX SELECTED STATES AS TO TOTAL PROGRAM AMOUNT AND NUMBER OF ENGINEERING EMPLOYEES[a]

State	Total program amount	Number of engineers		Number of engineering aids		Number of engineers and engineering aids	
		Total	Per million dollars of capital outlay	Total	Per million dollars of capital outlay	Total	Per million dollars of capital outlay
Mississippi	4	5	6	2	2	4	4
Nebraska	5	4	3	5	3	5	3
Oregon	2	2	5	3	4	3	6
Vermont	6	6	1	6	6	6	1
Washington	1	1	2	4	5	2	5
Wisconsin	3	3	4	1	1	1	2

[a] The highest amount or ratio is ranked 1 in each case, the next highest 2, etc.

though, if any relations do exist, they are inverse relations, and this too is as it should be. It is logical that the number of engineering employees per million dollars of work should decrease, at least to some extent, with an increase in the amount of work.

The relations between total number of engineering employees and number per million dollars of capital outlay, as indicated by Table 6, are quite surprising. For engineers alone and for engineers and engineering aids combined, these relations are not very positive; if they exist at all, they appear to be inverse. In the case of engineering aids, however, a direct and quite positive relation exists; no obvious explanation for this difference suggests itself, but again the complexity of the ratios for the number of engineering employees per million dollars of capital outlay is emphasized.

In any event, Table 6 establishes a direct relation between program amounts and number of engineering employees. As indicated above, this relation is not unexpected, and in fact almost has to exist, since "no relation," or an inverse relation, would be entirely illogical. The other relations indicated by Table 6, if they exist at all, are not very positive, and probably are not significant.

Table 7 presents information on the relative amounts of rural and urban work and of "surfacing only" and all other construction work performed by the states. The program amounts on which this table is based are different from those indicated in Table 1 and ranked in Table 6, and in some cases the period covered is other than the 1954 calendar year. In all cases the program selected was one which could be conveniently analyzed by the state concerned, and in most cases the analysis is based on contracts awarded.

The theory here is, of course, that states doing a high percentage of urban work or a low percentage of "surfacing only" work will require more engineers than other states, on the assumption that urban projects and projects involving work other than surfacing or resurfacing only require more engineering effort. Whether this theory can be demonstrated depends on a comparison of Table 7 with Tables 2, 3, 4 and 5.

The rural percentage of total program costs varies from 75 in Washington to 89 in Mississippi, for example, according to Table 7, so that the corresponding urban percentage varies from 25 in Washington to 11 in Mississippi. Theoretically, then, Washington should be using more and Mississippi fewer engineers than any other state included in the study. Table 5 indicates that Mississippi in fact uses fewer engineers per million dollars of capital outlay than any other state included in the study, and that Washington uses more than any other state except Vermont.

A comparison of the other data presented in Table 7 with the information presented in earlier tables reveals no additional relations. In fact, such a comparison raises some questions about the direct relation which appears to exist between the urban per-

TABLE 7

CHARACTERISTICS OF PROGRAM COSTS AND MILEAGES IN SIX SELECTED STATES

State	Rural percentage of total program costs	Rural percentage of total program mileages	Percentage of program costs involving work other than surfacing or resurfacing only	Percentage of program mileages involving work other than surfacing or resurfacing only
Mississippi	89	98	79	68
Nebraska	82	99	76	49
Oregon	88	94	85	73
Vermont	87	94	100	100
Washington	75	97	75	54
Wisconsin	80	96	85	59
Totals	82	97	82	60

centage of total program costs and the number of engineers employed per million dollars of capital outlay. Washington, for example, does the greatest amount of urban work on a percentage cost basis, but also does the greatest amount of surfacing or resurfacing work on the same basis. Generally, it would appear that program costs are a more valid indication of engineering effort than is program mileage, regardless of type of work.

The final program characteristic to be analyzed is that of project length. Table 8 presents information as to the average length of construction projects for both "surfacing only" and other projects, and for rural and urban projects. Although these data are interesting, no relations between project length and number of engineering employees are evident. Hence, since the data are self-explanatory, there is no need to discuss them here.

With respect to program characteristics in general, then, there appears to be a direct and quite definite relation between program amount and total number of engineering employees, whether engineers alone, engineering aids alone, or both together are considered. Also, there appears to be a direct relation between the urban percentage of total program costs and the number of engineers employed per million dollars of capital outlay, but a corresponding relation does not seem to exist in connection with engineering aids or engineers and engineering aids together. Other relations either do not exist or are not apparent, possibly because of the relatively few states included in the study, but also because certain intangibles, such as climate, terrain, soil characteristics, etc., cannot be evaluated.

MANAGEMENT PRACTICES AND PROCEDURES

Since this is primarily a classification study, and because time was somewhat limited, a full-scale analysis of management practices and procedures was not attempted. Nevertheless, some attention was given to management practices and procedures in each state studied, and their possible effects on engineering manpower requirements were noted and discussed with state personnel. Incidentally, it might be mentioned that classification is itself a management practice.

Of the six state highway departments included in the study, all but one are directed by commissions. In Mississippi, Oregon and Vermont these commissions are 3-member part-time bodies, while in Wash-

TABLE 8

AVERAGE LENGTH OF CONSTRUCTION PROJECTS IN SIX SELECTED STATES

State	Avg. length in miles of surfacing projects only		Avg. length in miles of all other construction projects	
	Rural	Urban	Rural	Urban
Mississippi	7.1	1.1	5.3	1.2
Nebraska	6.8	1.3	6.8	1.0
Oregon	2.8	1.4	1.5	1.2
Vermont	-	-	2.9	2.8
Washington	11.2	8.3	5.1	1.0
Wisconsin	5.0	0.6	4.3	1.1
Totals	6.5	2.0	3.8	1.1

ington the commission is a 5-member part-time body. In Wisconsin the commission is also a 3-member body, but serves on a full-time basis. The Nebraska Bureau of Highways is directed by a single executive, the state engineer. Probably the type of directing organization has little effect on engineering manpower requirements in these six states.

In Oregon and in Washington one individual serves both as chief administrative officer and also as chief engineering officer. In each of the other four states, the chief administrative officer and the chief engineering officer are separate individuals. The commission chairman serves as chief administrative officer in Wisconsin, and in Nebraska the state engineer serves as chief administrative officer, but in none of the other states does a member of the directing organization serve as either chief administrative or chief engineering officer. Again it seems that these differences have little effect on engineering manpower.

With respect to structural organization below the directing level, there are of course differences in the individual states, but all have field districts or divisions responsible to some extent for both construction and maintenance activities. All are decentralized to some degree, and all have the usual complement of central-office bureaus. In spite of this over-all similarity in structure, there are differences in operating methods which are significant in connection with a study of engineering manpower requirements.

In Mississippi, for example, which employs few engineers but many engineering aids per million dollars of capital outlay, operations are decentralized to a considerable extent. Location surveys are made by field district personnel, and the project engineer lays a tentative grade on the project plan, which is used by the central office road design people, if possible. Relatively inexpensive designs can be used because of the relatively light traffic in the state; and short cuts are used in the design process itself. Standard plans are used for over 90 percent of all bridges, and bridge construction and maintenance are done by the regular construction and maintenance forces. Difficulty is experienced in hiring the higher grades of engineering personnel, but the lower grades are more readily available.

In Nebraska, where the number of engineering employees per million dollars of work is just slightly above the average for the six states included in the study, location is a central-office function. Also, design has been a centralized function, but recently some design has been decentralized to the field, and eventually the field will probably design everything except structures. All construction work, including FAS work, is done to the same standards and specifications, and probably more inspecting is done than in most states. Also, the state has done most of the engineering on FAS jobs. With respect to personnel, detailers are more critical than designers.

Oregon and Washington are alike in many ways, but present a marked contrast with respect to operating procedures. In Oregon, operations are largely on a centralized basis, and the field organization is somewhat rigid. In Washington, on the other hand, operations are decentralized to a considerable degree, and the field organization is quite flexible. Nevertheless, each state has relatively few engineering employees per million dollars of capital outlay, and their records in this respect are the best of any of the six states studied, as is indicated by Table 5.

Vermont employs more engineers and fewer engineering aids per million dollars of capital outlay than any of the other states included in the study, and there is no obvious explanation for the particularly high number of engineers employed. Probably a combination of factors, including an extreme climate, a difficult terrain, and a small program amount, is responsible. State highway operations are more centralized than in most other states, but the field districts do a considerable amount of engineering on state-aid work which is not reflected in the program amount. Also, many employees classed as engineers do work which is done by engineering aids in other states, although this is because of the classification system, rather than in spite of it. Incidentally, the state reports that because of this new classification system the shortage of engineers is no longer a problem.

Wisconsin uses relatively few engineers, but more engineering aids than any other state studied, per million dollars of capital outlay. The state gives more time and attention to management practices and procedures than most other states, and its organization plan is one of decentralization with centralized controls. Planning is emphasized, and engineers are being used more and more in supervisory capacities rather than for operations. A trained corps of engineering aids or technicians is being developed, and these non-engineers are being substituted for engineers wherever possible. Expanded programs are being handled without any appreciable increase in the number of engineering employees.

It appears from what has been said that in any particular state there are some management practices which promote over-all efficiency and the efficient use of engineering personnel, and others which perhaps tend to be wasteful of personnel. Also, it might be noted that a procedure which promotes over-all efficiency may at the same time be somewhat wasteful of personnel. In any event, it is extremely difficult to correlate the ratio of engineering employees to capital outlays with particular management practices and procedures, and perhaps this ratio is determined primarily by other factors.

Wisconsin, for example, has emphasized the use of engineering aids, and its ratio of engineering aids to capital outlays is high. Vermont has adopted a classification plan which makes it possible for employees with only a practical background to attain relatively high-grade engineering classifications without taking examinations, and has the highest ratio of engineers to capital outlays of any state studied. Washington has accomplished the increased work resulting from a bond program without a proportionate increase in engineering personnel, while Oregon increased its engineering forces by only 40 percent over a 5-year period to handle a bond program which doubled the construction program. Probably, then, a major factor in the efficient use of engineering personnel is the necessity to get along with what is available.

CONCLUSION

This study of engineering-employee classification in six selected states was undertaken to explain wide variations in the number of engineering employees per million dollars of capital outlay in the individual states, as reported in a previous study. Some of the variations have been explained satisfactorily, and some have not, but in any event the complexity of the situation has been demonstrated. It appears that the variations are influenced by a number of factors, and that some of these lend themselves to analysis, while others do not. Whether or not the ratio of engineering employees to capital outlays is a valid indication of over-all operating efficiency remains a moot question.

The really significant finding of the study, however, is that nobody really knows how many engineers and engineering aids are employed by the several state highway departments. Much has been written about the current shortage of engineers, and of the states' needs and requirements in connection therewith, but certainly an accurate tabulation of present engineering employees is prerequisite to a solution of the problem. Probably, under the circumstances, a new and more definitive over-all study is desirable, so that data for all states can be reported on a uniform basis.

Michigan Engineering Inventory Trend Study

MERLE J. WALKER, Director, Personnel Division
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● IN beginning, let me state that the subject of this paper is not designed as a cure-all for the critical situation in which the Michigan State Highway Department finds itself, along with other states. Rather, it is a history of the attempts that have been made within the department to meet the large construction programs we are now facing, with the critical shortage of engineers which is common throughout this country. The paper is set up as a report on what we have done in the past, what we are doing at the present time, and our plans which are at present being stepped up to help meet the situation in the future.

As early as 1946, it became apparent to the Michigan State Highway Department that road construction would have to be stepped up in the next twenty years in order to meet increasing traffic demands. Road construction programs in Michigan, as in other states, were severely curtailed during the war years and although a strong effort was made to maintain and hold our present highway system, funds available for construction work from 1934 to 1945 ranged from ten to twenty million dollars per year and in 1945 the low ebb was reached with expenditures under ten million dollars on actual construction work.

Little thought was given during these years, because of lack of large construction programs, to the recruiting of engineering personnel on a broad scale. However, an analysis of the situation early in 1946 indicated that our organization of engineers in the Michigan Highway Department was growing old and that we were not obtaining through concentrated programs enough new engineers to carry out major programs in the event of expansion which appeared to be just around the corner.

Climatic conditions in Michigan make it necessary to perform the major portion of construction work during summer months. This seasonal expansion seemed to lend itself to the use of college engineering students during summer months when they were on vacation. It was felt advisable in the department to attract these students with the hope that upon graduation many of them would consider permanent employment on a career basis. A first step for developing future engineers was put into effect, with the cooperation of the major engineering colleges in Michigan and the State Civil Service Commission, by establishing the student engineer summer program in 1946.

The first year we employed approximately 35 college engineering students and since 1946, the program has grown to the point where an average of 70 engineering students are employed each summer. These students are paid in proportion to the level of their year in college and at the end of each summer's work they are granted a leave of absence to continue their education.

This program has provided a two-fold purpose. It enabled the highway department to supplement its field forces during the heavy part of the construction season with young, intelligent and semi-qualified personnel in the sub-professional engineer classes. At the same time, it provided the student with an intimate insight into highway work, giving him practical experience along the line of his college major at an attractive salary during his vacation periods.

In 1947, the Michigan State Highway Department went even further and in conjunction with the University of Detroit, inaugurated a work-study program, generally known as "The Cincinnati Plan," whereby engineering students during their junior, pre-senior, and senior years in civil engineering alternately are employed by the highway department in regular engineering positions at the lower levels and attend classes at the university for three month periods. Many of these students, upon completion of their college work, have been attracted to permanent employment with the highway department.

In 1949, a study of the engineering enrollment in various colleges in the United States against anticipated stepped-up construction programs in the various highway departments, as well as in private industry which would utilize the services of these engineers, indicated that there would be a severe shortage of engineers for future construction programs. In that year the highway department inaugurated a graduate program known as the Engineer Trainee Program. In this program, engineering graduates from accredited colleges are offered the opportunity to continue their training in practical work assignments

TABLE 1

TRAINEE AND FORMER TRAINEE DISPOSITIONS
December 1, 1955

Year	Trainees enrolled	Presently active	Trainees resigned	Leave Mil	Leave Ed	Trainee I	Trainee II	Engineer II	Engineer III	Engineer IIIA
1949	40	22	18					2	13	7
1950	22	10	12					1	7	2
1951	18	9	7	2				4	5	
1952	31	18	8	5	1			16	2	
1953	25	18	4	3		5		11	2	
1954	34	17	6	11		5	9	3		
1955	21	12	2	5	2	11		1		
Totals	191	106	57	26	3	21	9	38	29	9

COMPARATIVE SALARY RANGES[a]
December 1, 1955

(Note: Salary rates effective February 5, 1956)

	Class levels	Bi-weekly Minimum	Bi-weekly Maximum		Class levels	Bi-weekly Minimum	Bi-weekly Maximum
All Highway Engineer Classifications	I	$174.40	$215.20	All Other Professional and Regular Civil Service Classifications	I	$151.20	$192.00
	Tr. I	176.00	186.40				
	Ia				Ia	163.20	207.20
	II	198.40	242.40		II	177.60	222.40
	IIa				IIa	194.40	241.60
	III	235.20	293.60		III	211.20	271.20
	IIIa	252.80	313.60		IIIa	228.80	291.20
	IV	277.60	350.40		IV	252.80	325.60
	IVa	300.80	373.60		IVa	277.60	350.40
	V	336.00	424.00		V	309.60	397.60
	Va				Va	343.20	432.00
	VI	408.00	496.00		VI	381.60	471.20
	VIa	445.60	536.80		VIa	419.20	510.40
	VII	479.20	576.00		VII	452.80	549.60

[a] In addition to the salary, Michigan State Highway Department pays a $4.00 per diem subsistence allowance while on field assignments.

for a period of 12 to 18 months. These trainees are rotated within the department filling regular jobs on various types of engineering work in the several divisions.

The success of the Engineer Trainee Program has been highly recognized. It has been adopted by both Missouri and Wisconsin in practically its original form, and a number of other states have accepted comparable features of our program in setting up graduate trainee programs of their own. It also compares favorably to similar plans in private industry.

The Engineer Trainee Program consists of one year of extensive rotational, on-the-job, practical work; and up to six months of specialized training in the field of final assignment. The trainee is working and producing at the same time that he is in training.

Special salary rates were also instituted for the engineering classifications of work as shown on Table 1 of the attached charts. These salaries average about $50.00 a month higher than all other professional and regular Civil Service classifications in the highway Department and also apply to the engineer trainees.

After completion of the formality of enrollment, including the passing of a Civil Service examination for the position of Engineer Trainee I, the trainee is given a short period of orientation on highway procedure in general and the Trainee Program in particular. It is emphasized to the trainee that he already has the ability and knowledge of the graduate engineer and needs only to obtain practical work experience and fundamentals of highway organization and operation in order to become qualified as a capable highway engineer.

To accomplish this, he is assigned to eight separate functional sections of the department during his first thirteen months. Each cycle lasts seven weeks, and the trainee performs the same duties as are expected of other employees of the squad or party.

These duties are varied or rotated as much as possible by his immediate supervisor to determine his outstanding characteristics and abilities. In most instances, he actually occupies a position which would otherwise be filled by a regular employee. There is a minimum loss of over-all production due to extra supervision. Briefly, the program in each section is operated as follows:

Bridge Construction. The trainee is assigned to an active bridge project under immediate supervision of a bridge project engineer. Usually larger type projects are selected and, without hindering party progress, the trainee is given an opportunity to perform the various duties or jobs encountered. Practical experience gained on the job plus close observation of the individual abilities and capabilities are the determining factors in grading his seven week service rating.

Bridge Design. Each trainee is assigned to a separate bridge design squad under the immediate supervision of that squad leader. He is usually given a third or fourth priority structure which he handles from beginning to end. Each phase of design is processed as usual for approval so that plans completed in seven weeks are usually final. Trainees do not participate in squad work on the board. The seven weeks allows them just about sufficient time to complete their job if it has been reasonably simple without too many changes.

Road Construction. An Engineer Trainee is generally assigned to a road construction project and works under the direct supervision of the project engineer. In this assignment, he has the opportunity to observe the varied problems that arise. During this cycle, whenever possible, the trainee is rotated to road construction projects handling different forms of construction material such as concrete, bituminous, gravel, etc.

Road Design. Trainees are interviewed and assigned to separate squads. Under the immediate supervision of the squad leader, they participate in work on the board. During the seven weeks, an attempt is made to give them varied experience in all types of problems related to the development of a set of road plans. This includes reducing field notes, plotting cross sections, inking topography, computing vertical curves and working grade sheets, determining quantities and assisting with estimates. They become acquainted with standard designs and procedures. When possible they even participate in field checks on grade inspection, and observe procedures in the Route Location Section.

Road Surveys. An assignment on surveys is generally with a party that can make practical use of the trainee's services. Under the supervision of the survey chief, he is given the opportunity to gain experience as rodman, chainman, levelman, notekeeper and transitman. He is also trained to run the party during temporary absences of the survey chief.

Maintenance. The purpose of the Engineer Trainee program in the Maintenance Division is to acquaint and train engineers in administrative procedures. The trainee is first assigned to the division office in Lansing, for one week, where he is given an overall picture of maintenance operations. Instruction is given by the division administrative personnel and the section heads, so that the trainee is familiar with department policies and the plan of operation. Study of specifications and the Maintenance "Manual of Standard Procedures," with field trips conducted by section heads to emphasize any special work is also included in the first assignment. After the first week the trainee is assigned to a district maintenance engineer in an agricultural area of the state for a three-week period, and in an urban or industrial area for the last three weeks to acquaint him with the various conditions and factors which affect highway maintenance.

Planning and Traffic. Since the number of functions performed by the Planning and Traffic Division are too numerous to be effectively covered in a seven week cycle, the trainees are given a general outline of the functions of the division and then assigned to the work activity best suited to their training and the work load in the various sections.

The normal activities covered in the training cycle are trunkline system planning, traffic planning and design, traffic control, and traffic surveys. The training cycle often includes two to five weeks with the district traffic engineer covering field activities which are principally traffic control.

Testing and Research (Soils). In this section the Engineer Trainee is assigned for seven weeks to one of our districts under the supervision of the district soils engineer.

An effort is made to acquaint the trainee in the procedure of the following operations: Identification of soil profiles, making soil maps, swamp and peat sounding, borrow surveys, and soil survey reports, grade check of plans for soil and drainage design and problems, subgrade inspection and check during construction, bridge borings and studies, office reports, files, organization and administration. By assisting the district soils engineer, the trainee is given as much practical work as possible.

A performance rating is given in each assignment. This covers job intelligence, which includes a variable number of items that are applicable to the individual work phases concerned. It also includes job aptitude ratings which cover work quantity, work quality, work attitudes and work habits.

Of all the graduate engineers who have entered the program, approximately 25 percent have resigned from our employment since the beginning of the program in 1949. A number, however, have entered military service on military leave of absence. We believe our records speak for themselves as to the success we have had in recruiting and obtaining the young engineer graduate.

Following the completion of the rotation portion of the Trainee Program, the young engineers are in a position to receive permanent classifications in the department in a specialized field of work. Interviews with division heads are arranged whereby the trainees are interviewed individually by the group of engineering division heads and collectively by the Commissioner and Chief Deputy Commissioner. A Civil Service examination is given for the classification of Engineer Trainee II, which if passed, places the trainee in a higher salary range. Future promotions then depend on individual ability, initiative, and attitude toward work.

Experience shows that when trainees are being placed on final assignment, at least 90 percent are assigned to the field of highway work indicated by them to be their first preference. The only exception to this percentage figure is in the construction field which is advisedly preceded by a year of experience in the design section.

The various training opportunities offered the engineer student and graduate were moulded into one over-all interrelated program known as the "Highway Career Plan." To present and publicize the various programs encompassed in this plan, we made it a point to contact high schools and attend student functions at various colleges to discuss these opportunities with both the student and the faculty.

We have found that these engineer trainee and student engineering programs have been very beneficial to the department. Many of the graduates who went through our Engineer Trainee Program in its first two years have already advanced to the III and IIIa level positions which represent project engineer positions in the field in charge of construction, and squad leader positions in our design rooms in charge of design squads. Some have now advanced tc the IV level positions which represent engineering executive positions in our Lansing headquarters.

It is to be noted on Table 1 that the major portion of resignations in our program occurred in 1949 and 1950 when we first started the program. Our losses have been lower in the last four years. We attribute this to several factors which may be listed under the heading of fringe benefits.

1. Special rates were set up for the engineering classifications in 1951.
2. The Civil Service Commission in Michigan permits liberal annual and sick leave benefits; annual leave at the rate of 13 days per year after one year of service, 15 days per year after five years of service, 17 days per year after ten years of service, and 19 days per year after fifteen years of service. Sick leave accumulates with no ceiling at the rate of 13 days per year and in the event of retirement or death, one-half of this accumulated total is paid in a lump sum to either the employee or his estate.
3. Liberal retirement programs which permit an employee with 30 years of service and at age 65, regardless of salary range, to retire at approximately one-half his yearly salary. This guarantees a graduate engineer, who starts with the department at the I level and advances to the IV level or above in his total service with the highway department, retirement at a greater salary than his starting salary.
4. A Civil Service and Department program which gives job security comparable to that found in private industry, or better.

We believe that these features, along with the fact that the engineers entering the service of the department are given every opportunity to expand their knowledge during the first year and are encouraged by the division heads to develop themselves for rapid promotion, have resulted in our high retention of these engineers.

At the present time the prospect of longevity pay to be installed next July by the Civil Service Commission in Michigan is another attractive feature.

In 1953, however, a review of the engineering situation indicated that even with the summer student and engineering programs the induction of engineers into the department was not sufficient to handle the construction programs which were anticipated. Analysis indicated that we would lose approximately 70 of our engineers in the top level through forced retirement at age 70 in the next ten years; and it was felt that there was a strong possibility of the loss of at least 60 more from age 60 to 70 through voluntary retirement, and that the opportunities for the graduate engineers were so great that within the next ten years they would be occupying the higher positions in the department. It appeared necessary to establish a type of training which would fill the gap at the I and II levels, namely our instrumentman and inspection levels.

Steps were taken to supply the additional technical personnel needed to fill these gaps. One was the high school graduate program adopted to interest high school graduates in following engineering as a career with the hope that they would be attracted to highway work either immediately or after college graduation. It is a long range program worked out with George M. Foster, Chief Deputy Commissioner, Michigan Highway Department, C. J. Carroll, Executive Secretary of the Michigan Road Builders' Association, and Professor Earnest Boyce, Chairman, Department of Civil Engineering at the University of Michigan, and resulted in giving all qualified students an 8-week course of study in highway surveying.

The University of Michigan's Department of Engineering operates a summer camp for engineering students called Camp Davis located near Jackson, Wyoming. The camp facilities, because of changes in university operations, recently became adequate to accomodate up to 50 students, in addition to university requirements at the camp.

The total cost to attend this camp is about $300 per student. The Michigan Road Builders' Association is also very much concerned about the shortage of engineering personnel. In order to insure the success of this new plan and to attract the interest of the qualified high school graduate, the Road Builders' Association agreed to underwrite approximately one-half ($150) of the cost per student.

To qualify for the program, it is necessary for high school graduates to have completed a high school course in trigonometry; to have satisfactorily met entrance requirements of the University of Michigan's Department of Civil Engineering; and to have passed successfully the Michigan Civil Service examination for Engineering Aide B.

Students who completed the course at camp were offered jobs as Engineering Aids B with the State Highway Department at a starting salary of $124 bi-weekly, plus per diem expenses while in the field, rather than the normal initial salary of $116 bi-weekly. Top pay for Engineering Aides B, at the present time, is $3,445 annually (this was raised 10 percent on February 5, 1956) and is attained in six step raises. Thus, students completing the course were permitted to start at the third bracket and, with satisfactory work, advance to top pay within three years, provided nothing further was done to improve their status.

Of the first 30 high school graduates who entered the course (Table 2) 22 students

TABLE 2

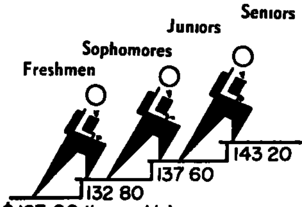
DISPOSITION OF HIGH SCHOOL STUDENTS WHO ATTENDED CAMP DAVIS, JACKSON, WYOMING

Status as of December 15, 1955

Summer at Camp Davis	Total Attend.	No. Separated	No. on Mil. L/A	No. on Ed. L/A	No. now employed	Ed. L/A engr.	Students non-engr.	Classification of those employed: Engr. Aide B	Engr. Aide A	Engr. Aide I
1953	30	9	1	8	12	8	0	4	7	1
1954	46	9	3	25	9	23	2	9	0	0
1955	48	0	0	29	19	25	4	19	0	0
Totals	124	18	4	62	40	56	6	33	7	1

Student Programs

Student Engineering Aide B



* field work in
- Bridge Construction
- Planning & Traffic
- Road Construction
- Road Surveys
- Testing & Research

* office work in
- Road Design
- Bridge Design
- Planning & Traffic

* employment during school vacation periods

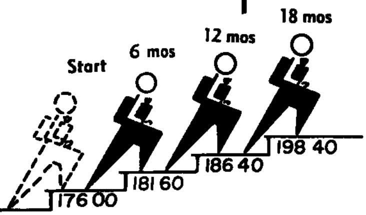
* leave of absence to return to school

* Permanent Civil Service status after six months on the job

* $4 00 per diem additional expense allowance on assignments away from home.

Graduate Program

Engineer Trainee I | Engineer Trainee II



* Intensive Rotational "On-the-Job" training throughout the state in the following fields
- Bridge Construction
- Bridge Design
- Maintenance
- Planning & Traffic
- Road Construction
- Road Design
- Road Surveys
- Testing & Research (soils)

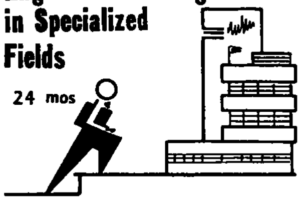
* Six to twelve months' specialized training in field of final assignment

* Consideration given to individual preference for final assignment

* $4 00 per diem additional expense allowance when away from home on trainee assignments

Engineer Assignments

Engineer II to Engineer VII in Specialized Fields



Permanent assignments are directed into various phases of engineering

CLASSIFICATION—

	BI-WEEKLY SALARY RANGE
Engr II	198 40 to 242 40
Engr III	235 20 to 293 60
Engr IIIA	252 80 to 313 60
Engr IV	277 60 to 350 40
Engr IVA	300 80 to 373 60
Engr V	336 00 to 424 00
Engr VI	408 00 to 496 00
Engr VII	479 20 to 576 00

* Promotions largely depend on individual ability, initiative and attitude toward work

* Employment with the Michigan State Highway Department offers a future—

—with maximum security
—at attractive salary ranges
—in a MAN'S Field

BASIC REQUIREMENTS

Student Programs

1 Enrollment in College Engineering
2 Juniors & Seniors must be civil engineer majors
3 Pass Civil Service Aide B examination
4 Satisfactory work performance

Engineer Trainee I

1 Engineer graduate of an accredited college
2 Pass Civil Service Engineer Trainee I examination
3 Satisfactory progress in Training Program

Engineer Trainee II

1 Successfully complete Tr I Program
2 Pass Civil Service Engr Tr II exam

Engineer Assignments

1 Satisfactory progress during 6 mos probationary period as Engineer Trainee II
2 C S Examinations for Higher Classifications
3 Registration for Engr IV and above

Figure 1.

availed themselves of the opportunity to begin employment with the department. Six of these later joined the other eight and entered the five engineering colleges and universities of the state to continue their education in engineering, with an understanding that they would spend their summer vacations in the department's employment. One of these has since resigned and the other 16 who went to work are continuing their employment with the highway department on a permanent basis.

This program was continued in 1954, and 46 high school graduates entered the program. In 1955, 48 entered the program and availed themselves of this opportunity. The attached Table 2, on the high school graduate program shows the number of students who elected to stay with the highway department on a permanent basis, the number who went on to college to take engineering courses and who no doubt will enter our summer student program, and the number who, after trying the program, resigned to enter other activities. In connection with this high school student program the Highway Department has made it a point to contact high schools to discuss these opportunities with both the student and faculty. Some of these high school graduates who entered this program in 1953

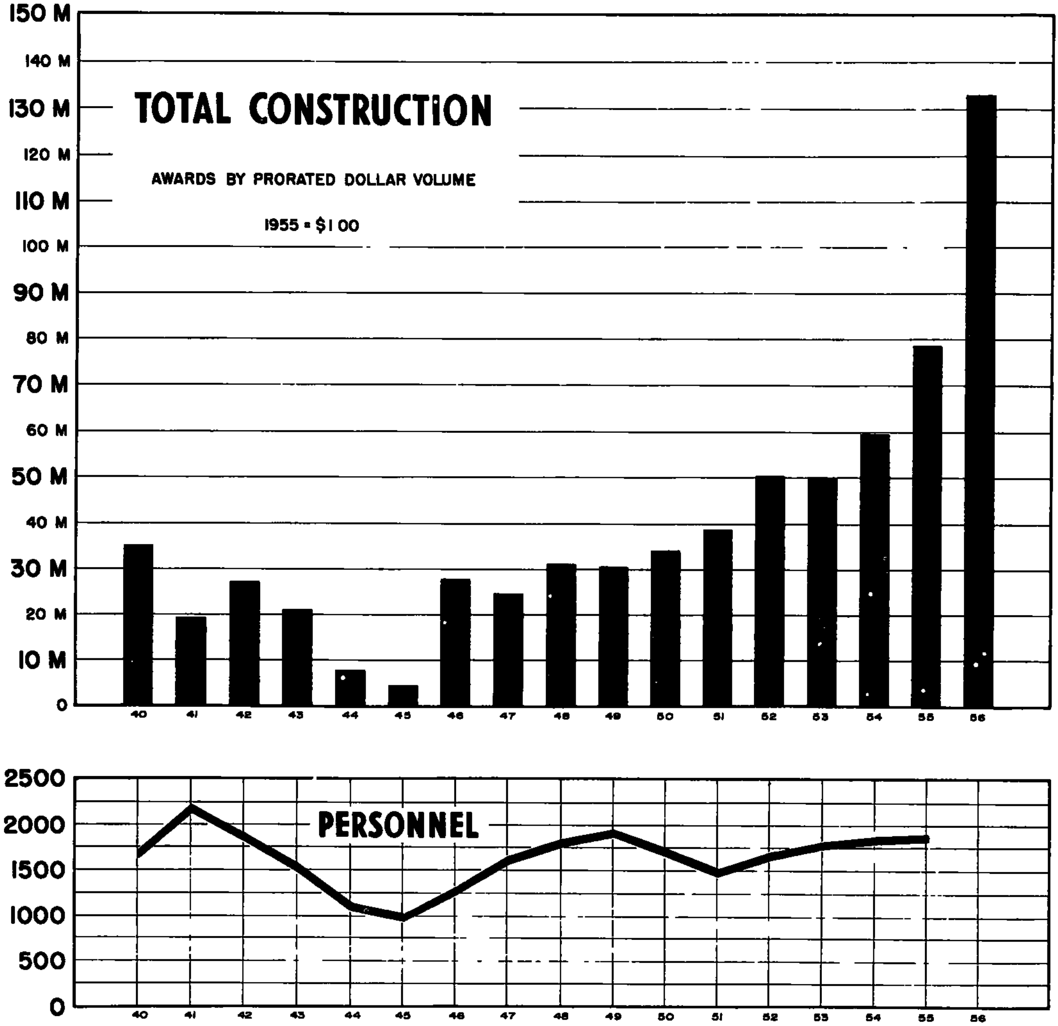


Figure 2.

have now advanced to the I level technical positions.

We now enter the third phase of our study of the engineering inventory trend situation. Recent studies still indicate that we will have great difficulty in staffing the programs which will face us in the next five years.

Our programs at the present time indicate 150 million dollars in actual construction in 1956 and increasing amounts through 1960. We are now turning to the problem of staffing this work.

Figure 2 shows the amount of construction completed by years from 1940 to 1955 with the number of personnel in the engineering divisions who handled this work year by year. This chart is based on the 1955 dollar and prorated back to 1940 on the basis of information prepared for the Michigan Legislative Study Committee by the Automotive Safety Foundation. In other words, in 1940 we accomplished approximately 20 million dollars worth of construction work, which shows on the chart as 33 million due to the difference in the dollar value, with approximately 1,750 employees in the highway department, excluding our Maintenance and State Ferry organizations. In 1955 we accomplished 78 million dollars worth of construction work with nearly the same number of employees, indicating an increase of approximately 45 million dollars. This would indicate that more than twice the amount of work was done in 1955 with about the same number of employees as in 1940. We believe there are three reasons for this:

1. Our design rooms and field forces have been on overtime schedules for the last five years. The employees in the design rooms are paid for this overtime and our inspectors in the field have been paid overtime for the past year.

2. Our project engineers in 1940 may have handled one project whereas they are now handling several. Inspectors have increased their responsibilities so that we have coverage over more phases of work from one inspector than in the past.

3. A much greater work load has been assumed by all of the employees engaged in the various activities of these divisions, and greater efficiency has been developed in the employee groups in our engineering divisions through training.

Figure 3 shows the dollar value of plan programs completed by year from 1940 to 1955 and programmed work for 1956. This chart is also based on the 1955 dollar and also shows that we have had to turn to consultants for a great deal of our plan work. In

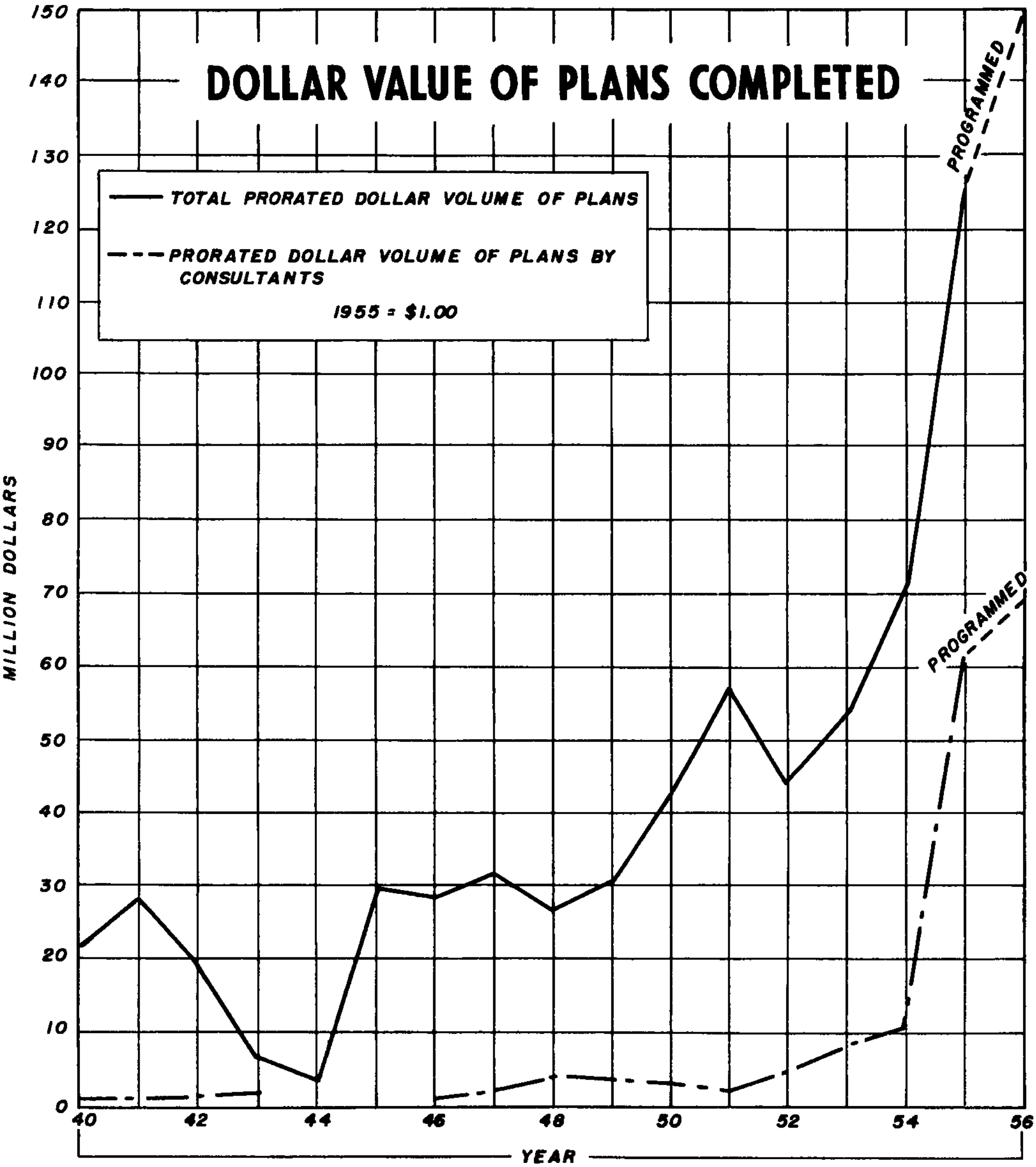


Figure 3.

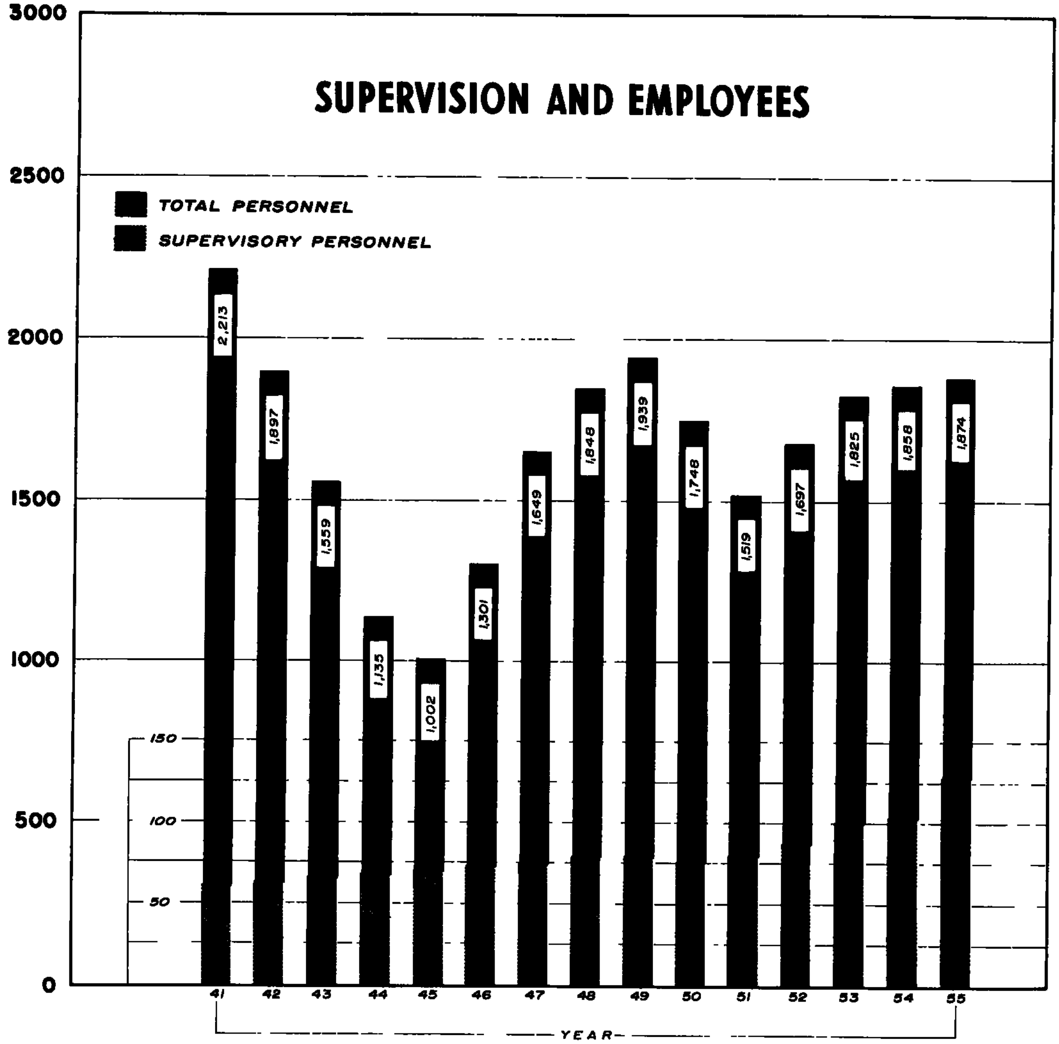


Figure 4.

1954, we had 10 million dollars in plan work assigned to consulting engineers whereas in 1955 consultants handled a little over 60 million dollars of plan work. It is estimated that in 1956 they will handle approximately 70 million dollars worth of plan work. This chart also shows that a little more than 20 million dollars of plan work was handled by the employees in the department in 1940 whereas approximately 65 million dollars worth of plan work was handled by practically the same number of employees in 1955.

Figure 4 shows the total personnel, again excluding Maintenance and State Ferry organizations, as against the supervisory personnel from 1941 through 1955. It is interesting to note that with a greater number of employees in 1941 the supervisory group is much lower than with fewer employees in 1955. The supervisory group represents the IV level classification and above or engineering administrative positions in the Michigan Highway Department.

In order to meet this increased work load in the department several steps are being taken at the present time. The Highway Department in cooperation with the Civil Service Commission is setting up a technical series of classifications in three of our major engineering functions; route planning, construction and drafting. The technical series will tap a group of approximately 150 employees in the department who have had a number of years of experience from the II to IIIa levels but have never been able to qualify for the special engineering rates due to the fact that they have not become registered or are not college graduates. By setting up these technical series an outlet will be provided for these men to advance and at any time they can pass the college level engineering test they can be reallocated to the engineering classifications with the special engineering salaries; or at any time they pass the state registration examination they can be reallocated to the IV level and above, or the higher level engineering classifications (see Figure 5).

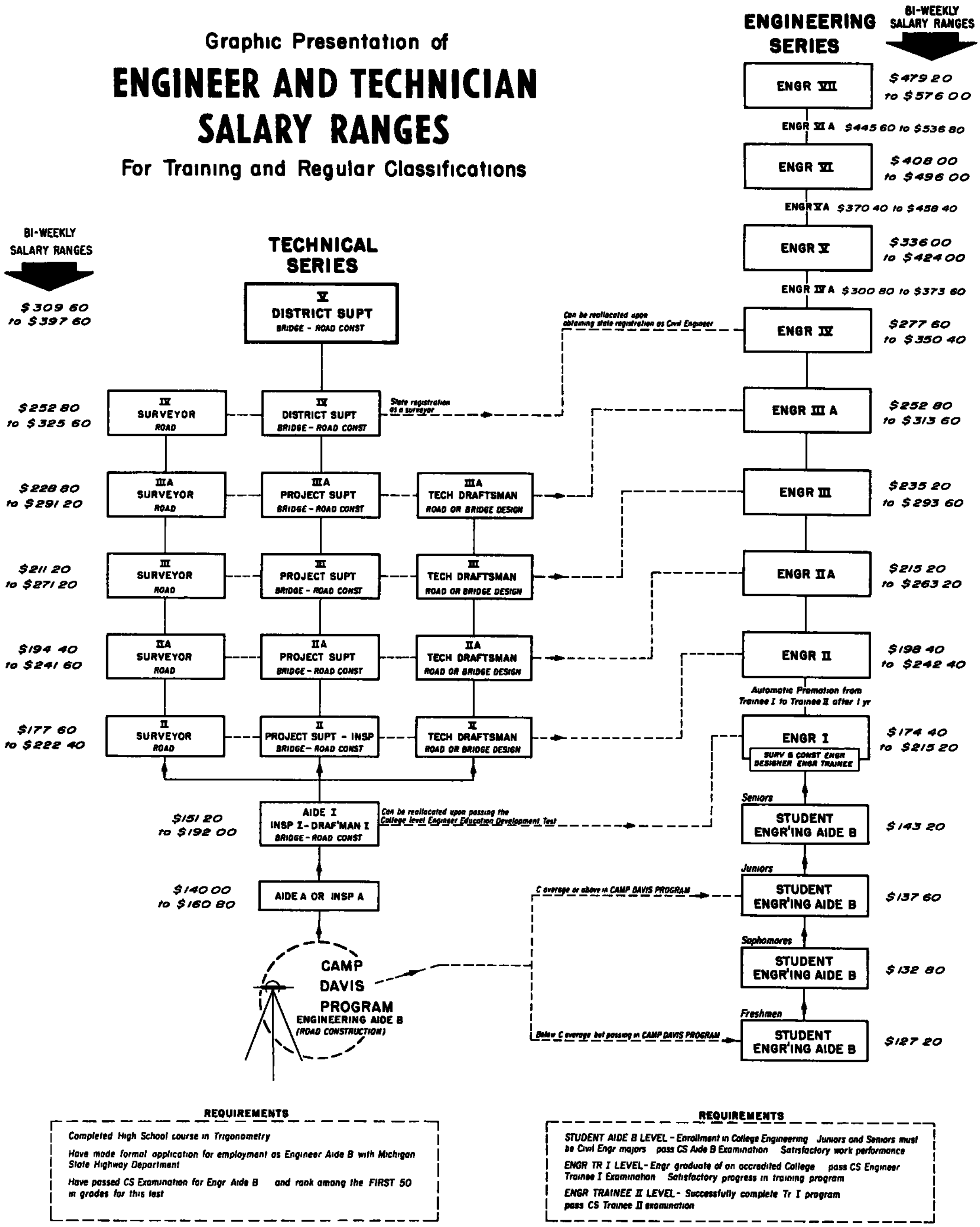


Figure 5.

We feel that this program will augment our engineering manpower at the higher levels in the department by utilizing the services of these technicians.

An analysis of our Construction Division indicates that even with larger projects being placed under construction we will need 28 additional project engineers for the coming construction season in order to staff the extra work. It also indicates that in order to staff these projects we will need about 50 additional instrumentmen or engineers and technicians at the I and II levels and about 70 additional inspectors. We are setting up in-service on-the-job training courses in which we are selecting 50 of our high school graduates at the Engineering Aide B level, both from the Camp Davis program and from other Engineering Aide B employees, and by placing them on actual instrument work through the winter months they will gain actual on-the-job training and be available for construction work next summer. These employees will be under close supervision this winter.

In the inspection group, we are picking an equal number of our older employees at the lower level and placing them on jobs where they will be subjected to actual inspection work in the hope that we can train enough of them to obtain coverage. In addition, we plan on holding schools in district areas for potential inspectors. In the instrumentman group, we are planning, if possible, to enlist the assistance of one of the engineering professors at the University of Michigan to add to our on-the-job training program with certain technical phases that the employee should have as a background to do instrument work.

In the past we have confined our recruiting to Michigan engineering colleges and have now taken steps to contact all of the engineering colleges in the central United States and plan, as other states are doing, to arrange either group or individual meetings with the graduates in order to extend information on our programs and fringe benefits to them with the hope that we may step up our present training program as far as recruitment is concerned.

Although we in Michigan have tried to keep abreast of the expanding construction programs by constantly studying salary schedules in effect in private industry and other states and by recruiting, training and developing our non-engineering employees, the problem of staffing the various phases of our work with engineers and technicians is difficult and becomes more difficult as time goes on. With increased construction programs, contractors are turning more and more to engineers to handle many phases of their work and although the services of these engineers are not lost to the highway industry, when they go to the contractors it does create a problem in the Highway Department to replace them.

We are also in the process of making a survey as to the possibility of use of electronic equipment in the field of contract programming and contract computations. Material of this nature might release engineers who are doing this work manually at the present time for other phases of engineering work. This is only in the preliminary study stage at this time.

As time goes on the problems of staffing our state highway departments' increased plan work and expanding construction work will become more difficult and many problems will arise. Knowing that highway construction will expand through necessity, we believe our biggest job will be proper and efficient staffing.

We must interest young people in highway engineering and help them through in-service training and education. The interest and cooperation of civil engineers and educators in our major colleges will go a long way toward accomplishing this goal.

Local Highway Engineering Manpower: Appraisal and Action

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● SINCE the summer of 1955, the Institute of Transportation and Traffic Engineering, University of California, has been devoting a portion of its effort to the problem of engineering manpower in city street and county road departments. The work includes a great deal of consultation with local officials on both recruitment and training problems and an extensive survey, now nearing completion, involving staff visits to approximately 100 cities and counties in the state.

The purpose of this paper is to report this work to the extent that either methods or results may have general application. Specific information on the California work is given first; a discussion of some general considerations which this work may suggest or illuminate then follows. The first part outlines the what and why of the Institute work, gives preliminary figures on the local manpower situation, as indicated by survey returns to date, and comments on the applicability of results. The more general discussion covers some of the peculiarities of local agencies with reference to engineering manpower and then speculates on some possibilities for collective or combined action.

IMPORTANCE OF LOCAL ENGINEERING MANPOWER

Before entering our discussion, it may be well to relate city and county roadway engineering to highway engineering manpower as a whole. Using roadway construction rates as indicators of engineering effort, we find that of total roadway construction in the United States in 1954, amounting to more than $3½ billion, 25 percent took place under city and county jurisdiction. Figures for 1955, in which construction ran some $1 billion higher, may perhaps show a lower percentage of local activity, but we should still be safe in thinking of cities and counties as accounting for one-fifth to one-fourth of all roadway engineering. A similar view is supported by taking construction needs rather than past performance as measures of engineering requirements. Automobile Manufacturers Association estimates, based on U. S. Bureau of Public Roads data, give the deficiency of local roads and streets not on state systems as 32 percent of the grand total. City and county engineering, we may conclude, will be an important part of any balanced, nationwide construction program.

MANPOWER IN CALIFORNIA

Developing an Assistance Program

Institute work on the local engineering manpower problem in California was prompted by recognition of the critical situation prevailing nationally, by the views of many local officials in California, and by appraisal of other approaches to the engineering situation throughout the country. All suggested that cities and counties were certainly not exempt from the presence or likelihood of a shortage in engineers. National surveys were indicating the dimensions of the over-all problem and held promise of giving emphasis to time-saving techniques to some extent applicable at the local level. These national programs could not, however, be expected to pinpoint the actual city-county situation in any particular area. This latter seemed to be a necessary or at least highly desirable preliminary to effective action. Such was the view in which the two California associations for cities and for counties and all key local officials questioned heartily concurred.

Several city engineers and road commissioners, together with representatives of the two associations — the County Supervisors Association of California and the League of California Cities — met with members of the Institute staff in the summer of 1955, and a first phase of study was decided upon. This consists of a survey to determine technical manpower needs and to pool opinions.

Three questions are being asked in this survey: (1) What is the technical working force and how would it have to be increased to handle additional work? (2) What are the possibilities for increasing the engineering output from existing technical personnel? (3) What are the obstacles to getting personnel and how may they be overcome?

Before going into some details of this survey, which form the basis for most of the remaining discussion, it should be mentioned that other approaches are being made. One is an exploration of possibilities for increasing technical competence through special training programs. Here again, the approach has been through organized conference with representative road officials. The outline of a practical short course for construction inspectors has been developed with a view to trying a pilot course as a guide for whatever institutions might appropriately conduct it in California. Discussion of the manpower problem has also been scheduled for the California Street and Highway Conference, presented annually by the Institute, in which city and county officials from throughout the state participate.

Method and Extent of Survey

California has 58 counties, 56 of which each spend more than a quarter-million annually for roads. Forty-six cities also each spend more than a quarter-million annually for streets. Together, these counties and cities account for more than 85 percent of all local road and street expenditures. Their engineering forces for roads and streets range from organizations of more than 100 technical personnel down to groups of 2 or 3.

Nearly all the counties have a road department dealing solely or primarily with roads. Nearly all the cities have engineering groups to whom street work is only one part of their responsibility. A few cities design subdivision streets, other cities and counties confine their engineering on subdivisions to review of plans and inspection. Several counties pay the State Division of Highways to do the engineering on their Federal-aid roads; some do it themselves.

These assorted considerations largely governed the decision as to method and extent of survey.

If findings were to be comparable — and without comparability there would be no point in a statewide survey — it became apparent that the question "how many men?"

1.a. What was your technical working force in 1954-55, and how would it have to be increased if more funds become available (see explanation on following page):

Organization Reporting ____________

	(1) Position	(2) Number of payroll positions involved	(3) Average monthly salary	(4) Technical effort, Street and Road Work only during 1954-55, in Man Months: By own staff	(5) Staff equivalent for services by the state	(6) Staff equivalent for services by private firms	(7) Total technical effort on Streets and Roads (Cols. 4+5+6)	(8) Part of total (Col.7) on work done at public expense	(9) Part of effort in Col. 8 on construction	(10) Part of effort in Col. 9 requiring position qualification	(11) If well-qualified men applied for work today, how many would you hire?	(12) Estimates of Additional Nee: Added needs in man-months if total funds rose 25%	(13) Added needs in man-months if total funds rose 50%
		No. of Men	$	M-M	M-M	M-M	M-M	M-M	M-M	M-M	No. of Men	M-M	M- M
(a)	"Engineer"												
(b)	Engineer Prospect												
(c)	Technical Specialist												
(d)	Construction Specialist												
(e)	Surveyor												
(f)	Draftsman												

b. If total street and road funds were increased 25% (as in Col. 12), what would you estimate as your % increase in funds for construction? ______ %

c. If total street and road funds were increased 50% (as in Col. 13), what would you estimate as your % increase in funds for construction? ______ %

d. Items b and c, and Col. (10) are based on 1954-55 construction amounting to $______________.

Figure 1. California survey question 1.

Organization reporting ____________________

2. a. In your organization, have you reduced (since 1950), or do you see opportunities for reducing your technical personnel requirements by means of:

Procedure	No	Have Reduced	See Opportunities
(1) Changes in organization or job classification?			
(2) Simpler right-of-way descriptions, plats?			
(3) Assignment of more right-of-way matters to realtors, etc.?			
(4) Mechanized handling of data, as for sufficiency ratings, inventories, etc.?			
(5) Aerial photography for mapping, surveying?			
(6) Short-cut surveying procedures?			
(7) Simplified drafting?			
(8) Charts, tabulations of design data?			
(9) Mechanization of earthwork computations?			
(10) Standard plans for drainage structures, small bridges?			
(11) Ready data for making quick relative cost estimates?			
(12) Short-cut methods of quality control, inspection?			
(13) Less record-keeping by technical personnel?			
(14) Simpler specifications and measures for materials?			
(15) Lump-sum instead of unit payments?			
(16) Short-cut methods of materials testing?			
(17) Aerial photography for materials location?			
(18) New procedures in foundation investigation?			
(19) Better communications or transportation?			
(20) Better cost accounting, budget control, etc.?			
(21) Other?			

b. Please indicate the specific nature of procedures marked "yes", and the extent or possible extent of manpower savings: ____________________

____

____

____

____

Figure 2. California survey question 2.

would have to be asked in rather complicated fashion. It seemed unlikely that the percent return on a complicated question would amount to much if asked by mail. It was estimated that staff time might permit visiting nearly all of the 102 units, thus holding forth the prospect of a close to 85 percent sample of local engineering positions in the state. This would also provide opportunity for discussion of considerations which might be overlooked in framing a survey questionnaire. Accordingly, the survey was designed

Organization reporting________________________

3. a. What -- aside from scarcity of qualified applicants -- is or would be the principal obstacle to your organization's obtaining technical personnel as needed:

	Is	Would Be
(1) Inadequate recruiting procedure	________	________
(2) Inability to pay sufficient starting salary .	________	________
(3) Insufficient career opportunity	________	________
(4) Unsatisfactory job classification	________	________
(5) Not authorized sufficient positions	________	________
(6) Location	________	________
(7) Other	________	________

____

____

b. To what classes of technical personnel (as defined for the table, item 1.a.) does the foregoing principally apply:

( ) "Civil Engineer" ( ) Technical Specialist ( ) Surveyor
( ) Engineer Prospect ( ) Construction Specialist ( ) Draftsman

c. What methods are you using or what are your suggestions for overcoming the obstacles mentioned in 3.a. above?

____

____

____

____

____

____

____

____

d. What recruiting procedure do you use?

____

____

____

____

____

____

Figure 3. California survey question 3.

to cover the three questions (How many? How efficient? Why can't you get them?) comprehensively and explicitly, rather than quickly and easily. While surveys of this type are generally agreed to be the bane of management everywhere, the advising city and county engineers felt that a detailed survey could be justified because information was urgently needed and could not be obtained in any simpler way. The three survey questions are shown in Figures 1, 2, and 3.

Progress to Date

The survey was begun in late summer, and all but a few of the 102 organizations had been visited by year's end. Because many of the visits were made late in the year, only 57 reports are available to date. The general reception to the survey has, however, been excellent, and a fairly complete return is anticipated. It is believed that the method and conduct of the survey will prove adequate to the purpose.

Findings to Date

A partial analysis has been made of returns to date in order to give a preliminary indication of the manpower situation at the local level. The returns are from 25 cities and 32 counties; these represent 56 percent of the number of units being surveyed, but only 29 percent of the dollar volume of city and county street and road construction in California. In other words, the current sample is unbalanced toward the smaller cities and counties. It cannot, therefore, be regarded as an accurate indication of the final results for California. It may, however, be more representative of conditions in many states than the final findings, because the units still to be reported include the unusually large cities and counties in the Los Angeles and San Francisco Bay regions.

Some of the preliminary findings are summarized in Table 1. The technical personnel being surveyed were divided into six types and labeled so as to minimize confusion with job titles, which vary from place to place. The first two are professional classifications, "engineer" being in quotes because it was not desired to confine the type to engineers registered under California law; engineer prospect in most cases covers college graduates with less than four or five years' experience. Technical specialist means an office or laboratory man doing some phase of engineering. Construction specialist generally means inspectors (if they are not engineers). Surveyor is confined to instrument man or chief of party. Draftsman applies to those who are not engaged in design (who would be classed as technical specialists). More elaborate definitions accompanied the questionnaire, but the foregoing may suffice for present purposes.

Each surveyed organization reported the man-months of staff time in 1954-55 applicable to streets and roads. These totals have been divided by 12 to obtain the first column of figures in Table 1, the equivalent full-time positions filled.

Positions vacant, shown in the next column, are on a different basis. These are the total authorized position vacancies reported in response to the question, "If well qualified men applied for work today, how many would you hire?" today being whatever day

TABLE 1

TECHNICAL MANPOWER PERSONNEL AND PERSONNEL NEEDS IN 57 CALIFORNIA CITY STREET AND COUNTY ROAD DEPARTMENTS

Type of Personnel	Equivalent Full-Time Positions			
	No. Filled	No. Vacant	% Filled	Added Number Needed for 25% More Funds
"Engineer"	96	17	85	17
Engineer Prospect	73	34	68	30
Technical Specialist	58	10	85	13
Construction Specialist	81	16	83	22
Surveyor	53	11	83	22
Draftsman	56	18	76	26

(in the latter half of 1955) each organization reported.

Although the two sets of figures are not in correspondence, a "percent filled" figure is given, based on the assumptions that present full-strength staffs would be the sum of positions filled (in 1954-55) and positions vacant (now), and that all vacancies represent full-time positions in street or road work. Despite the obvious probability of error in both assumptions, the percentages should be valid in relation to one another and serve to emphasize two major findings:

1. There is a present shortage in all classes of technical personnel at the local level.
2. There is a critical shortage of young engineers.

If the number of vacancies in this 29 percent sample were representative of conditions statewide, it would indicate that local street and road agencies in California are in immediate need of 59 "engineers" and 118 engineer prospects. To place these figures in perspective, it may be noted that to fill the indicated vacancies for engineer prospects alone would take half this year's civil engineering graduates from all accredited colleges in the state.

The last column in Table 1 shows the equivalent full-time positions represented by the local road officials' estimates of additional needs — additional, that is, to the actual man-months of engineering in 1954-55 — needs that would arise if total funds for streets and roads were increased 25 percent. (Incidentally, the reports indicate that a 25 percent increase in funds would result in about 40 percent more construction.) It is noteworthy that the shortage prevailing now is almost the same as the additional number of individuals estimated as needed to handle programs growing out of 25 percent more total funds.

A second view of the local engineering requirement is provided by the reports of actual engineering time devoted to street and road construction paid for out of the city or county treasury. This actual time was arrived at by first adding to the staff time any engineering time represented by state or private services, and then subtracting from this total any time devoted to maintenance, right of way, and subdivision and similar work. This actual time applicable to construction (not construction engineering but all phases of engineering applicable to construction projects) is shown in Table 2, converted to equivalent full-time positions and compared with the additional requirements (repeated from Table 1).

The subtotals and totals have been inserted in Table 2 to demonstrate that the figures are a great deal more reasonable than they appear at first glance. Give or take 1 percent, they simply state that 40 percent more construction is going to take 40 percent more engineers and 40 percent more total technical personnel. This is interesting because it is usually thought that a given increase in activity does not require an engineering organization to effect as large an increase in personnel. For some organizations

TABLE 2

ENGINEERING REQUIRED FOR STREET AND ROAD CONSTRUCTION IN 57 CALIFORNIA CITIES AND COUNTIES, 1954-55

Type of Personnel	Equivalent Full-Time Positions Applicable To Construction: Actual No. in 1954-55	Added Requirement for 25% Increase in Funds [a]: Number	Added Requirement for 25% Increase in Funds [a]: Percent
"Engineer"	71	17	24
Engineer Prospect	49	30	61
Professional Subtotal	(120)	(47)	(39)
Technical Specialist	48	13	27
Construction Specialist	61	22	36
Surveyor	46	22	48
Draftsman	42	26	62
Total	315	130	41

[a] A 25 percent fund increase is estimated to represent a 40 percent construction increase.

TABLE 3

TECHNICAL PERSONNEL PER MILLION DOLLARS OF STREET AND ROAD CONSTRUCTION IN 57 CALIFORNIA CITIES AND COUNTIES

Type of Personnel	No. of Personnel per $1 Million of Construction	
	Actual in 1954-55	Estimated for a 40% Larger Construction Program
"Engineer"	3.3	3.0
Engineer Prospect	2.3	2.6
Technical Specialist	2.3	2.1
Construction Specialist	2.9	2.8
Surveyor	2.2	2.3
Draftsman	2.0	2.3

this is true. But the reverse is true in some local agencies in California, especially counties, a fact brought to light in the conduct of the survey. The reason is that many of these agencies are now doing a considerable amount of construction with their own forces. An appreciable increase in construction would have to be accomplished through contract, resulting in a disproportionate increase in engineering.

Table 3 shows numbers of personnel, by type, required per million dollars of construction, the first column applying to the actual 1954-55 activity and the second to a 40 percent higher level of construction with the estimated additional personnel included. The first column was obtained by taking 1954-55 engineering and the construction expenditures in the same year. While much of the engineering in a given year is of course applicable to construction occurring in a later year, it is believed that this consideration is immaterial when these 57 surveyed organizations are considered as a group.

To summarize, then, findings to date indicate that local roadway agencies (1) face engineering manpower problems similar to those in larger organizations, (2) are presently in need of all types of personnel, (3) are critically in need of junior engineers, and (4) will need additional technical manpower in proportion to additional construction.

Usefulness

The nature and preliminary findings of this particular survey have been detailed to the extent that they may throw light on the local engineering manpower situation in general or be of use in detailed appraisal elsewhere. But we are really concerned with solving a recognized problem. We are coming to that. But first let us note that appraisal need not be a separate exercise in fact finding. The survey just described was designed to lead directly into corrective action. Here are some of the ways it may do so:

1. The fact of the survey's being made detailed rather than cursory, thus compelling more attention, may stimulate thinking and action in individual participating agencies.
2. The inclusion of a check list of time-saving procedures (Figure 2) forces attention to the possibility of their immediate application.
3. By visiting the agencies surveyed, the Institute has incidentally acquired information which would not have been obtained on paper and which is already influencing its other activities of service to city and county roadway engineering departments.
4. Final results of the survey will be promptly forwarded to participating agencies and other groups capable of influencing engineering manpower in cities and counties. This should (a) provide concrete facts which may assist city and county engineers in substantiating proposals for corrective measures as may be required in a particular locality, such as better salaries, authorization of positions, reclassification of jobs, or other factors affecting the hiring and keeping of technical personnel, (b) convey a picture of the situation to individuals on policy-making levels who can initiate general measures to alleviate the problem, and (c) provide the Institute staff conducting the survey with facts which can be directly communicated to the appropriate groups capable of effective action.

GENERAL PROBLEMS

The Over-All Shortage of Engineers

From one point of view, cities and counties are in the same boat as everybody else. They cannot get out until the boat lands, which is to say until there enough technical personnel to go around. This objective can be realized only by reducing the need for personnel or increasing the number available or both. Most local organizations seem to feel that they can do neither. As to reducing need, many say, they are either committed to the status quo, already so streamlined that possibilities of further improvement are trivial, or so small that time-saving techniques are inapplicable. As to increasing the number available, they say, that is a problem for somebody else. But the fact is that many local organizations are both reducing the need and increasing the number, and it appears that many others could do likewise.

Reducing the Requirement. The possibilities of better utilization of technical manpower were explored in the Institute survey by a question (Figure 2) listing specific procedures and asking whether these have been used effectively or hold promise of reducing technical manpower needs. Analysis of these reports has not been completed, but numerous examples have been found in which an organization feels that it could gain nothing by a particular procedure, whereas another organization, comparable to the first for all practical purposes, has used the procedure and definitely effected savings in engineering time.

The difficulty here appears to be that the lagging organizations are simply not fully informed. A solution would be to inform them. To a limited extent this is being accomplished by current surveys and reports that give emphasis to time-saving procedures. It is aided by the technical press, both commercial and professional. But the need seems to be for making sure that this information gets to the places where it can be used and is presented not as an interesting event occurring elsewhere but as a procedure having possibilities for immediate application. Many agencies are communicating in some way with cities and counties. A contribution could come from each.

There seems to be a general feeling that in view of what is now conventionally termed the critical engineering shortage, time-saving is a comparatively minor matter. But let's take an example. Suppose 30 percent more engineers are needed, or 130 percent of the present total. Suppose time -saving can cut the requirement by 10 percent, that is, to 117 percent. The need would then be for 17 percent more engineers, instead of 30 percent. Which is to say that the problem would be 43 percent solved by a 10 percent saving in engineering time.

It appears that an information program aimed at expediting time-saving procedures could contribute toward achieving some very substantial results.

Increasing the Number. Some local agencies in California are providing engineering-aide and similar positions under programs which encourage young men to pursue engineering study and go on to become registered engineers. These programs are of course designed primarily to reduce immediate personnel shortages. But they also draw into engineering young men who would otherwise drift into other fields and are thus a long-term contribution to increasing the future number of highway engineers. There appear to be many cities and counties in which such programs could be adopted.

Arguments against such programs are that what the organizations really need are men with some experience and that when beginners who are soon to become engineers are hired they leave the organization upon becoming engineers. True as these arguments are, the advocates of education assistance programs seem to take a more realistic view of the prevailing situation. "Certainly we'd prefer men of experience," they say, "but they aren't here now and we can't wait. It is better to adjust ourselves to positions we can fill than to have a more ideal, but unfilled organization." As to men leaving the organization, they point out that others are leaving also, that those encouraged to educate themselves may in fact be less likely to leave and if they leave will be more favorably disposed toward the organization which helped them on so that some may be more likely to return in the future.

Characteristics of Local Problems

Cities and counties come in assorted shapes and sizes. In California, for example, there are 58 counties and more than 300 cities. Among the largest, three cities and three counties account for 30 percent of all local street and road work. The manpower problems of these large organizations are more like those of state highway departments than like those of small cities and counties. Among the smallest units, more than 250 cities account for only 15 percent of all local street and road work. Most of these have no engineers and hence no engineering manpower problems. This range of sizes is fairly typical of conditions nationwide (although the counties are especially large). Hence when we refer to "local manpower problems" we should probably focus attention on the middle group, the large group deserves separate treatment, and the small group can be dismissed.

A local agency, as it figures in the manpower problem discussed here, is thus a unit with annual street or road funds in the general range of $\$1/4$ million to \$5 million and with a technical working force of from 2 or 3 to 50 individuals. Most agencies of this type attribute their difficulties in securing technical manpower to low salary ranges and limited opportunity for advancement.

These are undoubtedly prevailing problems and important factors in the manpower problem. But there are some significant exceptions. There are local units where salary ranges are not low. And there are local units offering low salaries and apparently limited opportunities that are not short of technical personnel. In other words, there is some evidence that shortcomings in salary and opportunity do not lead inevitably to personnel difficulties.

Information which may throw light on these problems is being obtained in the California survey. Reports of salary scales will be related to staff vacancies and where these do not correlate, attempt will be made to find out why. It is hoped that compensating factors may be found which may be generally applied by other cities and counties.

The preceding considerations apply if one thinks of single local units at single points in time. But when cities and counties are taken together and over the course of time, the premises are different. Salaries can be changed. Many cities and counties will grow. And in the general field of engineering in public administration there is plenty of opportunity. It is the view ahead as well as the immediate prospect that influences the young job applicant. Perhaps these considerations are already in the minds of some young engineers, accounting for the fact that local agencies are no worse off for technical manpower than they are. In many places such positive factors might well, as applicable in each case, be more effectively stated (or even just stated) in connection with recruitment activities. There is an almost fatalistic attitude toward the technical manpower problem in a good number of cities and counties. "Well, now why should a young engineer come to work here?" they ask. The response should probably be, "You're here. You tell me." Which might form the basis for a useful survey.

As local agencies are viewed collectively, a salary situation that is causing considerable loss of technical effort is found in many areas where several agencies are fairly close together. Most are in need of personnel and, as might be expected, few have exactly the same salary scales. The result is a continual movement of technical personnel from one agency to another. Often the move occurs about the time the individual has learned the procedure (and hence become of some use) in the place that he is leaving. Sometimes these moves are made for raises of as little as \$25 a month.

An aggravated example of this situation is found in southern California, where the Los Angeles metropolitan area includes 16 sizeable cities, in addition to the City of Los Angeles, and the Los Angeles County Road Department. An association of city and county engineers in the area is considering the problem, and it will be of interest to see if a workable solution can be developed.

In Conclusion

The foregoing disucssion of some outstanding technical manpower problems at the local level, together with examples of corrective action already being taken in isolated cases, is by no means intended to minimize the seriousness of the problem or to suggest that the examples cited hold prospect of complete solution. Quite the opposite. Data accumulated to date indicate that cities and counties are already seriously affected by technical manpower shortages. So far, most of them have been able to carry construction programs to the limit of available funds without delay. This appears to have been made possible by the presence of a nucleus of experienced personnel and by overtime work and other expedients. In other words, local engineering may be regarded as presently having an above-capacity output. There are many indications that the nucleus of experienced personnel is dwindling — thus the prospect of increased difficulties ahead and the importance of corrective action now. Some of this corrective action can be taken by individual cities and counties once they have the information on which to act effectively. Some of it will have to be taken on a collective basis. And this calls for immediate contribution by every agency with responsible interest in, and capabilities for, assisting in the solution of engineering manpower problems at the local level.

ACKNOWLEDGMENT

The specific facts and general ideas presented in this paper are the result of reports, counsel, and suggestions contributed at considerable expense of time and effort by the road commissioners and city engineers in most of the counties and principal cities of California in an effort to assist all cities and counties in meeting their technical manpower needs.

Potential Supply of Manpower for an Expanded Secondary Road Program

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The present and potential demand for technical and engineering assistance in secondary road administration was surveyed by a questionnaire circulated to executive road officials in each of the 87 counties of Minnesota and to 182 selected officials in 36 other states. Names in the latter group were taken from among those who have participated in the Forum of the Better Roads Magazine.

This problem is apparently of vital interest to county road men. Eighty of the 87 county highway engineers in Minnesota (91.9 percent) and 118 of 182 in the other states (64.8 percent) filled out and returned the questionnaires.

It is the opinion of these county men that:

1. The need for the largest numbers of engineering assistants in an expanded program will be for subprofessional personnel (rodmen, chainmen, draftsmen, and instrument men). These persons can be secured and trained by the counties, even if the present road program is expanded 100 percent. Not all counties can do this, whereas others can secure and train more than will be required.

2. The need for registered professional engineers will increase about 57 percent if the road program is expanded 100 percent. For example, 80 engineers in Minnesota estimated the need to be for 46 more engineers for a 100 percent expanded program. And these 80 men have had 42 assistants who have become county highway engineers.

The first requirement points to a need for coordinating distribution and promotion of subprofessional personnel across both county and state lines.

The second requirement points to the need for closer cooperation between the state and local highway administrations in the handling of professional personnel. If there were close cooperation between local and state road jurisdictions and among the various states, subprofessional personnel could start wherever jobs became available. As they learned through practice, they could expect to move to jobs requiring a greater degree of knowledge. Further, they could be expected to enter engineering schools either for full-time training or on a cooperative basis. Such a system would seem to hold genuine promise for an adequate supply of high type professional personnel.

● IN an expanding economy which is being leavened by increased scientific knowledge and mechanized by a constantly developing technology, the vital question is and will continue to be: Are there enough men being trained to replace specialists who now operate the whole material portion of our society? These men, like all others, find other jobs, lose interest, grow old, and substitutes must be ready on the bench or warming up to take their places if the game is to go on.

The problem of the supply of engineering and technical know-how at the local road administration level is particularly pressing at this moment for several reasons. (1) Since the coming of the automobile it has become necessary to add scientific knowledge to common-sense knowledge in order to build roads for present-day traffic. State highway departments as a rule have acquired this scientific knowledge. However, many county administrations do not yet have the every-day use of engineering know-how. This implies that more engineers must be trained if local roads are to be built as well as we know how to build them. (2) Sufficient men must be trained to replace those already growing old in the service of local road administrations. (3) If already existing needs for engineering personnel as well as needs for expanded local road programs are to be met, larger numbers of professional and technical personnel will be required.

A survey of the amount of professional and technical know-how in local administration and of the opinion of the road men as to potential needs was made by questionnaires.

Questionnaires were sent to all of the county highway engineers in Minnesota by a member of their professional association.[1] And to get some picture of the situation elsewhere, a more general sample was obtained by sending the questionnaires to 182[2] county highway engineers in 36 other states. The names of these men were taken from among those who have participated in the Forum of Better Roads.[3]

The results of these questionnaires are not necessarily representative of the whole country. Only 269 local road jurisdictions out of a total of more than 3,000 in the United States were covered. The men answering the questions probably are among the leaders in the local road field. While it is true that all the county men in Minnesota were covered, it also is generally recognized that Minnesota county highway men as a group are outstanding.

The response to the questionnaires was extraordinary. It suggests that these men feel the questions deal with a vital set of problems. Out of a total of 269 questionnaires distributed, 199 (73.97 percent) were returned. The number and percentage of returns for the two groups are shown in Table 1.

TABLE 1

	No. of Questionnaires Sent Out	No. of Questionnaires Returned	Percent Returned
Minnesota	87	80	91.95
Selected States	182	119	65.38

The questionnaire sent to the selected states differed slightly from that sent to the Minnesota men. Anyone who has engaged in research of this type involving tall stacks of questionnaires and seemingly endless columns of figures and tabulations knows the problems which crop up in analysis. Did everyone interpret the question in the same way? Is each answer the result of equally mature deliberation? And I am certain, too, that no one completes a study of this type without thinking of the old definition of a statistician as the man who drowned while crossing a pond with an average depth of eighteen inches.

This engineering survey is only a sample, and the findings should be labelled both "tentative" and "preliminary," but they do provide the beginnings of answers to some basic questions.

A primary question is: Can the road industry depend upon the present top-level local road men remaining on the job, or are they eager to find other employment? Two important facets of the answer to this question were brought to light by the questionnaires: (1) County highway engineers apparently plan to work as long as they are physically able. (2) The young county engineers are not being syphoned off.

A correlation of the engineers' completed service and intended service (see Figures 1 and 2) indicate almost to the man an expected career-span of at least 15 plus years. In Minnesota, only one man (60 answering the question) and two in the selected states (77 answering) who have been at the job less than fifteen years plan to quit in the next two years.

Although a considerable number of men (50) plan to retire in the next five years, three-fifths of these (30) have served already more than 20 years (see Figure 3).

It is quite common to find engineers with more than 20 years service in their jobs. For example, 24 of the 79 county highway engineers replying from Minnesota said they had served 20 or more years, and there were 36 of the 103 replying from the selected states in the same category. All of these facts emphasize the extensive amount of practical know-how and experience which is being accumulated at the local level. This facilitates good road administration because if good men are recruited initially, the longer they serve the greater the volume of know-how.

The replacement rate of present county highway engineers both for Minnesota and the selected states is shown in Figure 3. Of the engineers now serving, roughly ⅓ of those

[1] This questionnaire with a summary of the answers is in the Appendix.

[2] The executive official in the local road jurisdiction has been called county highway engineer in this paper for reasons of convenience regardless of his title and of the name of the jurisdiction.

[3] This questionnaire with a summary of the answers is in the Appendix.

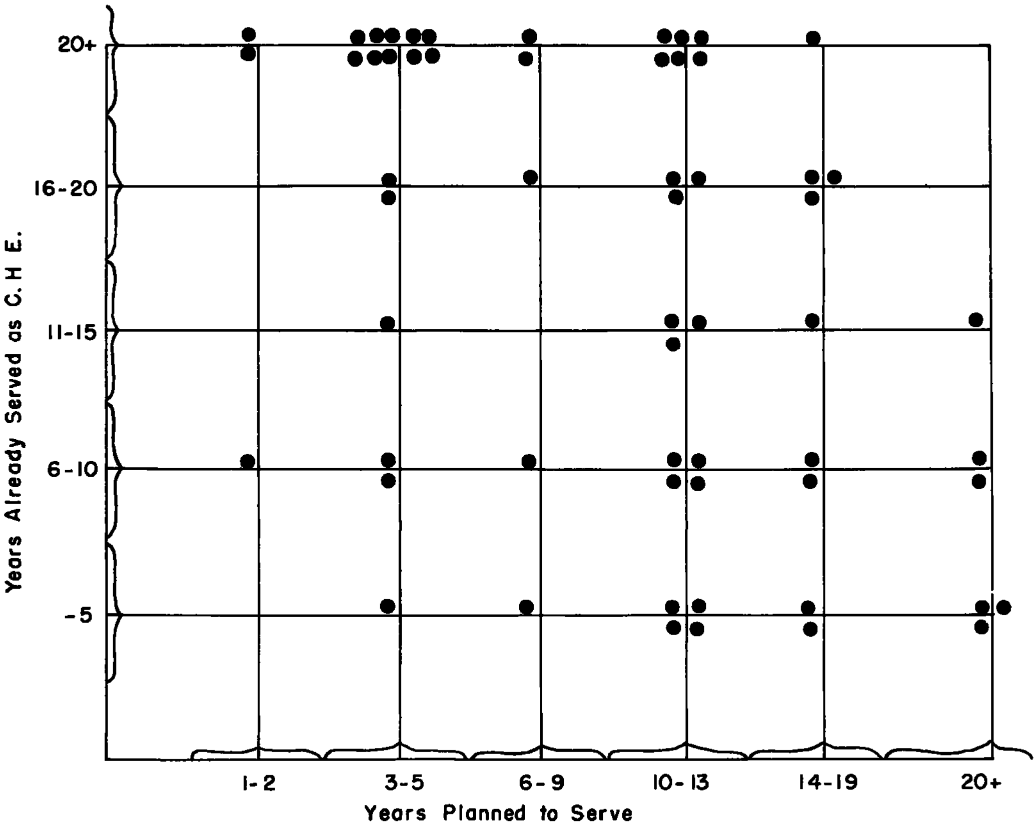

Figure 1. Relation between years of service and anticipated future service of county highway engineers, 59 county highway engineers in Minnesota reporting.

in Minnesota and ⅖ of those in the selected states must be replaced by the end of five years.

The next question is: Will men be available to fill these places? Two sources of supply are possible. (1) Men may come from outside of present local road employment. Such sources are engineering schools, private employment, including engineering and consultant firms, contractors, state highway departments, etc. In some states the state highway department is an important source of supply for county highway engineers. For example, in Minnesota two out of three of one large group[4] were formerly employed by the state highway department. (2) Men now employed in the local road jurisdictions constitute the second source. The questionnaires were designed to throw light on the number of men now in local road employment who could be expected to move into the positions of top responsibility.

There are 55 assistant engineers in Minnesota; 42 of them are below 50 years of age. Minnesota will need only 18 county highway engineers during the next five years to replace those now in service. Thus we have more than enough technically qualified men to fill anticipated vacancies in that state. In the selected states the potential supply of engineers while adequate is not so great; 32 vacancies are to be anticipated in the next five years and there are 46 assistant engineers under the age of 50.

While the assistant engineers do not represent the only source from which county engineers may come, it appears this source alone may contain an adequate number.

The number of assistant engineers whose ages are known, their age distribution and

[4] Sixty-six men were in this group.

their professional status is shown by Table 2.

In addition to the assistant engineers, present county highway departments have many additional personnel who are an important source of persons to move up the technical and professional ladder.

In order to determine the present condition of county highway department staffs, as far as personnel is available for promotion or training for promotion is concerned, a detailed review of the existing staffs was made. It was geared to the years the county highway engineers intended to retire to give a sharper picture of need and how it may be met.

Tables 3 and 4 indicate that present engineering resources are sufficient to meet top-level replacements over a considerable period, and that there is personnel suitable for additional training to bring staffs up to adequate standards for present program needs. For example, over a period of 21 years and more (see Table 3) Minnesota engineers indicated retirement intentions. The pool of potential engineering resources on present staffs to fill these 60 positions and others which will become vacant because of movement upward consists of: 42 assistant engineers, and a total of 172 engineering assistants. Among these are 48 engineering assistants who are either registered or are qualifying themselves for registration and 108 additional engineering assistants who can set grade lines and figure quantities. Also among these are 26 graduates of engineering schools, 13 college-trained men and 56 engineering assistants with the executive ability necessary to fill the position of county highway engineer.

Additional Minnesota potential is now available in the highway department staffs which was not included in Table 3 because the engineers did not indicate intended retirement

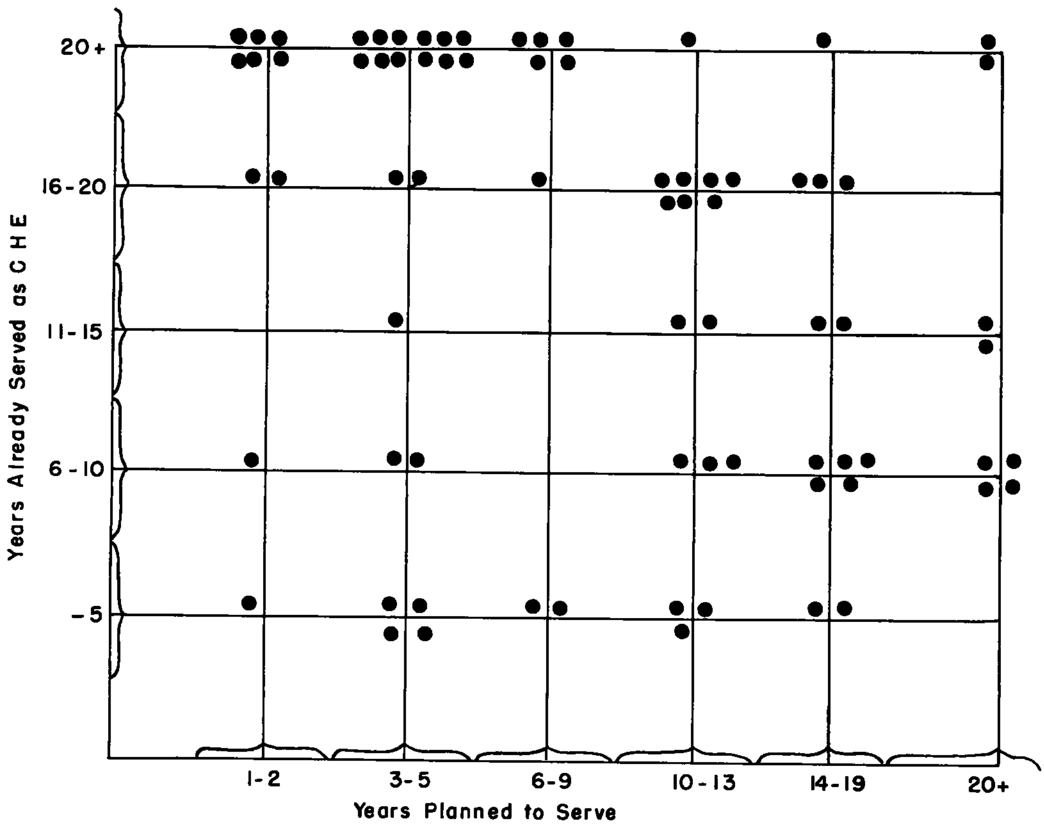

Figure 2. Relation between years of service and anticipated future service of county highway engineers, 77 county highway engineers in selected states reporting.

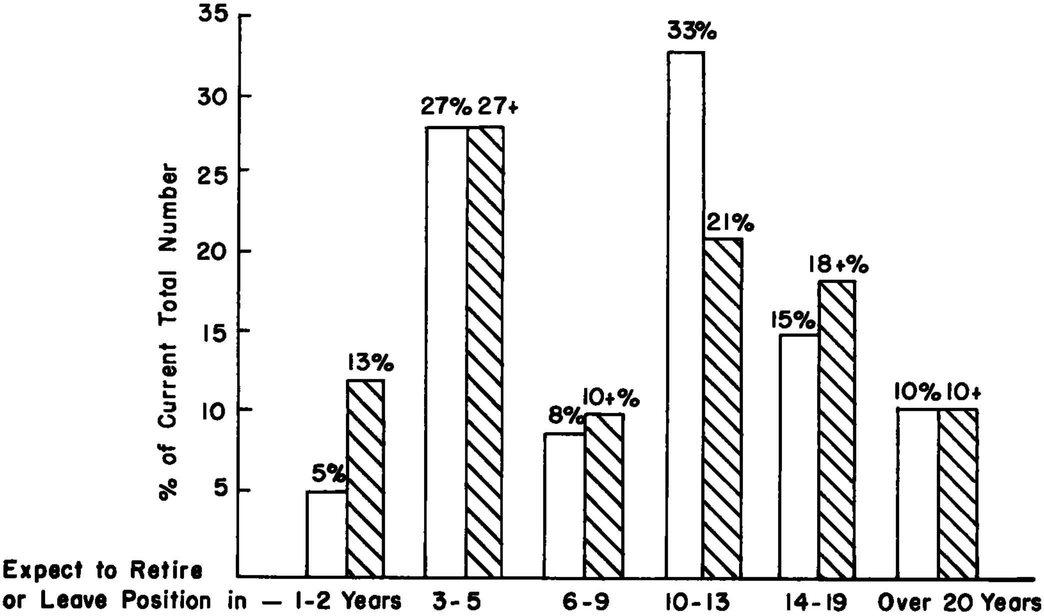

Figure 3. Potential replacement needs for present Minnesota and selected states - county highway engineers.

Note: This figure is based on the question - "How many years do you plan to continue as a county highway engineer?" 60 out of 80 or 75.0 percent of the Minnesota CHE' s returning the questionnaire replied to this question. 77 out of 111 or 69.36 percent of the selected states CHE's returning the questionnaire replied to this question. Percentages are corrected to the nearest whole number; fractions under .5 are indicated by a (+).

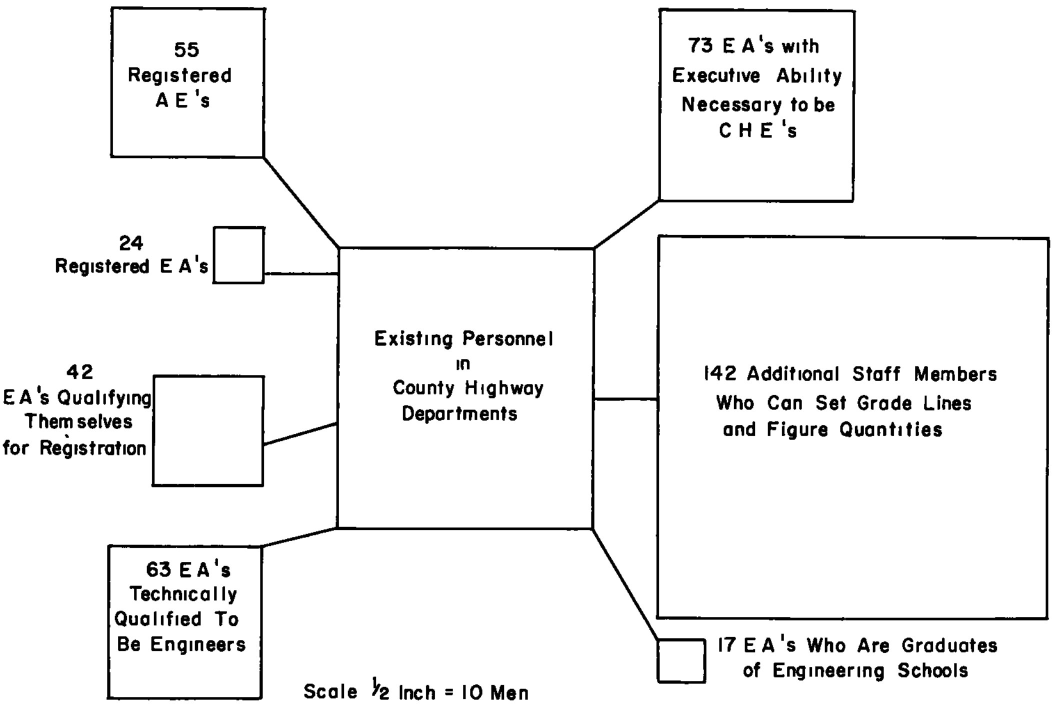

Figure 4. Potentials for professional staff replacement and expansion in Minnesota.

TABLE 2

AGES OF ASSISTANT ENGINEERS IN MINNESOTA[a] AND SELECTED STATES[b]

	Minnesota	Selected States
21-24 years	1	2
25-29 years	6	9
30-34 years	9	11
35-39 years	6	2
40-44 years	10	8
45-49 years	10	14
50 and above	9	28
	22 are below 40 years	24 are below 40 years
	29 are above 40 years	50 are above 40 years

[a] 55 or 70.5 percent of the CHE's replying to the questionnaire have AE's. Minnesota requires AE's to be registered.
[b] 78 or 73.58 percent of the CHE's replying to the questionnaire have AE's. 39.74 of those AE's are registered. Difference between number of AE's and total number for whom ages of AE's are arrayed results from fact that all CHE's did not indicate age of their AE.

dates. The potential on their staffs plus that already set forth in Table 4 is pictured in Figure 4. This figure reveals a surprising strength in Minnesota engineering manpower.

Comparable information on technical and professional resources to fill county engineer and other staff vacancies in the selected states for the twenty-one-year-plus anticipated retirement schedule shows that (see Table 4): there are 56 assistant engineers of whom 20 are registered,[5] and a total of 240 engineering assistants of whom 73 are registered or are qualifying themselves for registration, and 129 additional engineering assistants who can set grade lines and figure quantities; also among these are 52 engineering assistants who are graduates of engineering schools, 87 college trained men, and 63 with the executive ability necessary to by county highway engineers.

Although these tables and figures show a great deal of engineering talent, more than 50 percent of the Minnesota men and 72 percent of the men in the selected states indicated they would employ more engineering assistance if it were now available.

TABLE 3

A DESCRIPTION OF COUNTY HIGHWAY DEPARTMENT STAFFS

Minnesota Counties - 60 Answering

No of CHE's Needed in		Has AE	Hasn't AE	No of EA's on staff	No of CHE's with EA's reg. or qualifying	No. of such EA's	CHE's with EA's who are grads of eng schools	No. of grads	CHE's with EA's who are college trained	No of college trained	No of CHE's with EA's having ability to be CHE	No of these EA's	CHE's with add'nal personnel who can set grade	No. of such personnel
1 year	2	2	0	2	1	1	1	1	0	0	2	2	2	3
2 years	1	1	0	1	0	0	0	0	0	0	1	1	0	0
3 years	4	4	0	7	3	3	0	0	0	0	3	4	3	6
4 years	4	3	1	14	2	2	1	1	1	1	4	4	3	8
5 years	8	3	5	12	5	5	3	3	0	0	6	8	6	13
6 years	1	1	0	2	1	1	0	0	0	0	1	1	0	0
7 years	1	1	0	2	1	1	0	0	0	0	0	0	0	0
8 years	3	2	1	5	1	2	2	3	1	1	2	3	2	3
9 years	0	0	0	0	-	0	-	-	-	-	-	-	-	-
10-13 years	21	15	6	78	13	26	4	14	3	9	15	22	16	52
14-17 years	7	5	2	31	3	3	2	2	1	1	5	6	6	15
18-21 years	7	5	2	17	4	4	2	2	1	1	5	5	7	8
Over 21 years	1	0	1	1	0	0	0	0	0	0	0	0	0	0
Totals	60	42	18	172	34	48	15	26	7	13	44	56	45	108

This points up three facts. There is no surplus of numbers of persons but there is surplus talent which may be developed to strengthen present staffs and for expanded programs and which may not now be utilized fully. For example, there are now 73 engineering assistants in Minnesota who are reported to have the executive ability necessary to fill the top job in the county. This leads up to the second fact, that the scarcity may really be due to location and not to an absolute lack of talent. That is, there may be room for only one instrument man in County A although there are three rodmen who are capable of being instrumentmen whereas County B needs an instrumentman. This point will be discussed later. The third fact is that more money is needed so that more men can be employed and be started in the training process which has evidently been so successful to date.

The lack of money as a cause for present shortages of staff is supported by the opinion of 47.95 percent of the Minnesota engineers and 72.5 percent of the engineers in selected states.

[5] Only eight of the 36 selected states require assistant engineers to be registered.

TABLE 4

A DESCRIPTION OF COUNTY HIGHWAY DEPARTMENT STAFFS

Selected States - 77 Answering

No of CHE's Needed in		Has AE	AE registered	State requires regis	Hasn't AE	No of EA on staff	No of CHE's with EA's reg. or qualifying	No of such EA's	CHE's with EA's who are grad of eng schools	No of such grads	CHE's with EA's who are college trained	No of college trained	CHE's with EA's having exec ability to be CHE	No of these EA's	CHE's with personnel who can set grade lines	No of such personnel
1 year	7	5	3	2	2	23	3	7	3	10	4	11	5	7	6	16
2 years	3	2	1	0	1	8	1	5	2	4	2	8	2	6	3	8
3 years	5	3	1	0	2	22	2	3	2	4	2	3	2	3	3	12
4 years	5	2	0	0	3	7	2	3	1	1	2	3	2	3	3	6
5 years	11	9	4	2	2	29	4	8	4	5	8	12	8	12	7	13
6 years	3	3	1	0	0	7	2	3	1	2	1	2	3	3	3	5
7 years	2	2	0	0	0	7	1	5	1	5	1	5	1	3	1	4
8 years	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
9 years	2	2	1	0	0	14	1	6	1	4	1	6	1	2	2	15
10-13 years	16	12	1	1	4	52	7	14	4	6	9	14	8	10	7	13
14-17 years	13	10	4	1	3	50	5	12	4	7	6	15	6	7	7	19
18-21 years	8	6	4	2	2	20	4	7	3	4	4	8	4	7	4	18
Over 21 years	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Totals	77	56	20	8	21	240	32	73	26	52	40	87	42	63	46	129

In Minnesota the inadequacy of personnel for the present workload is not great. Sixty-one counties reported a need for a total of 16 registered engineers, 32 instrumentmen, 40 chainmen, and 43 rodmen (see Column 1, Table 5).

In the selected states the shortage of manpower to carry the present workload as reported by 92 counties was distinctly larger. They indicate a need for 83 more assistant engineers, an increase of 106.41 percent; 69 more draftsmen, an increase of 80.23 percent; 50 more instrumentmen, an increase of 72.37 percent; and 43 more rodmen, an increase of 36.13 percent.

Some of these figures are puzzling. Does it seem reasonable that the counties will need greater numbers of professional men then they need of some types of sub-professional men; for example, instrumentmen and rodmen?

When these data were being analyzed the idea was advanced that these figures probably revealed an exaggerated need of the counties because they did not have sufficient profession manpower. Subsequently, data of all these counties which reported employment of a registered assistant engineer were analyzed. These are compiled in Table 7, but the same pattern persists. More than two times the number of assistant engineers than rodmen are reported as needed.

The next problem is: How much technical and professional personnel will be required for an expanded local road program? A series of questions was submitted to the county highway engineers to secure their estimates as to the different classes of personnel needed if the program were to be expanded by 25, 50, 75, and finally by 100 percent.

These estimates for Minnesota are shown in Table 5, and the pattern of these needs is pictured in Figure 5. These data indicate that the Minnesota men have carefully considered their engineering manpower needs. There is a consistent relation between the various categories of personnel. A 100 percent expansion over present programs calls for about three times as many personnel in each category as is needed for the present work load.

TABLE 5

PERSONNEL NEEDS FOR PRESENT WORKLOAD AND EXPANSION

Minnesota - 61 Counties Indicating Needs

	Present Workload	25% expansion	50% expansion	75% expansion	100% expansion
Registered Engineers	16[a]	14[b]	18[c]	31[d]	46[e]
Instrumentmen	32	40	52	77	96
Chainmen	40	53	79	111	140
Rodmen	43	61	77	97	125

Note: There are now in the 80 counties returning the questionnaires 55 AE's and 24 registered EA's, or 79 registered engineers on the staffs of the county highway departments in addition to the CHE's. The percent increase over this number as indicated by the above needs would be: (a) 20.25% (b) 17.72% (c) 22.78% (d) 39.24% (e) 58.23%.

TABLE 6

PERSONNEL NEEDS FOR PRESENT WORKLOAD AND EXPANSION

Selected States - 92 Answering Question

		Present Workload		+25%		+50%		+75%		+100%	
	Present staff	Additional men needed	% increase	Additional men needed	% increase	Additional men needed	% increase	Additional men needed	% increase	Additional men needed	% increase
Assistant Engineers	78	83	106.41	80	102 56	119	152.56	155	198 71	185	235 90
Draftsmen	86	69	80 23	76	88 37	127	147 67	165	191.86	206	239 53
Instrumentmen	116	50	43.10	61	52.59	100	86.21	135	116 38	161	138 79
Chainmen	76	55	72 37	75	98.68	121	159.21	170	223 68	194	255.26
Rodmen	119	43	36.13	61	51.26	109	91.60	145	121.85	179	150 42

Note 66 CHE's or 72.53% said they would hire more personnel if they has more money 69 of 70 41% said they would if the assistance were available 40.91% of the CHE's answering think men needed for expansion are available. 73 96% of the CHE's said they could train the men needed.

TABLE 7

PATTERN OF INCREASE IN SELECTED STATES WITH REGISTERED ASSISTANT ENGINEERS

		Present Workload		+25%		+50%		+75%		+100%	
	Present staff	Additional needed	% increase	Additional needed	% increase	Additional needed	% increase	Additional needed	% increase	Additional needed	% increase
Assistant Engineers	31	26	83 87	21	67.74	38	122.58	54	174.19	64	206.45
Instrumentmen	44	17	38 64	14	31.82	31	70.45	44	100	51	115 91
Draftsmen	47	22	46 81	25	53.19	47	100	63	134.04	77	163 83
Chainmen	35	15	42.86	16	45 71	30	85 71	50	142 86	58	165.71
Rodmen	42	12	28.57	14	33 33	37	88.10	53	126 19	62	147 62

These data are shown in a different form on Figure 5.

The data from the selected states showing the anticipated needs for personnel in an expanded program are shown in Table 6. These same data were plotted on a chart to show the relations between the various classes of specialized personnel, Figure 6. (Note that needs in Figure 6 are expressed in percentages rather than in numbers of men.)

Attention should again be directed to the fact that the 92 county highway engineers from the selected states, as was seen in the report of needs for their present staff, have indicated greater needs for additional professional assistance for expanded road programs than for sub-professional personnel. For instance, for 100 percent expansion, the engineers said they needed 184 more registered engineers (or 235.9 percent increase over present staff) and 179 more rodmen (150.42 percent over present staff). Because of the apparent inconsistency between the requests reported by Minnesota county

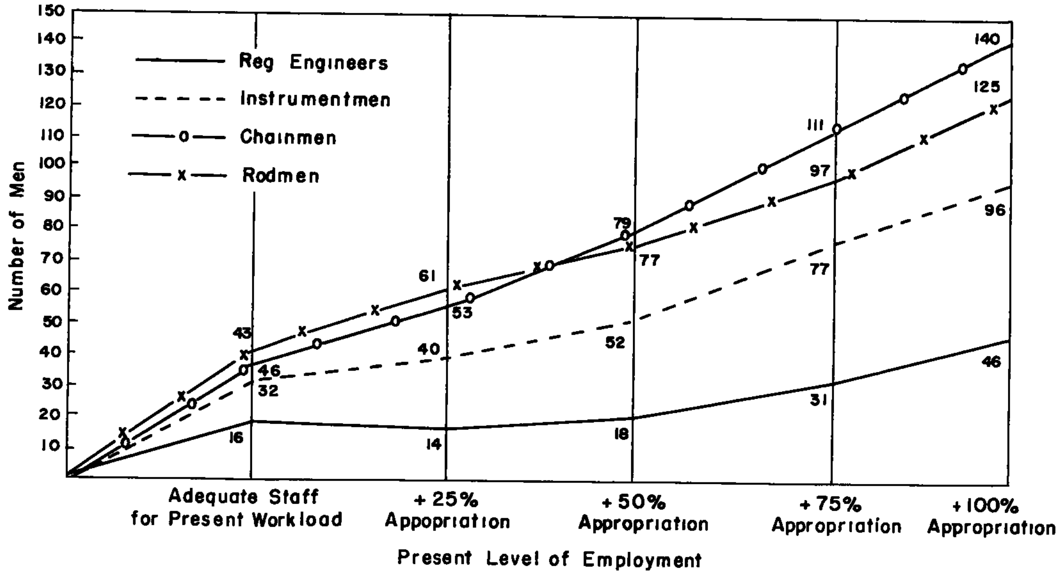

Figure 5. The pattern of personnel needs, adequate staffs for present workload and expansion in Minnesota - 61 Minnesota counties reporting.

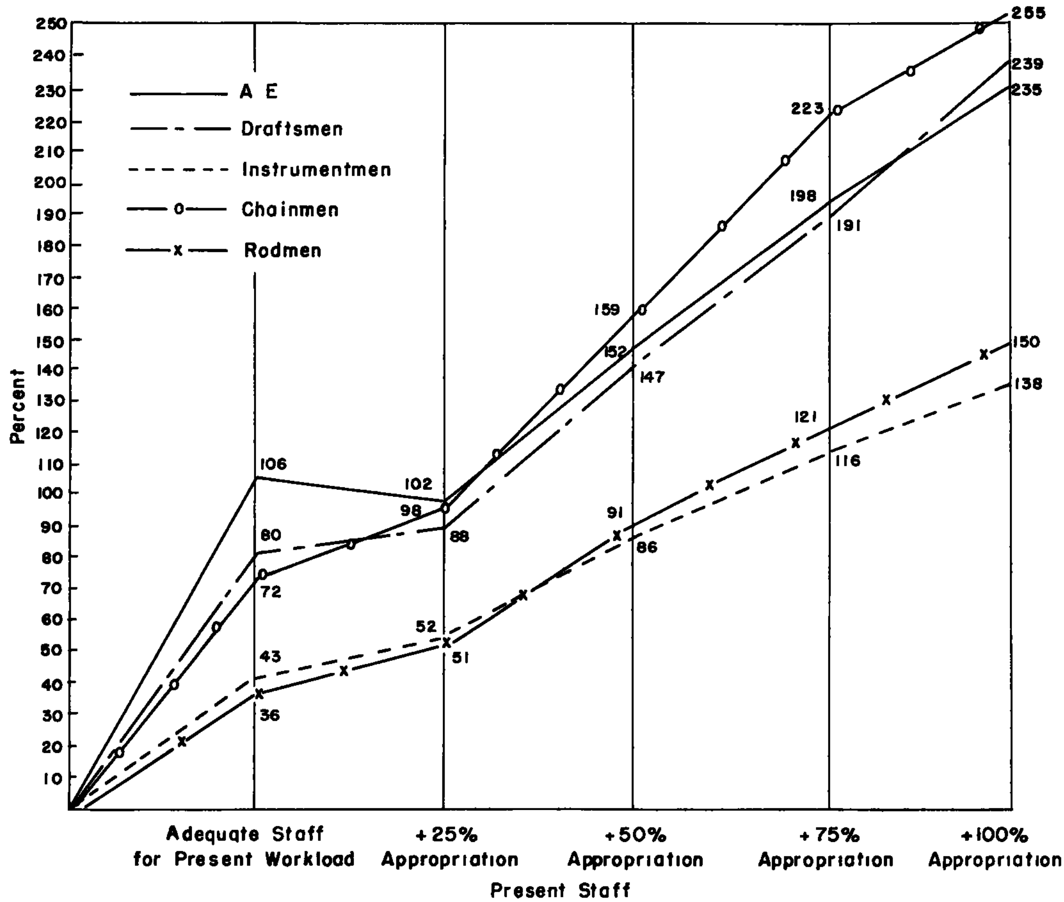

Figure 6. Pattern of personnel needs in selected states for present workload and expansion (in percentages), 92 county highway engineers reporting.

engineers and those of the selected states, it seems impossible to devise any formula to determine the needs for the various categories of personnel in expanded programs. A question arises as to the validity of the judgments as to personnel needs for an expanded program.

We come now to the problem: Will there be enough persons available to do the specialized work if the local road program is expanded? The answer to this question ulitmately depends upon the value which future job hunters attach to county employment. Will enough of them prefer it over that offered by competing employers? The pert, easy, but basically unsound answer usually turns on pay scales. If the pay is high, so run the comments, the positions will be filled. If pay were the only factor, the ranks of many callings would now be empty. Once minimum pay level is attained, then other considerations such as prestige, security, opportunity for advancement, working conditions, are as important or perhaps even more important then pay.

Let us approach the question from the standpoint of the opinion of the county highway engineers themselves as to whether a sufficient number of qualified personnel can be secured. Data in the questionnaires show that they think they can.

Sixty-four Minnesota county highway engineers answered the question on this point; 34 of them thought the necessary men could be obtained, 75 answered the question about their ability to train the needed men and 85 percent of those answering thought they could train them. The county highway engineers in the selected states were not quite so optimistic with respect to securing needed personnel.

The county highway engineers in the selected states were asked to indicate which of the categories of qualified personnel they could train. Those answering thought they could train from 81 to 96 percent of the various classes. It is interesting to note that they thought they could train 96 percent of the needed chainmen and 94 percent of the needed registered engineers. They were not so sanguine about training assistant engineers or draftsmen. The estimate of the numbers which they could themselves train was only 81 percent.

This confidence in being able to train qualified personnel may smack of over-confidence. What is their training record? To begin: (1) The county highway engineers particularly in Minnesota are not, as a rule, graduates of engineering schools. Some of them have not attended college. Only 15 percent of the Minnesota engineering assistants were trained in engineering schools and only 7.46 percent of the engineering assistants are graduate engineers. In the selected states 32 percent of the engineering assistants were trained in engineering schools and 18.79 percent were graduates of engineering schools. (2) Despite their lack of formal training they have graduated men from their staffs to top level jobs in the counties and to equally responsible jobs in other services. Twenty-six Minnesota engineers reported that 42 of their engineering assistants had become county engineers and 30 in the selected states reported 68 of their engineering assistants had achieved like advancement. Minnesota counties supplied 75 men to jobs in other places of equal responsibility and in the selected states 184 had taken similar positions. (3) Their present staffs have been shown earlier in this paper to have a surprising amount of technical and professional talent.

When these facts are brought together, the record shows the estimate of these county men of their own ability to produce the technical and professional manpower to manage an increased program is no idle boast.

The position of county highway engineer appears from the evidence in the questionnaire to be satisfactory to those who are in it. It was pointed out above (see Figures 1 and 2) how the engineers plan to continue in their position of county highway engineers so long as they are physically able. Further evidence of their satisfaction with their jobs is to be found in the data on years of service. Table 8 shows this for both Minnesota and selected states.

TABLE 8

Years of Service	Minnesota (79 answering)	Selected States (103 answering)
1 - 5	18	17
6 - 10	16	25
11 - 15	11	8
16 - 20	10	17
20+	24	36
Total	79	103

On the other hand county work appears not to have been as attractive to assistant engineers in either Minnesota or in the selected states since $2\frac{1}{2}$ times more of them went into other occupations as became county highway engineers. Or it may have been that opportunities did not occur for them to become county highway engineers. But whether it was in preference for other employment or lack of opportunity, this leads to the suggestion that some kind of arrangement be established whereby available technical and professional personnel and the demand for it can be brought together.

The Assoication of County Highway Engineers in Minnesota provides this service for its members. When a county engineer vacancy occurs, the secretary of the Association sends a notice to each of the other 87 engineers. A vacancy in one conty may result in as many as five shifts being made. This kind of arrangement could be extended to include all professional and sub-professional personnel between county and state highway departments if salaries are sufficient to make moves attractive.

One Minnesota county highway engineer remarked to the writer that the high schools were full of boys who want to earn money during the summer. In the time these boys are available to work with a field crew their aptitudes are discovered and interests developed. But, he said, although he had found many boys who appeared promising, his organization was too small to provide a ladder for their advancement. This indicates that some way should be found whereby technical and beginning professional personnel may be given work and responsibility in accordance with developing talent. This is done in states for county engineers like Minnesota and Michigan, when the engineers move from county to county. However, it would seem that a twofold type of advancement might be possible if the proper machinery to accomplish it were provided, movements from county to county and movement back and forth between state and county highway departments. Already a high cooperative attitude is being shown in some states to assist local road jurisdictions with their technical and professional personnel.

For example, the Minnesota State Highway Department permits members of its staff to take positions as county highway engineers. They are given leaves of absence from their jobs with the state highway department. They do not lose Civil Service status, and they are free to return whenever they please. Further, the state department permits technical persons to work with state crews in order to improve their training. For example, counties may send concrete or bituminous inspectors to join a state crew for a period. Cooperation of this kind should be extended so that technical personnel could expect to find work in keeping with increasing knowledge and skills.

Ladders of advancement from county to county and from county to state highway departments are just one aspect of improving the atrractiveness of road work. A similar ladder should be established across state lines. Recently an Iowa man was given the executive position in a Michigan county. The engineer in one of the larger Michigan counties was attempting to employ this man for his staff. The Michigan man was at the same time asked by a county road commission of a county of which he had formerly been the engineer to recommend someone. When he reported what he knew about the Iowa man the commission proceeded to appoint him.

The movement of professional personnel across state lines in not unusual. City managers are not confined by state lines. Neither are school men. The interchange of public school people has developed so far that arrangements are being developed for reciprocal retirement credit. California, Ohio, Illinois, among other states, take men from engineering schools wherever they can find them.

In a time when it appears that not only is the present supply of professional men too small to meet the demand but it is likely to continue to be too small in the foreseeable future, it would appear to be an act of wisdom to open up all the possible doors of advancement for highway personnel. For it to become known that jobs will be available to match the capacity is one of the most certain ways of attracting young men to prepare themselves for them. The high school boys who take a summer job on a survey crew are more likely to go to college when they are laid off in the fall if it becomes common knowledge that there will be a job waiting when they finish. The supply of capable young men with intellectual capacity to use a college education has not been exhausted. One sociologist estimated that only half of those with the ability to do college work actually go to college.

And may I add that despite the opinion of the men who filled out the questionnaires for me that they could train nearly all of the personnel needed to step into their places and to carry on the expanded road program, we must hope for more and more school-trained professional men. The job they are doing is too complex; the knowledge they need is too profound and is developing too rapidly for our society to depend upon learning by doing alone. Opening the way for advancement across county and state lines between departments and counties would probably have a most beneficent effect in publicizing the inherent advantages of the highway engineering profession. And it could have a most beneficial effect on salaries.

The machinery for doing this could take many forms. City managers use their own association to bring the vacancy and the prospective manager together. Notices of vacancies appear in their journal and in their newsletters. Their executive secretary is a kind of walking employment office. The same kind of thing could be done by journals which are available to road men. Notices of needs for personnel and notices of men wishing positions could be listed in the County Officer, the Journal of the National Association of County Officials. Likewise the monthly journals published for the benefit of the county road men could also carry such information.

This may be a problem which the Board of County Engineering Consultants of the Chief of the Secondary Branch of the Bureau of Public Roads might well consider. It could be that the Council of State Governments might find ways to assist with this. The county engineers themselves might want to organize for purposes of collecting and disseminating information in respect to job opportunities. Or it may be that the local division of the American Road Builders Association would welcome an extension of its activity for such a service.

Two objections, among others, may be raised to such proposals as these. A county engineer may be willing to have the way open for himself but balk at full cooperation in opening the way for members of his staff. This would be a short-sighted attitude. Improving the status, opportunities, and prestige of road men everywhere redounds ultimately to the benefit of all men and for the benefit of the country. True enough, an engineer may have his program demoralized by his assistant engineer leaving him on June 1, but if the machinery is available to take away his chief lieutenant, it should also be available for him to secure another.

In the second place, state interchange of personnel may seem to be impractical because legal residence as a qualification for public employment is required by law in some states. Often a close examination of such law reveals a way to avoid it. For example, such a restriction may bar hiring an official but not an employee. In that case a non-resident can be given the status of an employee; when he has established legal residence he then can be given the official position. It is believed that a considerable number of states do not have statutes barring the employment of non-residents. These could establish the practice and if it worked, the basis for asking for the repeal of undesirable statutes of other states would then be established.

The advantages of erecting ladders of promotion for technical and professional personnel are of inestimable value in establishing better pay, and in improving the status of the profession. The freedom to move from county to county in Minnesota coupled with the publication of pay rates has tended to put a floor under salaries. A county board is reluctant to admit that its county is willing to put up with a second rate engineer. Further, good engineers are freed from servile dependence upon a job if the policy controlling in that place does not permit the use of sound and efficient practice.

It might seem in the first instance that a system of promotion across state lines would rob the poorer states of most of their best technical and professional talent. A more mature consideration of the matter will suggest that such procedure might be the best way to improve their practice. The first step toward improvement is a recognition of the need for improvement. An exodus of talent would provide a dramatic evidence of the need.

It may be concluded that an expanded road program could have a long run effect to cure present shortages of manpower and to improve the quality of technical and professional personnel.

ACKNOWLEDGMENTS

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Appendix

COUNTY HIGHWAY ENGINEERING MANPOWER (MINNESOTA)

A symposium on highway engineering manpower is being planned for the January meeting of the Highway Research Board. The following questions are designed to provide some factual data on the visible and potential supply of engineering ability at the county level.

This questionnaire was sent to the 87 counties of Minnesota. Eighty questionnaires or 91.95 percent were returned.

Please note that the following abbreviations were used:

CHE = County Highway Engineer
AE = Assistant Engineer
EA = Engineering Assistant

The Potential Demand

1. How many years do you plan to continue as a county highway engineer?
   (a) 60 answered the question.
   They plan to continue:

1 - 2 years	3	10 - 13 years	21
3 - 5 years	16	14 - 19 years	9
6 - 9 years	5	over 20 years	6

Potential and Capacity of Engineering Assistants

1. Do you have an assistant engineer?
   (a) 78 answered the question.
   (b) 55 or 70.51 percent have AEs. Their ages are:

21 - 24 years	1
25 - 29 years	6
30 - 34 years	9
35 - 39 years	6
40 - 44 years	10
45 - 49 years	10
50 and above	9

   Four did not indicate the age of their AEs.
   AEs in Minnesota are required to be registered.

2. How many engineering assistants do you have?
   (a) Number of CHEs with one or more EAs, 78.
   (b) 78 CHEs have 228 EAs or an average of 2.92 EAs per county.

3. How many are registered?
   (a) 79 answered the question.
   (b) There are registered EAs in only 12 counties, and the total number of assistants registered is 24.
   (c) This means 10.53 percent of the EAs in all the counties are registered. (24 of of 228 EAs registered)

4. How many show the executive ability necessary to be a county highway engineer?
   (a) 78 answered the question.
   (b) 59 CHEs said they had 73 EAs with this ability.
   (c) This means that 32.02 percent of the EAs in all the counties have necessary executive ability. (73 EAs out of 228 EAs)

5. How many are technically qualified to be engineers?
   (a) 79 answered the question.
   (b) 46 CHEs answered that they had 63 EAs technically qualified to be engineers.
   (c) This indicates that 27.63 percent of the EAs in the counties (63 EAs of 228 EAs) are technically qualified to be engineers.

6. How many of the non-registered engineering assistants are qualifying themselves for registration?
   (a) 78 answered the question.
   (b) Only 18.42 percent or 42 of the 228 EAs in all the counties are qualifying themselves for registration.

7. How many of your engineering assistants are over fifty years old?
   (a) 78 answered the question.

(b) Only 15 counties have EAs over 50 years old. There are 25 such men; this means that only 10.96 percent of the EAs in all the counties are over 50.

Training

1. How many of your engineering assistants were trained in an engineering school?
   (a) 79 answered the question.
   (b) 35 out of the 228 EAs or 15.35 percent were trained in an engineering school.
   (c) These 35 EAs are in 22 of the 79 counties replying to this question.

2. How many are graduates of an engineering school?
   (a) 78 answered the question.
   (b) Only 17 of the 228 or 7.46 percent of the EAs in all the counties are graduates.
   (c) These 17 men are in 11 counties; 68 counties have no EAs who are graduates of engineering schools.

3. Exclusive of those mentioned above:
   (a) How many employees do you have who can set a grade line and figure quantities?
      (1) 79 answered the question.
      (2) 60 of the CHEs had 142 men who can set grade lines.
   (b) How many employees do you have who can operate an instrument?
      (1) 80 answered the question.
      (2) 73 of the CHEs had 176 men who can operate instruments.
   (c) How many rodmen or chainmen have you who are capable of becoming instrumentmen or draftsmen?
      (1) 79 answered the question.
      (2) 57 of the CHEs answered affirmatively and indicated they had 97 men in this category.

4. How many engineering assistants have you had who have:
   (a) Become county highway engineers?
      (1) 78 answered the question.
      (2) 26 CHEs or 33.33 percent of those answering indicated that 42 of their EAs have become county highway engineers.
   (b) Gone into other equally responsible positions?
      (1) 75 answered the question.
      (2) 40 of the 75 CHEs or 53.33 percent of those answering have had 105 EAs who have become the equivalent of CHEs.

   Note: The answers to (a) and (b) above suggest that advancement is out instead of up.

5. The answer to the above questions would have more meaning if the number of years you have served as a county highway engineer were known. That number is?
   (a) 79 CHEs answered the question.
   (b) They have served:

1 - 5 years	18	11 - 15 years	11
6 - 10 years	16	16 - 20 years	10
20 or more years	24		

Workload

1. Do you need more engineering assistance now?
   (a) 80 answered the question.
   (b) 34 or 42.5 percent need more engineering assistance now.

2. With your present workload would you employ more engineering assistance if:
   (a) You had more money?
      (1) 73 CHEs answered the question.
      (2) 35 of these or 47.95 percent could employ more engineering assistance with more money.
      (3) 38 or 52.05 percent would not employ more.

(b) If the assistance were available?
   (1) 66 answered the question.
   (2) The answer was split 50-50.

3. If the answer is yes, how many more of each class would you now employ:
   (a) 32 CHEs want 43 more rodmen; an average of 1.3 additional rodmen per county requesting.
   (b) 26 CHEs want 40 more chainmen; an average of 1.5 more per county requesting.
   (c) 30 CHEs want 32 more instrumentmen; an average of 1.06 more per county requesting.
   (d) 12 CHEs want 16 more engineers; an average of 1.33 more per county requesting.

4. How many of your technically trained personnel spend time on non-technical work?
   (a) 68 answered the question.
   (b) 22 CHEs answered they had a total of 33 persons doing such work, an average of 1.5 persons per county staff involved.

5. What percentage of the time of these persons is spent on non-technical work?
   (a) These 33 persons spend an average of about 25 percent of their time on non-technical work, although individually the percentages ranged from 5 to 90 percent of their time.

6. If the money available to your department were to be increased, indicate how it would affect your need for engineering assistance. If the money were to be increased -

25 percent — You would need:

Rodmen - 41 CHEs wanted 61 more.
Chainmen - 37 CHEs wanted 53 more.
Instrumentmen - 37 CHEs want 40 more.
Registered Engineers - 13 CHEs want 14 more.
48 CHEs indicated needs for increased staffs with a 25 percent increase in appropriation.

50 percent — You would need:

Rodmen - 53 CHEs want 77 more.
Chainmen - 49 CHEs want 79 more.
Instrumentmen - 46 CHEs want 52 more.
Registered Engineers - 15 CHEs want 18 more.
56 CHEs indicated needs for increased staffs with a 50 percent increase in appropriation.

75 percent — You would need:

Rodmen - 48 CHEs want 97 more.
Chainmen - 48 CHEs want 111 more.
Instrumentmen - 49 CHEs want 77 more.
Registered Engineers - 24 CHEs want 31 more.
54 CHEs indicated needs for increased staffs with a 75 percent increase in appropriation.

100 percent — You would need:

Rodmen - 52 CHEs want 125 more.
Chainmen - 51 CHEs want 140 more.
Instrumentmen - 54 CHEs want 96 more.
Registered Engineers - 33 CHEs want 46 more.
58 CHEs indicated needs for increased staffs with a 100 percent increase in appropriation.

7. Could you obtain the men needed for handling increased funds?
   (a) 64 answered the question.
   (b) 34 or 53.13 percent of the CHEs think the men are available.

8. Could you train these men?
   (a) 75 answered the question.
   (b) 64 of the 75 or 85.33 percent thought they could train the men.

COUNTY HIGHWAY ENGINEERING AND TECHNICAL MANPOWER (SELECTED STATES)

This questionnaire was sent to the heads of 182 local road jurisdictions in 36 states. One hundred nineteen or 65.38 percent were returned. Five of the questionnaires were not used in the tabulation because the data were obviously not representative and would have distorted the averages.

The following abbreviations were used:

CHE - County Highway Engineer
AE - Assistant Engineer
EA - Engineering Assistant

The Potential Demand

1. How many years do you plan to continue as a county highway engineer?
   (a) 77 answered the question.
   (b) They plan to continue:

1 - 2 years	10	10 - 13 years	16
3 - 5 years	21	14 - 19 years	14
6 - 9 years	8	over 20 years	8

Potential and Capacity of Engineering Assistants

1. Do you have an assistant or deputy engineer?
   (a) 106 answered the question.
   (b) 78 or 73.58 percent have AEs.
   (c) Their ages are:

21 - 24 years	2
25 - 29 years	9
30 - 34 years	11
35 - 39 years	2
40 - 44 years	8
45 - 49 years	14
50 and above	28

   (d) 30 of the AEs or 38.46 percent are registered.

2. Does your state require that your deputy or assistant engineer be registered?
   (a) 74 answered the question.
   (b) Number of states requiring AEs to be registered, 8, or 22.22 percent of the 36 states represented in the questionnaire.

3. Other than the assistant engineer how many engineering assistants do you have?
   (a) Number of CHEs with one or more engineering assistants, 84.
   (b) Number of such EAs, 346 or an average of 4.12 EAs per county.
   (c) 15 CHEs did not have an engineering assistant.

4. How many are registered?
   (a) 98 CHEs answered the question; only 22 of them had one or more registered EAs.
   (b) The number of registered EAs is 38; or 10.99 percent of the EAs in all the counties are registered.

5. How many show the executive ability necessary to be a county highway engineer?
   (a) 95 answered the question.
   (b) 62 CHEs said they had a total of 90 EAs with this executive ability. These 90 EAs are 26.01 percent of all the EAs in the counties studied (90 EAs out of 346).

6. How many are technically qualified to be engineers?
   (a) 86 answered the question.
   (b) 55 CHEs said they had 90 EAs technically qualified to be engineers.
   (c) These EAs equal 26.01 percent of the assistants in all the counties.

7. How many of the non-registered engineering assistants are qualifying themselves for registration?
   (a) 86 answered the question.
   (b) 37 CHEs said they had 54 EAs (15.61 percent of the EAs in all counties) qualifying themselves for registration.

8. Of these assistants, how many are classified as rodmen, chainmen, instrumentmen, draftsmen?

Rodmen, 119
Chainmen, 76
Instrumentmen, 116
Draftsmen, 86

Note: The total of these engineering classifications is 397 as opposed to the 346 EAs the CHEs said they had in question 3. Evidently some staff members serve in a dual capacity and therefore were counted in more than one category.

9. How many of your engineering assistants are over fifty years of age?
   (a) 47 counties had EAs over 50 years of age.
   (b) There are 85 such men; this means that 24.57 percent of the EAs in all counties are over 50 years of age.

Training

1. How many of your engineering assistants were trained in an engineering school?
   (a) 87 answered the question.
   (b) 59 CHEs said they had 111 EAs who were trained in an engineering school. This is 32.08 percent of the 346 EAs.

2. How many are graduates of an engineering school?
   (a) 85 answered the question.
   (b) 39 CHEs said they had 65 EAs who were graduates of engineering schools. 18.79 percent of the 346 are graduates.

3. Exclusive of those mentioned above:
   (a) How many employees do you have who can set a grade line and figure quantities?
      (1) 94 answered the question.
      (2) 65 counties have 184 EAs who can set grade lines and figure quantities.
   (b) How many employees do you have who can operate an instrument?
      (1) 95 answered the question.
      (2) 73 counties have 219 EAs who can operate an instrument.
   (c) How many rodmen or chainmen have you who are capable of becoming instrumentmen or draftsmen?
      (1) 86 answered the question.
      (2) 61 counties have 120 rodmen who could become draftsmen.

4. Do you prefer for your instrumentmen to be registered engineers or registered surveyors?
   (a) 98 answered the question.
   (b) 62 CHEs prefer that their instrumentmen be engineers; or 63.27 percent.

5. Do you prefer for your draftsmen to be registered engineers?
   (a) 97 answered the question.
   (b) 50 of the CHEs or 51.55 percent prefer that their draftsmen be registered engineers.

6. How many engineering assistants have you had who have:
   (a) Become county highway engineers?
      (1) 85 answered the question.
      (2) 30 CHEs (or 35.29 percent of those answering) have had 68 EAs become CHEs.

(b) Gone into other equally responsible positions?
(1) 56 CHEs (or 65.88 percent of those answering) have had 184 EAs become the equivalent of county highway engineers.

7. The answer to the above questions would have more meaning if the number of years you have served as a county highway engineer were known. That number of years is —
(a) 103 answered the question.
(b) They have served:

1 - 5 years	17
6 - 10 years	25
11 - 15 years	8
16 - 20 years	17
20 or more years	36

Workload

1. Do you need an assistant or deputy engineer?
(a) 73 CHEs out of 108 answering, or 67.59 percent, said they needed an assistant engineer.

2. With your present workload would you employ more engineering assistance:
(a) If you had more money for salaries?
(1) 66 CHEs out of 91 answering, or 72.53 percent, said they would hire more engineering assistance if they had more money. 25 CHEs would not hire more men.
(b) If the assistance were available?
(1) 69 CHEs out of 98 answering, or 70.41 percent, said they would hire more men if the assistance were available. 29 CHEs would not hire more men.

3. If the answer is yes, how many more of each class would you now employ:

Additional Men Needed		Percent Expansion Over Present Staff
Assistant Engineers	83	106.41
Draftsmen	69	80.23
Instrumentmen	50	43.10
Chainmen	55	72.37
Registered Engineers	43	36.13

4. If the money available to your department were to be increased, indicate how it would affect your need for engineering assistance. If the money were to be increased 25 percent, you would need:

Additional Men Needed		Percent Expansion Over Present Staff
Assistant Engineers	80	102.56
Draftsmen	76	88.37
Instrumentmen	61	52.59
Chainmen	75	98.68
Registered Engineers	61	51.26

If the money were to be increased 50 percent, you would need:

Additional Men Needed		Percent Expansion Over Present Staff
Assistant Engineers	119	152.56
Draftsmen	127	147.67
Instrumentmen	100	86.21
Chainmen	121	159.21
Registered Engineers	109	91.60

If the money were to be increased 75 percent, you would need:

Additional Men Needed		Percent Expansion Over Present Staff
Assistant Engineers	155	198.71
Draftsmen	165	191.86

Additional Men Needed		Percent Expansion Over Present Staff
Instrumentmen	135	116.38
Chainmen	170	223.68
Registered Engineers	145	121.85

If the money were to be increased 100 percent, you would need:

Additional Men Needed		Percent Expansion Over Present Staff
Assistant Engineers	184	235.90
Draftsmen	206	239.53
Instrumentmen	161	138.79
Chainmen	194	255.26
Registered Engineers	179	150.42

5. Could you obtain the men needed for handling increased funds?
   (a) 88 answered the question.
   (b) 36 or 40.91 percent think the men are available for expanded programs.

6. Could you train these men?
   (a) 96 CHEs answered the question.
   (b) 71 or 73.96 percent of the CHEs say they could train the men needed.

7. If you cannot train all of them, how many of them could you train?
   (a) 26.04 percent of the CHEs said they could not train all the men needed.
   (b) The percentage needed for 100 percent expansion which could not be trained, however, is very small. The percentages which the CHEs indicated they could train are as follows:

Assistant Engineers	81.27 percent could be trained
Draftsmen	81.45 percent could be trained
Instrumentmen	85.78 percent could be trained
Chainmen	96.39 percent could be trained
Registered Engineers	94.59 percent could be trained.

Minnesota's Organization and Methods Section

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● MINNESOTA has been asked to describe the functioning of its Organization and Methods Section and any success this section may have had in relieving the shortage of engineering talent. In making this request, Earl Campbell of the Highway Research Board indicated that the unit was perhaps somewhat unique among highway departments and would, therefore, require some explanation. We will attempt to describe the unit, its purpose, the policy governing its operation and examples of past accomplishments.

First of all, the unit consists of two young men who are classified as administrative analysts. They are differentiated from "efficiency experts" in that they are primarily involved in analyzing administrative procedures to seek out ways and means of reducing the total workload by eliminating unnecessary steps, streamlining procedures and introducing new machines and equipment. They have not been used to determine how many units of work can be performed by a specific employee on a specific operation or to establish standards of production for a group of employees. We feel this to be the function of the operating supervisor.

The Organization and Methods Section is assigned to the Personnel Division, partly for lack of a better location, but largely to insure that their efforts are directed at reducing the workload where qualified personnel are in short supply. From the home base of the personnel office, they are loaned out to the other division heads to assist them in developing and installing improved administrative systems. The loan feature is extremely important for three major reasons. First, the head of the operating division is responsible for accomplishing the activity delegated to him and is responsible for the procedures used to fulfill that responsibility. The central agency would have to usurp a portion of the division head's responsibility in order to introduce new systems without his approval. Second, if the central agency were to assume responsibility for developing and installing operating systems and procedures it would be held accountable for the success or failure of the project. This is certainly a responsibility of the division head. Finally, if the central agency were to be looked upon as the unit responsible for developing new systems and procedures, the operating employees and supervisors might feel obligated to continue using an outmoded system until instructed to modify it by the administrative analysts. The analysts are available to assist the division head and his designated subordinates, to inform them of new machines that are available, to describe systems used in similar situations elsewhere, and to tailor-make systems to fit individual situations, but the operating divisions must feel free and obligated to continually develop short-cuts in their methods and techniques.

Inasmuch as the division head is always charged with the success or failure of the project, credit for successful projects must be given to him and his staff. If the analysts assume credit for developing and installing a simplified process, the operating employee will expect them to clear up any rough edges and work out minor difficulties. If the process is credited to the operating employees, they will insure that it is given a fair test. The percentage of failures is infinitely small.

These analysts have participated in several projects which have resulted in improved production or service with less personnel and considerably reduced costs. Many of these assignments have been necessary due to the lack of office space and the need to immediately relieve congestion. The main question to be answered in this paper, however, is, "What have they done to relieve the engineering shortage?" The answer is based principally on the theory that engineers should be able to concentrate full time on engineering tasks and non-engineering personnel should perform the remaining tasks.

At the start of the program, the accounting function was decentralized into each of the operating divisions and carried on by both engineers and accountants. In either case, the engineer-division head found it necessary to devote at least a portion of his time to supervising the activity. As a result of an administrative study, both accounting and cost accounting have been centralized in the Finance Division and are subject to the direction of a chief accountant. Hundreds of hours of engineering time that were expended monthly on personal service payrolls, materials and supplies payrolls and cost accounting can now be devoted to engineering tasks. Field reports, which had been held up while the project parties distributed costs and prepared detailed cost distribution sheets, can now be processed much more quickly.

A much less extensive program involved installing dictating machines to relieve the stenographer shortage. When stenographers are in short supply, the engineers find it necessary to write a considerable portion of their work in long hand and turn it over to typists for copying. By using dictation equipment in situations where the engineer must interrupt his dictation frequently to answer the telephone, look up land descriptions, titles, etc., the stenographer can be engaged in taking correspondence and memoranda from other engineers. This led us into another project the success of which is very questionable. We installed dictating equipment in the automobiles of some of the district engineers in order that they might dictate their memoranda in the field rather than kill time waiting for someone, or making lengthy long hand notes from which memoranda were to be dictated in the office. It worked very well at the outset, but the machines are not of sufficiently strong construction to withstand the constant jarring they take in the automobile. When the machines breakdown too often, they are not worth the trouble to keep them in operation.

A project that has been delayed for several months but is scheduled to start within a few weeks involves listing and analyzing individual tasks performed by each engineer from the chief engineer down to the first line supervisors. We expect to find some duplication of effort, some steps that can be eliminated altogether and a number of tasks that can be performed acceptably well by non-engineers. Insofar as we can, we will assign good executive assistants to the divisions to supervise the office management functions such as typing, filing, timekeeping, preparation of non-technical correspondence, management and assignment of office machines and equipment, and so on. Once the non-engineer office manager is in place, the engineers can delegate to him any task that does not require engineering training for its performance. Insofar as we can relieve the engineers of this type of work, we can expect them to devote their talents to the more technical phases of the total program.

The business machine companies are currently attempting to mechanize the computing functions in the road design divisions of a couple of states. Our technicians are responsible for keeping posted on the progress of these experiments in order that we may avail ourselves of the equipment when it is ready. We have already purchased a typewriter so constructed that it can be used to type all the lettering on the plan sheets and thereby relieve the draftsmen of the need to spend valuable time free-hand lettering. If computing can also be performed by high speed computing machines, we can all obtain some relief in our design rooms.

A more subtle methods technique of relieving the engineering shortage can be found in revamping our system of clearing decisions with higher authorities. The required brevity of this paper does not permit lengthy discussion of any one portion nor the use of a variety of examples, but I cannot resist inserting one more item. The offices of the top level engineering personnel tend to become congested with detail for several reasons. Sometimes the organization itself does not provide a logical system for delegating responsibility or the type of personnel to whom such assignments can be made. More often the subordinates are permitted to pass difficult problems up the line of command for solution. In some cases, this is quite proper. In many instances the channel is used to avoid gathering all the facts, making an analysis and coming to a conclusion. It is much easier to pass the problem on to the next higher authority and let him worry about it.

Another systematic method for wasting valuable engineering time consists of encouraging members of the public who are interested in the development of a particular construction project to go in and see the commissioner, the chief engineer or the plans and surveys engineer. Similarly, subordinates can increase the congestion by forwarding simple supervisory, disciplinary and grievance problems, relatively minor procedures questions and minor technical questions on to higher authority for solution. Problems that can be handled by the first line supervisor himself should be handled by him without involving the time and energy of one or more higher level officials. This, too, is an organization and methods problem.

In summary, our Organization and Methods Section is small but very productive. The two analysts spend their full time in developing ideas of operating employees for reducing the workload. They keep their eye on industry, other governmental units, and the various divisions and sections of our own department in order to keep posted on new developments that can be used to advantage in simplifying particular operations. They concentrate on grinding out small changes as well as extensive modifications. Finally, they follow a simple set of rules:

1. If the current system has existed for more than five years, it needs to be studied.
2. The employees using the system may have good ideas for modifying it, but little time to develop their ideas.
3. To insure success of a new idea, let it come from the employee responsible for the function involved.
4. When you see a good system, leave it alone.

Time-Saving Ideas in Highway Engineering

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It became apparent in 1954 that a likely expansion in the nation-wide highway improvement program would require utilization of every adaptable time-saving technique in order to extend to its optimum the specialized production of the highway engineers. In view of this emerging need the Highway Research Board's Committee on Highway Organization and Administration conducted a canvass of the highway departments of the 48 states, the District of Columbia, Hawaii, and Puerto Rico to learn what time- and labor-saving methods, procedures, and devices they had developed or adapted to use. Nearly 300 highway engineers responded, contributing over 1,500 statements on the subject.

The contributions are now being summarized for publication. Every area of possibility seemingly has been discussed in the responses. It is clearly evident that no single course of action will afford a solution to the complex set of problems in highway engineering manpower, and the memoranda submitted show that the several highway departments are seriously engaged in resolving the problems through combined advance on all fronts.

● WHEN President Eisenhower in July 1954 challenged the governors to evolve "a grand plan for an articulated highway system," he threw out a challenge not only to those who must find a way to finance the improvements but also to every agency and to every individual who must find ways to administer and execute that grand plan. The boldness of that plan and the daring required to initiate it and execute it fascinates and fires the imagination of the least poetic — the potential of that plan for the common good inspires the most prosaic to exclaim: "I want to have a part in that!"

Quick to recognize that the execution of the plan would demand additional professional highway engineers and also require the best use of available talent, the Highway Research Board's Committee on Highway Organization and Administration accepted the unmistakable challenge and began its attack on the manpower problem.

The committee found, first, that the proposed program would require at least 11,000 more highway engineers, possible 25,000 if present engineering productivity is not greatly increased (1). The next move was directed toward finding ways to obtain the most favorable utilization of available talent or, more specifically, toward finding ways to husband the time and energy of the highway engineer.

The committee recognized that no single course of action would solve the total manpower problem of the highway departments. Laws, policies, management, housing, and equipment would affect the problem. The rate of development of additional highway engineers through education and training would also have its effect. Notwithstanding, the committee was confident that, if time-saving methods were fully exploited, much would be done towards reducing the requirements for professional engineers from a maximum of 25,000 to a minimum of 11,000. The 11,000, plus replacements, must be trained and recruited.

On this premise the committee said: "Let's ask the highway engineers to pool their experiences in time-saving methods." This was done by a canvass made in April 1955. The canvass extended to highway departments of the 48 states, the District of Columbia, Hawaii, and Puerto Rico. Each of these highway departments made a contribution. Without doubt the challenge of the grand plan had captured men's minds, for more than 300 highway administrators, professional highway engineers, and supporting technologists contributed to the pool of 1,500 ideas in one of the finest of cooperative efforts.

This report will not attempt to recapitulate the ideas acquired in that vast pool, for they are being summarized and published by functional category (2). Rather, this report will attempt to interpret and to sketch in broad strokes the motif and meaning of these 1,500 ideas.

First of all, one is greatly impressed with the extent of interest manifested in the problem of best utilization of highway engineering talents, and by the great range in methods of attacking the problem. It is evident from the suggestions received that there is a great variety of problems to be solved in the matter of saving time. It is also evident that the highway departments are alerted and are at work developing and adapting experiential methods. The response showed quite clearly that a good beginning has been made (3).

Second, the content of the ideas points out decisively the complementary character of administrative processes and special time-saving techniques. Administration deals with policy making, planning, and management, and as such vitally affects the potential of engineering production. The execution of the improvement program is essentially an engineering function, and technological advances can be effective in increasing production.

With this observation, the content of these 1,500 ideas can be examined to see where present administrative and technological developments are leading.

ADMINISTRATIVE RESEARCH

An idea must be put to work if it is to be effective. It is not self-executing or efficacious of itself: 1,500 dormant ideas are as useless as one. Without administrative guidance, invaluable ideas, born within the department or available from other agencies, may lie dormant while prodigal use of engineering talent continues unabated. Perception of this truth has led to salutary administrative action in several highway departments and bureaus.

Illustrative of this action was the creation of a unit of administrative research in the Minnesota State Highway Department, denoted as a "Section on Organization and Methods." (Activities of this section have been reported elsewhere in this symposium.) The purpose of the section is to make a continuing study of the department's organizational structure, functions, staffing, management, and housekeeping procedures, so that functions can be suitably related structurally and fitted to objectives, and so that business procedures can be kept simple and integrated to the whole system and adapted to machines where practical.

With similar objectives, the Wisconsin Highway Department began a reorganization of its structure about two years ago. A Division of Administration inaugurated at that time, working with the commissioners, has effected a complete reorganization of the structural, functional, and managerial aspects of the department, a reorganization and renewal that has permitted the accomplishment of twice as much highway construction without appreciable increase in the number of professional engineers. A monograph (4) of the Wisconsin experience recites a host of particulars, including greater delegation of responsibility and increased emoluments, better housing and equipment, instigation of training programs for engineers and technicians, better coordination of work flow, and use of special time-saving techniques.

The New Jersey State Highway Department also has included an office for research into administrative procedures. And the Civil Service Commission of New Jersey has given many substantial cash awards for practicable ideas.

Another example worthy of mention is the unit in the Highway Department of the District of Columbia that has been doing administrative research and has been helpful in the reorganization of the District Highway Department.

These illustrative examples, plus many others received, suggest the complementing value of administration, and the value of operations research to efficiency and economy in administration and engineering (5). Apart from the suggestions received during the canvass, interest in the potentials of better organization and administration is evidenced in the many requests for the Committee on Highway Organization and Administration to prepare a guide on the subject.

TRAINING AND RESEARCH

Some of the most rewarding efforts have been made in the training and research programs. Cooperative education is now conducted in 16 states and in-service training programs are being conducted in 12 state highway departments. Eight states have programs designed to prepare the high school graduate as a supporting technician (6).

It has been noted that at least 11,000 additional engineers must be trained and recruited to execute the contemplated program. When it is discovered that replacements of losses amount to more than 400 engineers per year, and then it is found that but 1,000 graduate civil engineers can be obtained annually, one comes to the inescapable conclusion that all of the engineers required cannot be obtained in the desired time period from engineering colleges (7). Upgrading of sub-professional personnel through in-service training should prove a fruitful source of supply of engineering and supporting disciplines.

Continuing inquiries and suggestions relating to form of research organization and scope of program give promise that research will become an important factor in an expanded highway improvement program. Socio-economic problems related to transportation, including system size, tax equity, traffic safety, highway law and administration, transportation economics, and economy of pavement structure, are just a few of the vital areas of research. Answers to these questions would affect the manner of improvement and provide a sound basis for taxing and apportioning funds. Research costs money, but the highway program costs more without it. Training and research will secure enormous savings in the expenditure of the $100,000,000,000 involved in the contemplated program.

LIAISON AND COMMUNICATION

Next is another aspect of administration, that of providing proper mechanism for coordination of operations. A great many ideas have evolved and have been put to practical use to provide linkage of the extensive and decentralized offices of the highway department. In order to expedite work orders, work flow, and to speed the exchange of information and ideas, new channels of communication and new formats are evolving for their transmission. To contain the transmitted information itself, new devices for recording, transcribing, reproducing, and storing have been developed.

To illustrate: 35 states are using two-way radios in the management function to save time of department personnel and the travelling public, and to save equipment mileage. Quite often linkage is provided with other governmental agencies, such as the Weather Bureau and Office of Civil Defense.

Other types of communication include teletype, television, direct telephone lines, aeroplane, inter-office communication systems, and loud-speakers. Studies have been made of routings of communications and work-flow to provide direct channels between sender and recipient. Forms and reports have been scrutinized to see that they are clear and can be integrated into the machine and manual procedures.

In the field of communication there is an increasing use of voice recorders, not only for dictating purposes but also for use in recording notes and ideas in the field. Sense-marking of punch cards eliminates manual punching. And for storage purposes punched cards, magnetic tapes and drums, micro-film, and 105-mm. film are finding increasing use.

Coordination offers many problems in a growing and decentralized organization. An expanded highway program will undoubtedly precipitate many problems in liaison and communication.

With this brief review of the administrative aspects, a look at the technical aspects and some of the special techniques is called for.

HIGH-SPEED COMPUTING

Among the highly reiterated suggestions was that of adapting highway engineering computations and statistical records to high-speed computers. The term "high-speed" has various connotations as used by the respondents, and with justification. It is still a relative term, as the truly "high-speed"—the "lightning-speed"—era has just been ushered in. In the recently developed electronic date-processing machines, actions are measured in terms of micro-seconds (millionths of a second). Notwithstanding, both the electric (mechanical) and the electronic computers are quite generally called high-speed machines. Perhaps the most noteworthy point is that there is now such a variety of calculators available that one can find the kind of machine best adapted to his specific job, from the desk type to the "giant brain," and can procure the services of both the digital and analog types.

One of the significant developments among the highway departments is the exploration now underway to determine what highway engineering computations can be performed on the electronic-type computers. In this symposium a report is given on the progress made by the California Division of Highways in utilizing business machines in traverse and earthwork computations.

Another significant development was found in New York State, where the Bureau of the Budget has set up a section to explore the possible adaptation of computations to machines. The Bureau has already completed preliminary conferences with the staff of the Department of Public Works to determine what procedures can be mechanized.

The Oregon State Highway Department has mechanized earthwork computations by translating field cross-section notes into code for punch cards. The Bureau of Public Roads has assigned engineers to study the application of high-speed electronic computers to highway engineering operations and to consult with industries as to the use that has been made of these machines (8).

The Bureau of Standards likewise is studying the possibilities of adapting various procedures to electronic computers and other devices.

Additional work on adapting engineering computations to machines is covered in several significant papers presented at other sessions, sponsored by the Traffic and Operations Department, at the 35th Annual Meeting of the Highway Research Board (10).

Indeed, it would seem that any mathematical procedure that is frequently repeated and can be programmed as a series of sequential steps should be considered for mechanization.

STATISTICAL CONTROL AND INTERPRETATION

In materials testing, in physical research, and in statistical and administrative studies, the selection of the sample and determination of its probable degree of error are readily accomplished by the statistical control technique. This technique allows the highway engineer to process a minimum of statistical data, or conduct a minimum of tests to obtain an answer of required and predetermined accuracy.

Routine use of statistical control techniques was reported by 23 planning, 16 traffic, and 8 materials and tests bureaus.

Statistical techniques used to control and interpret research constitute a powerful tool and are gaining favor among engineers who have formerly looked askance at the utility of the probability theory in engineering procedures.

OTHER SPECIAL TECHNIQUES

Among the fast developing techniques are aerial photography, map-making, and reproduction processes. Aerial photography is used by 47 planning bureaus, 46 locating bureaus, 29 design bureaus, 21 materials and tests bureaus, 18 soils bureaus, and a substantial number of right-of-way bureaus. Aerial photography is used for measurements (photogrammetry), for identification of soils, structures, etc., and simply as photographs for many purposes.

Map-making has borrowed from the commercial graphic arts. Innovations include "stick-up" letters and symbols, negative scribing, and, of course, aerial mosaics. The Vari-Typer machine has been used with remarkable success to type notes and tabular data on road plans. Prints received from South Dakota which were prepared by Vari-Typer on tracing cloth are exceptionally neat and legible.

There have been so many developments in reproduction equipment and media that no attempt will be made to discuss them in this paper.

RESPONSE RELATED TO READINESS

In conclusion, it should be noted that the following questions have been asked: "What do the responses show? Have the highway departments fully exploited time-saving methods? Are they ready for the grand plan?"

A check of the responses discloses that there were five negative answers to every three affirmative answers to questions asking if certain developments have been used. In other words, in more than 60 percent of the cases the respondent had not developed or tried the particular new method. Again, review of the 87 questions used in the canvass indicates that they do not nearly exhaust the possibilities in an inquiry into time-savings.

Hence, it would appear from a cursory appraisal that there is some basis for the recent statement that the survey "discloses that there is no concerted effort on a broad enough scale for a full 'package' modernization of highway engineering practices" (8). On the other hand it should be noted that it was not expected that all of the necessary forces would be or needed to be marshaled at the time of the canvass. The canvass was not intended to ascertain the degree of preparedness, but rather to obtain and make available time-saving techniques to those states which had not yet tried them. Therefore, it appears that the report will serve with optimum usefulness. The very fact that so many departments have not fully exploited all of the time-saving ideas gives promise that much can be done to prepare for the new program levels. Enough bureaus have pioneered in time-saving methods to prove them, yet a larger number of bureaus remain to profit from these pioneer endeavors.

There are, therefore, assurances that the technological advances already made are but the first fruits of the harvest.

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Increasing Productivity in Engineering

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In planning for a further acceleration in highway construction it is evident that it will not be possible to provide the additional engineering capacity required simply by employing more engineers. Even with more intensive recruitment, it appears unlikely that additional engineers can be brought into the highway field from the colleges and from other segments of civil engineering in numbers much larger than those required to offset losses.

Consequently, the larger capacity needed will have to be provided by increasing the productivity of the engineering force available, both engineers and supporting personnel, to the extent necessary to bring production into balance with program needs. Furthermore, this will have to be done without any significant impairment of the quality of engineering performance.

There are a number of ways in which engineering productivity might be increased, all of which appear to offer promise. However, the discussion in this paper is limited specifically to ways and means of increasing productivity through improved engineering operations, particularly in location, road design, bridge design, and the preparation of plans and estimates. It is this series of processes which frequently controls the speed with which programmed projects can be placed under contract.

●IN 1955, the Highway Research Board conducted a survey to determine the progress made by the state and territorial highway departments in improving their operations and in adapting to their needs the time-and labor-saving methods, procedures, and devices made available by recent technological developments. A progress report was issued in July 1955 (1) and the complete findings are now being published.

This survey, together with information from other sources, reveals that considerable progress has already been made in one highway department or another in increasing engineering productivity through the adoption of improvements in engineering operations. The progress has been spotty however, and the procedures, methods, and devices used in much of our highway engineering work are essentially the same today as they were years ago.

The reductions in time and manpower requirements achieved in the individual highway departments which have developed improved practices indicate that a very substantial increase in over-all productivity can be attained simply through the general adoption of such practices. They also indicate the further advantage to be gained through continued investigation and development.

NEW DEVELOPMENTS AND FURTHER POSSIBILITIES

Some of the improvements in engineering operations in the highway departments are the result of a more advantageous utilization of procedures, methods, and devices which have been used to a lesser extent for a number of years. Others consist of entirely new methods which have been developed within the highway agencies. Still others are devices or adaptations of methods which originated outside the highway field. In some cases, further possibilities, not yet fully explored, are indicated.

Use of Aerial Surveys and Photogrammetry

Most of the highway departments use aerial photographs in preliminary location studies and to some extent in final location. A lesser number use topographic maps prepared by photogrammetric methods in lieu of ground surveys and maps prepared manually. Photogrammetry has developed rapidly in the last few years and the highway departments which use it report savings in time up to about 75 percent of the time required by ground methods. The saving in manpower is even greater. Where the work is done by contract, aerial photographs and preliminary location topographic maps are obtained without using any highway department personnel. A very considerable added advantage of the aerial survey method is the wider coverage and the complete information provided which tend to permit better engineering analysis and a more economic location.

In many cases, by using aerial photographs and maps made from them, the necessary reconnaissance studies can be completed, the final line and grade established, the construction plans and specifications completed, the engineer's estimate made, and right-of-way negotiations either completed or at least begun without placing a survey party in the field except for checks on unusual conditions.

Further increases in productivity are available through the use of aerial photographs in the determination of drainage areas, drainage conditions, structure requirements, and property damage; in access studies for limited access facilities; in the identification of soil types along the route including areas where rock or unstable material occurs and of possible sources of aggregate; and for detailed layouts of interchanges, grade-separations, and bridges.

Used to maximum advantage, aerial surveys and photogrammetry offer a means of very substantially increasing productivity not only through manpower savings but also through reductions in over-all time requirements for advancing projects to the construction stage.

Mechanization of Survey Computations

Survey computations for location traverses and property boundaries are tedious and time-consuming. In recent months, the California Division of Highways (2) in collaboration with the International Business Machines Corporation, and independently, the Corps of Engineers' Research and Development Laboratories (3) in collaboration with the Monroe Calculating Machine Company, have both developed methods for computing coordinates, error of closure, and area on electronic computers. Attention is now being directed to the solution of other surveying and engineering problems on the computers. The Corps of Engineers has under contract the development of an electronic computer housed in a van-type vehicle which is to be used for all types of survey computations in the field.

New Surveying Instruments

Surveying instruments of improved design have been developed which make possible substantial savings in time with equal or better precision than the usual instruments. For traverse work, compact, lightweight transits with optical plummets, direct micrometer reading of circles, and other time-saving features are available. For leveling, a new self-leveling level is reported to reduce by 50 percent the time required to run levels. At the same time it produces results of first order accuracy. It is a small, ruggedly constructed instrument with a circular plate level which is centered approximately in setting up the instrument. A pendulum and prism device inside the telescope then levels the line of sight automatically and keeps it level no matter which way the telescope is pointed. California and Virginia are using this level and both report good results.

For distance measurement, an electronic instrument called a "geodimeter" has been developed in Sweden. This instrument is easily portable and operates by projecting an almost invisible red light beam which is reflected from a plane mirror target. For distances up to 10 miles, an accuracy of 1 in 300,000 is obtainable. The time required to set up the equipment and take the observations is about 2 hours with an additional hour or two required for computation. While this device is not appropriate for ordinary highway work, it is interesting as an example of the progress being made in this area and as a possible forerunner of electronic distance measuring instruments suitable for highway and property surveys.

Use of State Plane Coordinate Systems

In the past, much wasted effort has resulted from failure to "tie in" traverse points and property corners to state plane coordinate systems. The immediate advantage in using the coordinate system lies in the elimination of the return traverse for closure, but of much more importance is the elimination of the need for complete new surveys when change or reconstruction becomes necessary. In a number of highway departments, it is now standard practice to reference surveys to the state system of plane coordinates and to monument traverses and property boundaries. In these states an increasingly dense network of monumented control points is being developed through this practice. In addition to preserving the survey, the monumented points provide a convenient means of closure for other surveys and can be used for ground control in aerial mapping projects.

Aids in Soil Surveys

The use of aerial photographs in identifying soil types has been mentioned previously. In combination with agricultural soil maps, geological maps, and where appropriate the refraction-seismic or earth-resistivity methods of subsurface exploration, their use permits obtaining desired information with a minimum of sampling and testing. The use of engineering soil maps where available is particularly helpful not only in soil surveys but also in tending to improve the utilization of local materials in road construction.

Road Design Standards and Standard Designs

In road design, standards for various elements of geometric design have been developed by a number of highway departments. Others rely on the design values and details recommended by the American Association of State Highway Officials in "A Policy on Geometric Design of Rural Highways" published in 1954. A companion treatise, "A Policy on Arterial Highways in Urban Areas" is in preparation. Design methods and standards for the structural design of the roadway have also been developed in a number of highway departments.

While these data are intended to serve as guides and criteria in assuring adequate design, they incidentally contribute to improved productivity.

Standard designs for culverts, endwalls, underdrains, inlets, catch basins, manholes, slope protection, cribbing, retaining walls, and other appurtenances are used in varying degrees by many of the highway departments. Charts and nomographs for rainfall intensities, runoff for small drainage areas, and culvert size determinations are used to some extent.

A few of the highway departments include all design material of this kind in a manual together with other data in tabular and chart form needed for day-to-day reference. This is not only effective in saving time for the experienced designer but it is invaluable for the young engineer newly assigned to design.

Bridge Design Aids and Standard Designs

In bridge design, many aids are available and are used in varying degrees in a number of highway departments to increase the designer's productivity. These include influence lines for reactions, shears and moments, tables and charts for reinforced concrete factors, slab thickness and reinforcement, fixed-end moments, carryover and stiffness coefficients, deflections, direct stress and bending, retaining wall design, pile footings, rainfall intensities, runoff, open channel flow, and other similar data.

In addition, a number of highway departments use standard designs for bridge superstructures. In two or three states standard designs are used for simply supported spans up to about 60 feet and for continuous spans up to about 250 feet, for various roadway widths and skews. In California, standard plans have been developed for multiple span, longitudinally reinforced, concrete slab superstructures which are complete to such an extent that a detailer can produce a complete set of finished plans even though he is not familiar with structural analysis and design procedures. In Georgia and New Mexico, standard designs using precast deck units have been developed.

Standard substructure designs including various types of bents, piers, and abutments are also used but to a lesser extent.

The potential increase in engineering productivity through maximum utilization of design aids and standard designs appears to be quite large and to warrant further development. A common objection to the use of standard bridge designs has been that the skew is different in practically every crossing. In this connection, is it necessary to use skews measured to the nearest minute of angle or even to the nearest degree? Would it not be possible to use skews to the nearest five degrees particularly for stream crossings where the banks are not normally aligned precisely. If so, it might be practicable to use standard supersturcture designs for many of the bridges to be constructed in the expanded programs.

Standard designs are obviously not practicable for the larger, more complex structures, but even there some advantage may be gained by the greater use of standard details.

Another device of value in increasing productivity is used in Nebraska and possibly in other states. As many design procedures as possible are outlined and detailed by steps to minimize errors and to permit designers with limited experience to make adequate designs expeditiously. Procedures of this kind would appear to be effective in adapting standard designs to individual situations as well as in original design.

While high-speed electronic computers have been used only to a very slight extent in bridge design up to now, their potential value in design computation, particularly for indeterminate structures, appears to be quite considerable and to warrant further investigation. Very substantial increases in productivity may be possible.

Preparation of Plans

There is considerable variation among the highway departments in the amount of detail shown on construction plans and in their format. Modifications have been made in a number of states to eliminate duplication and unnecessary detail. The principal developments include the placing of information relative to drainage structures, guardrail, fencing, and other miscellaneous items in consolidated lists or schedules instead of on the individual plan sheets; the elimination of notes that are covered in the specifications; the inclusion in the general notes of many of the notes previously shown on plan-profile sheets; and the increased use of standard sheets covering typical sections, incidental construction, general notes and tables, quantity tabulations, small bridges, and culverts and other drainage structures and facilities.

A number of highway departments have substituted typing for hand lettering for the index of sheets, the tabulation of quantities, various schedules and tables, and the general notes. One or two departments use printed adhesive acetate sheets which are affixed to the tracings in place of hand lettering.

In a few highway departments, tracing has been almost entirely eliminated. Plans are prepared in pencil only and cloth reproductions equivalent to ink tracings are made by photographic reproduction processes.

Michigan and also Kansas are investigating the possibility of making plan and profile sheets by photogrammetric methods direct from aerial photographs. It is estimated that this process, if proven practicable, will reduce the cost of preparing plan and profile sheets by about 60 percent. At the same time, it would make possible very considerable reductions in time and manpower requirements.

In developing construction plans for bridges, the photographic reproduction method of producing "tracings" is also used to good advantage in few of the highway departments. By this method a tracing is produced in a matter of minutes where several days might be required in the ordinary manual method. In addition, this method provides considerable flexibility in the development of new plans from parts of plans for previously designed structures and from standard details. In this connection, it is interesting to note that the General Electric Company, by the use of a similar process recently adopted, is reported to have reduced the time required for producing engineering drawings by 95 percent. The engineer prepares a coded order to the reproduction department where a composite film transparency comprising reusable positive film overlays is used to print a translucent positive photo-mechanically which then becomes the original "tracing."

In addition to saving the designer's time, eliminating tracing and reducing over-all time requirements, this process eliminates errors which are bound to occur in manual copying and tracing.

Mechanization of Earthwork Computation

In computing earthwork quantities by the traditional method, weeks and even months are spent in plotting, checking, inking, templating, and planimetering cross sections. One highway department, in preparing work schedules, allows an average of 17 engineering aid man-days per mile for this work including the computation of volumes. While this may be a liberal allowance, it will serve for comparison. Oregon has developed and is using a method (4) in which earthwork quantities are computed on IBM business machines at an average rate of one mile in 7 hours without plotting cross sections at all.

In an entirely independent study, the Bureau of Public Roads, in collaboration with the International Business Machines Corporation, and also with the Bendix Aviation Company, has developed a method for computing earthwork quantities on high-speed electronic computers at the rate of about 3 hours per mile also without plotting cross sections. Where the cross sections are taken by ground methods, the rod readings and offsets as shown in the field notes are fed into the computer together with design data and the answer is delivered in cubic yards of cut and fill for each station length or partial station length and also cumulatively to any desired point or for the entire project. Where the cross section data are taken from aerial photographs or topographic maps made from them, elevations and offsets are fed into the computer instead of rod readings and offsets, otherwise the process is the same.

California has also been working on this problem and has very recently developed a solution for use with an IBM computer.

Elimination of Field Cross Sectioning

Where aerial photographs or topographic maps made from them are available at appropriate scales, adequate cross section data can be obtained from them thus eliminating the need for field cross sectioning. Considering that complete cross sections normally are taken at least twice on each project and in many cases, three times, the productivity increase available from the elimination of field cross sectioning is appreciable. Comparisons which have been made show that earthwork quantities obtained by using cross-section data taken from aerial photographs or maps agree within 3 to 5 percent with quantities obtained by using cross-section data taken by ground methods. There is, of course, no reason to assume that either method is more accurate than the other.

Two or three highway departments recently have used this new method for computing final pay quantities as well as quantities for bidding purposes. In order to obtain specific comparisons of the two methods and also to explore more fully the advantage of using electronic computation in combination with photogrammetric methods in highway location the Bureau of Public Roads is planning time, cost, manpower, and quality studies on selected forest road projects in the west. The studies will also include comparisons with the method being investigated by California which it calls the "contour-grading" plan (5). In this method, volumes are obtained by multiplying areas lying in horizontal planes by vertical distances in contrast to the conventional method of multiplying areas lying in vertical planes by horizontal distances. The areas enclosed by the original and final contours at each contour level are planimetered, averaged, and multiplied by the contour interval. This method has served well in other fields of civil engineering and California is exploring its suitability for highway work.

Where grading is light, it is often feasible to make payment for grading on a mileage basis thus eliminating earthwork computations for roadway excavation entirely. In some states excavation for pipe culverts and other drainage facilities is not paid for separately, but is included in the payment for construction of the facility. A detailed study of bid items may reveal other cases in which computation can be eliminated by using a mileage or lump sum basis, or by covering incidental work in the basic item.

Centralization of Estimating and Pricing

In some states, there is an estimating and pricing section in the design department which is responsible for analyzing bids, maintaining current price data for all parts of the state, and preparing and pricing estimates. All work of this kind is centered in the section thus tending to develop a high degree of efficiency.

Increasing Length of Projects Let to Contract

Increasing the length of projects let to contract eliminates repetition and duplication all along the line and thus contributes substantially to increased productivity. The advantage carries over into construction where better utilization of field personnel is made possible. This has been done in a number of highway departments with good results.

CONCLUSIONS

In conclusion it appears from this discussion that if each highway department were to adopt the improvements developed in each of the other highway departments and if, in addition, they were to use aerial surveys and photogrammetry, photographic reproduction processes, electronic computers, standard designs, and other time-saving methods and devices to maximum advantage, much of the increased productivity needed to meet new program demands might very well be attained by these means alone and in a relatively short time.

If this were done, field surveys would be considerably reduced, manual plotting of topography and cross sections would be practically eliminated, survey and earthwork computations as well as other lengthy computations would be done by electronic computers manned by trained operators, structural design and drafting for drainage structures and other appurtenances would be limited to unusual situations, bridge design would be limited largely to complex structures and the adaptation of standard designs to special conditions, detailing and drafting would be reduced considerably, and tracing would be eliminated entirely.

Corresponding adjustments in organizational and operational arrangements based on an optimum combination of machines, operators, clerks, technicians, engineering aids, and engineers would produce still further gains in productivity. Routine operations could be performed by trained machine operators and engineering clerks supervised by technicians skilled in photogrammetric methods, electronic computer programming and operation, photographic reporduction processes, estimating and pricing, and other specializations. The supervising technician positions could well be career service positions carrying considerable responsibility with attractive salaries. Under these conditions, it should be possible to recruit and hold individuals of high competence capable of sustained production with a minimum of direction.

The engineers would thus be relieved of time-consuming routine tasks and direct supervision of production leaving them free for analysis, evaluation, design, and development in a truly professional way.

These accomplishments and potentialities demonstrate the value of the kind of investigation and development which has led to the improved procedures, methods, and devices cited, not only in improving engineering productivity, but also in lowering costs and in reducing the time required to advance projects to the construction stage. They emphasize the importance of continuing and extending such investigation and development, at an accelerated rate and on a coordinated basis if possible, to achieve still further increases in engineering productivity and still further reductions in lead time and cost.

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Utilizing Business Machines in Traverse and Earthwork Computations

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As an aid in overcoming the critical shortage of engineering manpower, the California Division of Highways has investigated and instituted procedures for calculation of traverse and earthwork data by means of punched card equipment already available in the California Highway Planning Survey tabulating section.

This paper outlines the general procedure used by the engineer in preparing the basic information for computation of traverse and earthwork data.

Samples show, on a standardized computation sheet, the required method of recording the fourteen different problem types currently being processed. The results are listed mechanically on a standardized traverse form.

Eleven samples for earthwork computations are also included, five of which show the acceptable methods of recording the terrain notes, and three the methods of recording the roadbed notes. Also shown are a method of recording data from contour-grading plans, a method of recording additions to the computed quantities for use in compiling data for the mass diagram, and a sample of a suggested form for transmitting the data to the tabulating section.

Included is a sample of the tabulated results of earthwork computations which is returned to the engineer. This tabulation lists the volume of excavation and embankment between each cross section and gives totals for each station. The data furnished will also enable the engineer to prepare a mass diagram.

This paper also outlines some of the changes in procedure necessary on the part of the engineer to make fullest use of this computing service.

While the whole procedure calls for a somewhat different approach to the problem on the part of the engineer, we have found that the savings in both time and money have made this service well worth the effort.

● THE California Division of Highways has been investigating means of reducing the elapsed time and engineering man hours necessary to produce the engineering plans for its expanded highway construction program. The Division has particularly been concerned with the time consumed in computing traverses, plotting and planimetering cross sections, and calculating earthwork quantities. The time required to make and check the traverse computations and to calculate the earthwork quantities manually has been a considerable drain on skilled engineering manpower and has also been a significant portion of the cost of preparing the plans.

For the past 19 years the Division of Highways has utilized conventional tabulating equipment for the solution of many problems. These machines have been employed in the analysis of origin and destination surveys including the assignment of trips to proposed facilities, of construction and maintenance costs, traffic accident reports, personnel statistics, road life studies, road inventories, status of highways, and for many other tasks.

Aware of the rapid development and extended use of electronic computers and automatic calculating processes in scientific, industrial, and business fields, the Division has been seeking methods to short-cut the expensive drudgery of manual calculations.

In January 1955, the writers were assigned the task of finding which, if any, calculations made by engineers in the eleven district offices of the Division of Highways could be adapted to machine computation. There is little doubt that complete automation would be possible for many problems on the complex and expensive electronic computing machines now available. The immediate target, however, was an approach to automation through the use of equipment already available in the tabulating section of the California Highway Planning Survey.

F. M. Reynolds of the California Highway Planning Survey and J. C. Young, Design Engineer, impressed upon the writers that the reason for the investigation was the ultimate release of engineering personnel, now performing the computations, for engineering functions. Comparative costs were to be considered but were not necessarily to control.

In the California Division of Highways, all phases of the preparation of plans except bridge design are the responsibility of the various district offices, and therefore almost all engineering computations are made in these district offices.

Upon investigation it was decided that the greatest immediate over-all benefit would be the application of the equipment to traverse computations such as are involved in location surveys, intersection design, and right-of-way engineering.

The key to the problem of traverse computation was found in a procedure for obtaining the sine and cosine of a bearing accurately to seven decimal places.

As the planning and procedure writing progressed, a traverse computation service was made available on a trial basis to selected units. By July 1955 eight types of traverse problems were considered adequately tested and all districts were informed of the required procedures and the service made available for their use. By November 1, the following fourteen problem types were in use:

1. Traverse computation where all sides and bearings are known. This may be used for original computations in coordinating a traverse or as a check of original computations.

2. Traverse computations where the lengths of two sides are unknown.

3. Traverse computation where the length of one side and the bearing of another side are unknown.

4. The problem described as Type 1 where, in addition, the area within the closed traverse is desired.

5. The problem described as Type 2 where, in addition, the area within the closed traverse is desired.

6. Traverse computation where the length of one side and the bearing of that same side are unknown.

7. The problem described as Type 3 where, in addition, the area within the closed traverse is desired.

8. The problem described as Type 6 where, in addition, the area within the closed traverse is desired.

9. Traverse computation where the bearings of two sides are unknown and the area within the closed traverse is desired.

0. Traverse computation where the bearings of two sides are unknown.

C. Traverse adjustment by compass rule.

D. Traverse adjustment by compass rule where, in addition, the area within the closed traverse is desired.

T. Traverse adjustment by transit rule.

U. Traverse adjustment by transit rule where, in addition, the area within the closed traverse is desired.

Appendix A contains the instructions to the engineer on how to submit the above problem types for machine calculation. It also shows samples of properly submitted traverses and their tabulated results.

To make use of this service, the engineer in the district office, when confronted with a traverse such as the typical example shown in Figure 1, fills out a portion of a traverse sheet with the necessary data, as shown in Figure 2. However, instead of making the usual routine computations, he goes on to more productive work. These traverse sheets are gathered up and mailed into Headquarters daily; air mail is used where it will materially shorten the time in transit.

When the traverse sheets reach the tabulating section the data are first punched on cards, one course to a card. The cards are verified by a second punching operation and are then ready for the calculator.

The bearings are reduced to radians, the sine and cosine computed by the truncated formulas:

$$\text{Sine } x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \ldots + \frac{x^{13}}{13!}$$

$$\text{Cosine } x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \ldots - \frac{x^{14}}{14!}$$

and the results punched on the cards in one pass of the cards through the calculator.

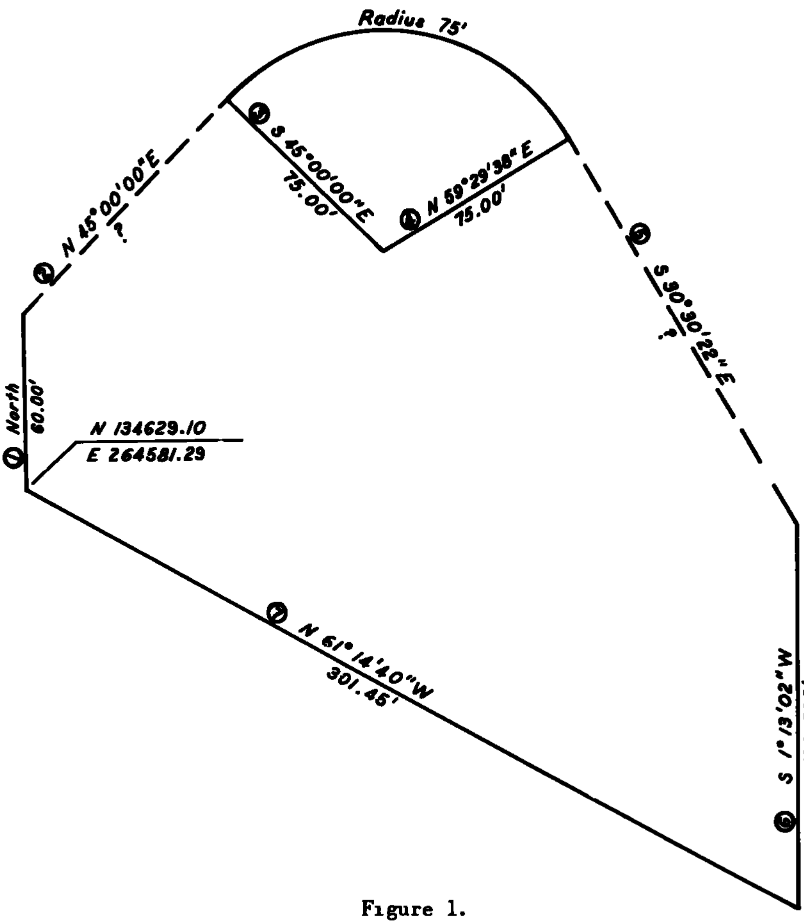

Figure 1.

The process developed depends on a modified IBM Electronic Calculator, Type 604. However, the following six other types of conventional equipment are also required in the process:

Type 024 - Key Punches	Type 082 - Sorters
Type 056 - Verifiers	Type 402 - Tabulators
Type 077 - Collators	Type 513 - Reproducing Punches.

To process all 14 problem types, 96 separate steps are taken using the above equipment, and 19 different wiring panels are utilized in the Type 604 Calculator. Some of these panels accomplish more than one function.

From a tabulating standpoint the volume of cards handled daily in processing these traverse problems is small. However, since calculations are repetitive in nature it is possible to prepare boards which are kept wired permanently for the various steps of each problem type.

This type of equipment is admittedly not the most efficient for these calculations. However, the volume of calculations has not been sufficient to warrant one of the more expensive computing machines at this time.

CHPS TRAVERSE SHEET

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
5	13	A	12	8

STATION	CSE NO.	DISTANCE	BEARING	FUNCTIONS COS	FUNCTIONS SIN	COORDINATES N	COORDINATES E
	00				>	13462910	26458129
	1	60000	N000000E				
	2	?	N450000E				
	(3)	75000	S450000E				
	4	75000	N592938E				
	5	?	S303022E				
	6	130625	S 11302W				
	7	301450	N611440W				
	99					13462910	26458129
Add	3	75000	1042938				

Punch / Verify — Calc Date — Chd Date — Plot Date — Chd Date — Dist Co Rte Sec. — Item — Sheet — Book

Figure 2.

TRAVERSE COMPUTATIONS

Problem Type	District	Group	Batch	Traverse	Course	Distance	Bearing	Cosine	Sine	Latitude Or Area in Acres	Departure Or Sine of Delta	North Progressive	East Totals	Seg Ck or Unknown
5	13	A	12	8										
												13462910	26458129	
					1	60000	N000000E	10000000		6000				
												13468910	26458129	
					2	(101780)	N450000E	7071068	7071068	7197	7197			*
												13476107	26465326	
Calculated Unknown					3	75000	S450000E	7071068	7071068	* 5303	5303			
												13470804	26470629	
					4	75000	N592938E	5076303	8615750	3807	6462			
												13474611	26477091	
					5	(152540)	S303022E	8615750	5076303	* 13142	7743			*
												13461469	26484834	
					6	130625	S011302W	9997743	0212429	* 13060	* 277			
												13448409	26484557	
					7	301450	N611440W	4810738	8766801	14502	* 26428			
												13462911	26458129	
					99									*
										Error of closure		(1)	*	
										(01)	*	1	99999999	
						Traverse Area	44907			1031			Error of closure to end coordinates	
					3	Segment Area	2406			055	(9681743) ← Sine of delta			
						Net Area	47313	(Sq Ft)		1086 (Acres)				

* South * West

Figure 3.

After all the calculations have been completed and the traverses have been listed they are separated by district and mailed. As a general rule, the traverses are processed and mailed out the same day they are received.

In general, no inspection or check of the finished tabulation is made before mailing. The users of this service have found that a detailed check of the computations is not necessary. A check of the traverse sheet before submitting it for computation, together with an inspection of the error of closure, end coordinates, and closure to end coordinates on the completed tabulation will usually show up any significant error.

It is interesting to note that wherever possible each unknown is calculated separately instead of using a forced closure procedure. This provides an additional check of the work.

A sample of the tabulation which is returned to the originator of the traverse is shown in Figure 3.

The whole procedure calls for a somewhat different approach to the problem of traverse calculations on the part of the engineer. One of the greatest obstacles to overcome was the reluctance of the engineers to tolerate a waiting period of approximately one and one-half days between submittal of the problem and the return of the completed computations. At first many of the engineers did not believe this delay was tolerable, as they had been accustomed to using the answer of one calculation as a known quantity to continue on to the next calculation, a procedure which resulted in a string of interdependent traverses. When the engineer made his own calculations there was no object in trying to avoid this situation.

However, to obtain maximum benefits from the new service, the engineer must plan his work to avoid interdependent traverses wherever possible. Controlling networks must be submitted in advance of detailed computations so as not to hold up later work. He should write as many independent traverses as possible for one portion of the work, and then go on to other sections of the job while the computations are being done for him. As an aid in this procedure, certain noncritical distances or bearings may be measured from a scale drawing of the area, leaving, for example, only two unknowns to be solved on a ramp control line.

The change from the usual procedure is difficult for the engineer to get used to, but the saving in time and money makes it well worthwhile. This procedure, of working on more than one section of a job at a time, has been accepted almost universally by the engineering personnel involved in these computations. Short-cuts are being developed within the various design sections, and timing is being revised so that engineering computations are not concentrated at a given time in the design cycle.

In planning for traverse calculations every attempt was made to keep to a minimum the changes in forms and procedures as they affect the engineer. The form used to submit the data for processing can be used by the engineer for manual calculations as well, since it is similar to our previous traverse sheets. Added to our standard traverse sheet are blocks which show problem type, district, group letter, batch number, and traverse number. A column for course number was also added. These are to facilitate processing of the cards and identifying the completed tabulations for return to the originator of the traverse.

Distances may be recorded to an accuracy of $\frac{1}{1000}$ of a foot. However, latitudes and departures and coordinates are rounded to $\frac{1}{100}$ of a foot at the end of each course. When the engineer desires to obtain latitudes and departures and coordinates to $\frac{1}{1000}$ of a foot, he moves the decimal point for distances and coordinates when recording the data on the form. Bearings are recorded to seconds. The calculations of the sine and cosine are accurate to seven decimal places, which is considered sufficient since a distance would have to be greater than 10,000 feet before accuracy of $\frac{1}{1000}$ of a foot is lost.

The procedure used in calculating unknowns by use of the tabulating equipment sometimes gives slightly different answers when compared with manual calculations. For example, an engineer calculating two unknown sides in a traverse normally calculates one unknown side and then forces a closure on the second unknown side. With the tabulating procedure setup, each side is calculated separately. Under the manual approach, in most cases the traverse will show zero error of closure. Under the tabulating machine approach, since the closure is not forced, several hundredths of a foot for the error of closure can appear. The failure to close is bothersome to many engineers as they were accustomed to obtaining a mathematical closure but has the advantage that the error may be distributed by the engineer in a logical manner.

To date we have found the procedure gives remarkably accurate results. The few errors we have found were usually due to human failure. In most cases errors are very apparent as the traverse does not close. Due to the volume being processed it is not possible to note all the nonclosing traverses and have them investigated. In the large majority of cases the reason for the nonclosure was that faulty data was submitted, such as a reverse direction on a bearing, an incorrect distance, or, in the attempt to get $1/1000$ of a foot accuracy, forgetting to move the decimal place in both the recorded distances and starting and ending coordinates. These errors are left to the engineer, who submits the problem, to locate and correct.

Although comparative costs were not considered as important as a saving in engineering time in the planning of the program, it turns out that the saving in cost is not neglıgible. When we were processing a minimum number of problem types it was estimated that if we could process a thousand courses a day the average cost per course would be under five cents. This estimate includes labor and machine rental. This compares with estimated cost of 13 cents per course when done manually, checking not considered. At present we are processing from 1,000 to 3,000 courses daily. This takes from 12 to 24 man-hours of key punch and tabulating machine operator time.

To obtain an estimate of saving ın engineering time is rather difficult since there is no such thing as a typical job and the approach to the problem had to be revised for greatest efficiency. However, the users of the service have informed us that savings are definite. Examples are as follows: (a) One squad leader formerly used from three to five men for calculating in the designing process. He now uses from one to two. (b) One man volunteered the information that he designed an interchange in approximately one-half the time it used to take him. (c) A squad leader informed us that one of his

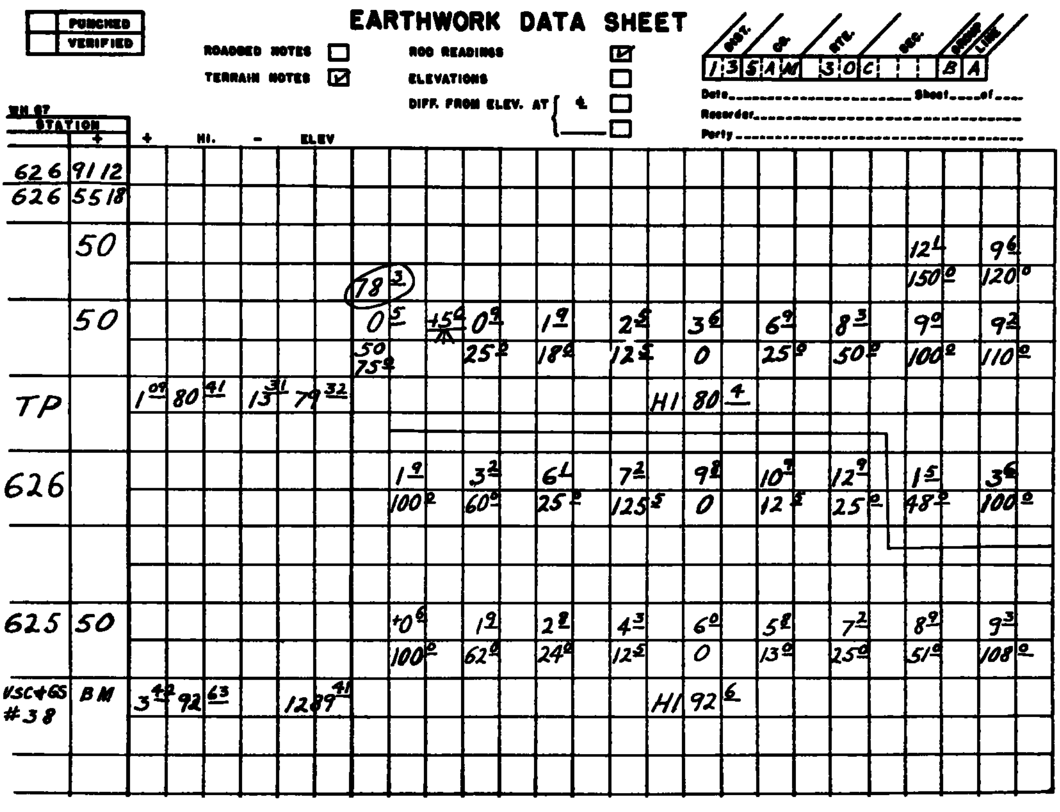

Figure 4.

men completed the geometric design of three freeway interchanges in two weeks.

Before all of the above-listed problem types were programmed and tested, three districts were selected to work with us in planning the procedures for earthwork calculation. We were aware that some work was being done by other states in the machine calculation of earthwork quantities from cut and fill construction notes. However, it was realized that an even larger percentage of time would be saved if it became unnecessary to plot each cross section to scale for planimetering to arrive at the earthwork quantities in the design stage. The procedure that we have set up enables us to take the terrain data from one source and the roadbed data from another, bring them together for the calculation of two catch points in each cross section, and then continue for the calculation of the end areas by the trapezoidal rule and volumes of excavation and embankment by the average end area method. Thus our calculations may be used for preliminary earthwork quantities in the design stage or for final pay quantities in the construction stage.

Again, changes for the engineer from his usual methods of keeping notes were kept to a minimum consistent with machine processing of the data. Appendix B contains instructions to the engineer on how to submit earthwork data for machine computations. It contains samples of properly filled out data sheets.

Terrain notes or original ground cross sections may be submitted as true elevations, as rod readings, or as a difference in elevation from centerline or offset line. Transcribing of field notes prior to punching is not generally necessary. Figure 4 shows a sample of terrain notes based on rod readings. Roadbed template notes may be submitted as true elevations or as a difference in elevation from centerline or offset line. Figure 5 shows a sample of roadbed notes based on difference in elevation from centerline. Roadbed notes may be given to subgrade or to finished grade, in which case correction quantities may be submitted in tabular form. Thousands and hundreds of feet may be omitted from the elevations as long as they are recorded on the same basis for both terrain and roadbed notes for each cross section.

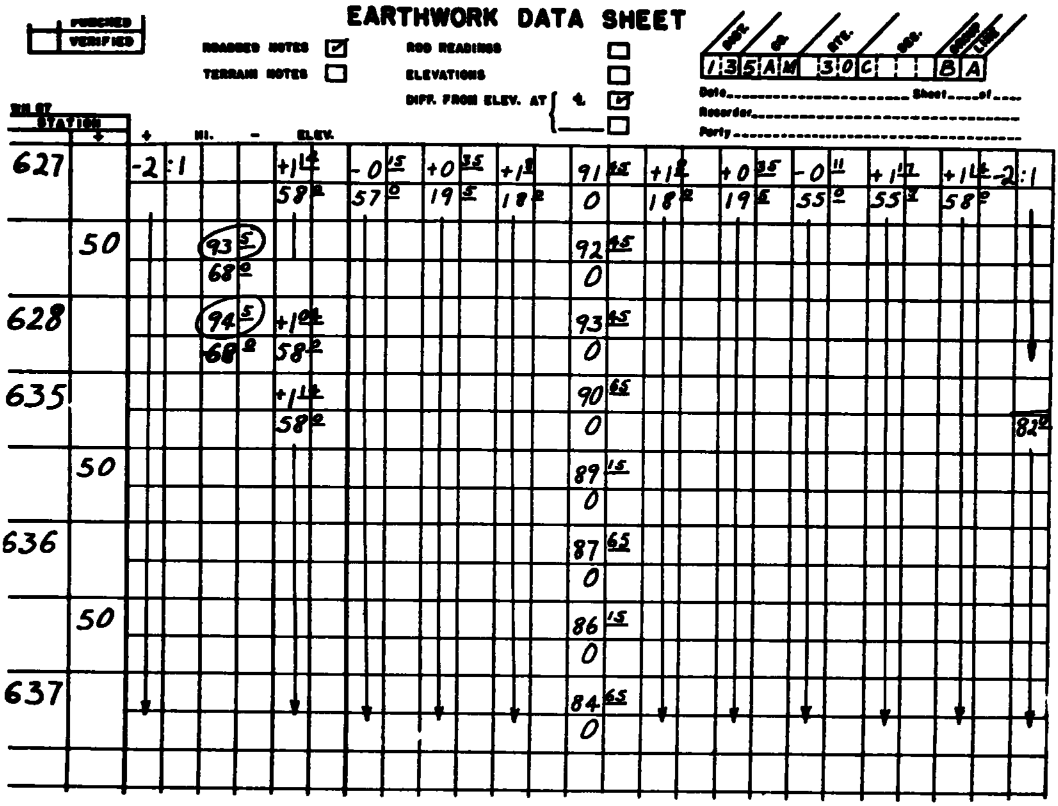

Figure 5.

EARTHWORK QUANTITY SHEET

DIST	COUNTY	ROUTE	SECTION	GROUP	LINE	STATIONING	+	SHRINKAGE FACTOR	EXCAVATION END AREA SQ FT	EXCAVATION CUBIC YARDS	EMBANKMENT END AREA SQ. FT	EMBANKMENT CUBIC YARDS	MASS DIAGRAM ORDINATE
2	TEH	2S	E	A	E	473	0000	8500			3007		
							5000	8500			* 3715	6224	* 96847
											*	7481	* 96099
											*	13705	*
						474	0000	8500			4364		
											*	4055	* 95693
							2500	8500			4395		
											*	4141	* 95279
							5000	8500			4550		
											*	7554	* 94524
											*	15750	*
						475	0000	8500			3608		
											*	2705	* 94253
							2000	8500			3695		
											*	2426	* 94010
							3500	8500			5037		
											*	2312	* 93779
							5000	8500			3285		
										72	*	4239	* 93361
										72	*	11682	*
						476	0000	8500	78		1293		
										73	*	2813	* 93086
							5000	8500	1		1745		
										1229	*	2119	* 92979
										1302	*	4932	*
						477	0000	8500	1326		543		
										8056	*	503	* 93613
							5000	8500	7375				
										17294	*		* 95083
										25350	*	503	*
						478	0000	8500	11303				
										20696	*		* 96842
							5000	8500	11049				
										18605	*		* 98423
										39301	*		*
						479	0000	8500	9044				
										12428	*		* 99479

Figure 6.

The following tabulations are furnished to the engineer: (1) a tabulation of reduced notes for terrain and roadbed, containing elevations and distances from centerline to a tenth of a foot; (2) a tabulation of catch point elevations and distances from centerline which is used in plotting the limits of the work for right of way acquisition and for use in slope staking; (3) a tabulation showing stations, end areas, quantities, shrinkage factors, and mass diagram ordinates. A sample of this tabulation is shown in Figure 6.

The quantities for each side of a divided highway may be computed separately and subsequently combined with quantities for frontage roads, ditches, and corrections for the structural sections to provide totals and mass diagram ordinates by stations.

Although a basic procedure has been set up for earthwork, each job has a certain amount of work that requires individual attention.

The cost by station of computing earthwork quantities by machine is not uniform. The cost of punching is directly proportional to the number of points used for the roadway and for terrain. The cost of processing the cards is dependent on the number of points involved, the number of cross sections taken, and the type of processing required. These factors vary considerably in different areas of the state and depend upon the type of terrain and the facility proposed for construction. Further savings in design time can be realized, however, by the re-use of the terrain data for several trial lines. Occasional savings can be made in the re-use of roadbed notes when uniform portions of roadbed data from one trial line can be used in subsequent lines.

The procedure as set up arranges for the notes to be transmitted to the key-punch section in installments to reduce the punching load. It has been determined that a key-punch operator will punch and verify over 1,200 points per man-day of terrain or roadbed notes.

On a divided highway project, ten miles in length, through rolling country, the engineer was furnished, within ten working days after the completion of the punching phase, computed elevations and distances from centerline of catch points, end areas and volumes of cut and fill, and ordinates for a mass diagram. Several projects of this sort may be in process simultaneously. Processing of the cards was accomplished by tabulating personnel supervised by professional personnel in a non-engineering classification. This compares with estimates of four engineering man-months to do the equivalent work in the district office.

While our use of business machines for earthwork computations has not been made available to all districts in the Division of Highways at this time, since we still consider it to be in the trial stage, indications are that savings in engineering time and cost realized in this computation procedure may exceed the savings that are being realized by the machine computation of traverses.

It is realized that further savings will occur should the volume of this work increase, requiring the use of a more advanced type of computer such as an IBM Type 650 Drum Calculator. Not only is it expected that the cost will be reduced but the over-all processing time after the key-punch phase will also be reduced materially.

Appendix A

Instructions for Calculation of Traverse Data by Punched Cards

The traverse computation service is furnished by the Tabulating Section of the California Highway Planning Survey. It may be used either for original computations or as a check of the districts' calculations.

This service is limited to the problem types listed below. The necessary information is to be furnished on Form WH-328 in accordance with the following instructions:

Fill in the blocks in the upper right-hand corner for identification purposes during processing as follows:

Problem Type

Record the number of the problem type from the following list:

1. Traverse computation where all sides and bearings are known. This may be used for original computations in coordinating a traverse or as a check of original computations.
2. Traverse computations where the lengths of two sides are unknown.
3. Traverse computation where the length of one side and the bearing of another side is unknown.
4. The problem described as Type 1 where, in addition, the area within the closed traverse is desired.
5. The problem described as Type 2 where, in addition, the area within the closed traverse is desired.
6. Traverse computation where the length of one side and the bearing of that same side are unknown.
7. The problem described as Type 3 where, in addition, the area within the closed traverse is desired.
8. The problem described as Type 6 where, in addition, the area within the closed traverse is desired.
9. Traverse computation where the bearings of two sides are unknown and the area within the closed traverse is desired.

0. Traverse computation where the bearings of two sides are unknown.
C. Adjustment of traverse by compass rule.
D. Adjustment of traverse by compass rule plus area of the adjusted traverse.
T. Adjustment of traverse by the transit rule.
U. Adjustment of traverse by the transit rule plus area of the adjusted traverse.

District

Record the district in arabic numerals.

In Districts IV and VII, for ease in distribution, separate district numbers for use by sections submitting this work are assigned as follows:

District IV. 4 - R/W Engineering; 24 - Design - J.C. Black; 34 - Design - W.P. Smith; 44 - Design - A.E. Simmons; 54 - Design - J.A. Spence; 64 - Surveys; 74 - Administration - H.S. Miles; 84 - Construction.

District VII. 7 - Design A - J.E. Eckhardt; 17 - Design B - E.G. Hanson; 27 - Design C - L.S. Van Voorhis; 37 - R/W Engineering; 47 - Surveys; 57 - Construction.

Headquarters departments will use District 13. The Division of Water Resources will use District 73.

Other sections or districts desiring special district number assignments for this work may request them from the Tabulating Section.

Group Letter

Record the group letter assigned to you.

Group letters A through Z should be assigned within the district to various departments or sections which will be submitting work. The Tabulating Section should be furnished a list by the district showing the person or section to which each group letter is assigned.

If the district desires that work submitted under various group letters be mailed separately to reduce the time loss in distributing the completed calculations, this fact should be indicated on the list. Please inform the Tabulating Section of changes in group letter assignment.

Batch Number

Within each group, give a batch number to each separate transmission of traverses to headquarters. The numbers from 1 to 99 may be used.

Traverse Number

Within each batch, number traverses to a maximum of 99.

The same group, batch, and traverse designation should not be repeated within five working days.

The body of the sheet is to be filled in as shown below. Also, see the special remarks for the particular problem types that appear after these general instructions. To facilitate the card-punch operation, vertical lines have been ruled in the various columns on the sheet. Place only one figure to a square, oriented with the dashed line as the decimal.

Station

This column need not be filled in except for the recording of "add" or "subtract" for segments of circular areas as discussed under Problem Types 4, 5, 7, 8, and 9 below.

It may be used for supplemental notes for district use if desired.

Course Number

Identify as Course 00 the beginning coordinates of the traverse. Then number the courses consecutively from 1 to a maximum of 98.

In all traverses containing unknowns, identify the ending coordinates as Course 99. This must be done for both closed and open ended traverses.

When Problem Types 4, 5, 7, 8, and 9 contain circular segments, certain course numbers are to be circled as discussed under these problem types.

Distance

Record the distances to thousandths, using the dashed line as the decimal and filling all the spaces to the right of the decimal. The maximum distance that can be handled either as given data or the solution of an unknown is 99,999.999.

In traverses containing unknowns, place a question mark in the spaces where the unknowns occur.

Bearing

Record the bearing in degrees, minutes, and seconds. Decimals of seconds cannot be handled. Due north should be recorded as N 00-00-00 E, due west as N 90-00-00 W, etc.

In traverses containing an unknown, place a question mark in the space where it occurs.

In Problem Types 4, 5, 7, 8, and 9 containing circular segments, the delta of the arc is recorded in the bearing column below the regular traverse as discussed under these problem types.

Functions

These columns need not be filled in, as the functions are computed by the punched card equipment. The columns appear so that the forms may be used for district computation as desired.

Coordinates

Fill in the coordinates of the origin of the traverse to two decimals opposite Course 00. The California Coordinate System should be used when the work in on that basis. If these are not available, coordinates should be assumed preferably of such size that negative coordinates do not occur, even at the center of long radius curves.

In all traverses containing unknowns, record the ending coordinates after the last course of the traverse and identify as Course 99. This must be done for both closed and open ended traverses.

The coordinates of Course 00 and Course 99 may only be given as positive or zero. However, if the traverse proceeds into another quadrant, the true negative coordinates will be tabulated. Therefore, to record a traverse occurring in other than the NE quadrant begin on a zero coordinate line and use one or more courses with bearings of 90 degrees or 0 degrees to go to the beginning of the traverse, and, if course 99 is required, return in the same manner.

General Notes

Do not place more than one traverse on a single sheet. All latitudes, departures, and unknown lengths are calculated to thousandths of a foot, and printed to the nearest hundredth.

An asterisk preceding a number on the tabulation sheet indicates a negative number.

On the completed tabulation sheet, the error of closure will appear after the last course in the latitude and departure columns. This figure should be examined for closed traverses to see that it is within allowable limits before further use is made of the traverse. In open ended traverses, the figures in this position give the latitude and departure of the closing course.

Where unknowns are involved and a Course 99 is given, the difference between the tabulated coordinates of the end point of the traverse and the given coordinates of that point, if any, will appear in the coordinate columns on the line below the listing of Course 99. The last set of numbers in the coordinate columns are meaningless and should be ignored.

Remember that the Headquarters personnel working with your sheets are not engineers. To avoid errors, follow these instructions carefully and write clearly.

Traverse sheets for computation should be mailed to: G. T. McCoy, Attention CHPS Tabulating Section, Room 547, Public Works Building, Box 1499, Sacramento 7, California.

To reduce delay in the mail it is recommended that the traverse sheets be mailed separately by the districts, and not included in the regular bulk mailing. The use of air mail is suggested where this will materially reduce the time in transit.

Traverse sheets will not be returned to the district with the completed tabulations except where errors or incorrect recording methods are found.

The calculations for these problems are based on seven place functions, and latitudes and departures correct to one hundredth. Therefore, closures on problems involving flat angle intersections or extremely unbalanced length of sides in the two unknowns, and which usually involve special calculation procedures in the district, may require adjustments by the engineer when the tabulations are returned.

If it is desired to use thousandths in the coordinate field or to obtain unknown distances to thousandths, it is necessary to record both the distances and coordinates one space to the left of the usual position.

Special Notes for Problem Types 4, 5, 7, 8, and 9

Where the area desired is bounded in part by curves, list the traverse as passing through the center of the curve (BC to R, and R to EC) and circle the course number of the first of the two radius courses. In this case the traverse may not start at the center of a curve. Also, record at the bottom of the traverse the circular segment to be added to, or subtracted from, the traverse area as follows:

1. Indicate in the Station Column "add" if the segment is to be added to the traverse area or "subtract" if it is to be subtracted to obtain the net area.
2. Record the course number of the circled radius.
3. Record the radius in the distance column.
4. Record the delta of the curve in the bearing column.

The area bounded by the long chord of the curve will then be calculated and listed, the areas of the segments and the net area of the traverse will be computed and listed.

The delta of curve segments must be given by the engineer. It cannot be computed from an unknown radial bearing in Problem Types 7, 8, or 9.

The area of segments with a delta greater than 180 degrees cannot be computed by the machine. In cases where this occurs the traverse may be written so as to split the curve into two segments.

On curves of large delta and long radius where the long chord would cut other lines of the traverse, the curve must be broken into smaller segments, as in the manual procedure, to avoid a false area.

Note that we do not handle areas containing circular segments in Problem Types D and U.

Special Notes for Problem Types 3, 7, 9, and 0

Since there are usually two possible solutions to Problem Types 3, 7, 9, and 0 the person submitting these problem types will have to provide for two solutions by indicating in the traverse block two numbers that are consecutive. Both solutions will be returned, one under each of the traverse numbers indicated. The engineer will discard the unwanted solution.

Special Notes for Problem Type 6

Where a series of coordinates are known and the distance and bearing of the courses are desired, they may be listed as Problem Type 6, as shown in the sample traverse numbered 31 to 37. In this case, each course is tabulated as a separate traverse and one traverse number must be allowed for each course.

List the coordinates in order on the sheet. Number the first set as Course 00; the last, 99. Do not number the intermediate courses or coordinates.

Special Notes for Problem Types C, D, T, and U

The data for traverse adjustment may be transmitted to Headquarters in one of two ways. The first, shown in traverse 10, is by returning a tabulation sheet marked as follows:

Cross out the original problem type and write in the letter for the problem type desired. If both compass and transit adjustment are desired, two letters may be used on the one tabulation. The group, batch, and traverse numbers may remain the same, or can be changed, if desired, by crossing out the printed one and writing a new one below.

At the bottom of the traverse, below all other figures, write 99 in the course column, and opposite this in the coordinate columns, write the end coordinates to which the traverse should be adjusted. These may be the same as the 00 coordinates, or may be different. Where the information is submitted on a tabulation sheet, it will be returned to the district with the adjusted tabulation.

If the original traverse has been computed in the district, the work may be submitted as in Traverse 11. Only the data required by the tabulating section is shown on the sample. Bearings and functions may be recorded if desired. Do not include intermediate coordinates. Two problem type letters, C and T or D and U, may be recorded if desired. The coordinates of the origin are recorded and identified as Course 00. Courses are numbered and listed in order, and the distances recorded. Calculated latitudes and departures are recorded in the coordinate field to hundredths. North and east are shown by a plus sign, and south and west by a minus sign. The end coordinates to which the traverse is to be adjusted are listed at the end and identified as Course 99. These may be the same as the 00 coordinate, or may be different.

Since in adjusting a traverse any pairs of radii will not usually remain the same length, and since the delta between them will change in the adjustment, we are not prepared to handle areas containing circular segments in Problem Types D and U. The area furnished will be that bounded by the traverse lines. You are cautioned that, as in the manual procedures, when any course crosses another, a false area will result.

Sample Traverse Sheets

CHPS TRAVERSE SHEET

PROBLEM TYPE 1 All sides & bearings known; 2 Two sides unknown; 3 1 side & 1 bearing unknown; 4 Type 1 with area; 5 Type 2 with area; 6 1 side & its bearing; 7 Type 3 with area; 8 Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
1	13	A	4-8	12

STATION	CSE NO.	DISTANCE	BEARING	FUNCTIONS COS	FUNCTIONS SIN	COORDINATES N	COORDINATES E
	00					20163529	11346212
	1	62340	N621321W				
	2	211395	S123529E				
	3	29150	S631400W				
	4	1011620	N011300E				
	5	645	S845931W				
	6	136244	N302000E				

TRAVERSE COMPUTATIONS

* South or West

Problem Type	District	Group	Batch	Traverse	Course	Distance	Bearing	Cosine	Sine	*	Latitude	Departure	Coordinates North Progressive	Coordinates East Totals	Seg Cl.
1	13	A	48	12									20163529	11346212	
					1	62340	N621321W	4660392	8847640		2903	5516	20166434	11340696	
					2	211395	S123529E	9759495	2179966	*	20631	4608	20145803	11345304	
					3	29160	S631400W	4503502	8928480	*	1313	2604	20144490	11342700	
					4	1011620	N011302E	9997743	0212429		101139	2149	20245629	11344849	
					5	645	S895931W	0001406	10000000			65	20245629	11344784	
					6	136244	N302000E	8631019	5050299		11759	6881	20257358	11351665	
											93859	5453	20257388	11351665	

Closure

CHPS TRAVERSE SHEET

PROBLEM TYPE
1. All sides & bearings known
2. Two sides unknown
3. 1 side & 1 bearing unknown
4. Type 1 with area
5. Type 2 with area
6. 1 side & its bearing
7. Type 3 with area
8. Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
2	13	A	48	13

STATION	CSE NO.	DISTANCE	BEARING	FUNCTIONS COS	FUNCTIONS SIN	COORDINATES N	COORDINATES E
	00					13035733	20802897
	1	199510	N755838W				
	2	?	S140122W				
	3	1218330	N323753E				
	4	?	N573207E				
	99					13035733	20802897

Ref Data

Punch

Verify

Calc Date

Chkd Date

Plot Date

Chkd Date

Dist Co Rte Sec

Item

Sheet

Book

TRAVERSE COMPUTATIONS

* South or West

Problem Type	District	Group	Batch	Traverse	Course	Distance	Bearing	Cosine	Sine	Latitude	Departure	North Progressive	East Totals
2	13	A	48	13								13035733	20802897
					1	199510	N755838W	2423076	9701995	4834	19356	13040567	20783541
					2	1217750	S140122W	9701995	2423076	* 118146	29507	12922421	20754034
					3	1218330	N323753E	8421571	5392322	102603	65696	13025024	20819750
					4	199510	N573207W	5367802	8437221	10709	16833	13035733	20802897
					99							99999999	99999999

Unknowns

Zero error of closure to end coordinates

CHPS TRAVERSE SHEET

PROBLEM TYPE
1. All sides & bearings known
2. Two sides unknown
3. 1 side & 1 bearing unknown
4. Type 1 with area
5. Type 2 with area
6. 1 side & its bearing
7. Type 3 with area
8. Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO.	TRAV NO
3	13	A	48	14 / 15

STATION	CSE NO.	DISTANCE	BEARING	FUNCTIONS COS	FUNCTIONS SIN	COORDINATES N	COORDINATES E
	00					13064050	20938710
	1	?	N374146E				
	2	759620	S830729E				
	3	652359	?				
	99					13045863	21089541

TRAVERSE COMPUTATIONS

* South or West

313A4814

Course	Distance	Bearing	Cosine	Sine		Latitude	Departure	North	East
								13064050	20938710
1	384590	N374146E	7912650	6114733		30431	23517	13094481	20962227
2	759620	S830729E	1197085	9928091	*	9093	75416	13085388	21037643
3	652359	S524226E	6058881	7955498	*	39526	51898	13045862	21089541
99								* (1)	*
					*	18188	150831	99999998	99999999

Unknowns

Error of closure to end coordinates

Note

The alternate solution is shown as traverse #15. The engineer must decide which to use.

TRAVERSE COMPUTATIONS

* South or West

313A4815

Course	Distance	Bearing	Cosine	Sine		Latitude	Departure	North	East
								13064050	20938710
1	393770	N374146E	7912650	6114733		31158	24078	13095208	20962788
2	759620	S830729E	1197085	9928091	*	9093	75416	13086115	21038204
3	652359	S515404E	6170206	7869470	*	40252	51537	13045863	21089541
99								*	*
					*	18187	150831	99999999	99999999

Unknowns

See note on traverse #14

CHPS TRAVERSE SHEET

PROBLEM TYPE 1 All sides & bearings known; 2 Two sides unknown; 3 1 side & 1 bearing unknown; 4 Type 1 with area; 5 Type 2 with area; 6 1 side & its bearing; 7 Type 3 with area; 8 Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
4	13	A	48	16

STATION	CSE NO.	DISTANCE	BEARING	COS	SIN	N	E
	00					10000000	20000000
	1	1034220	N004140W				
	(2)	75000	S450000E				
	3	75000	N592938E				
	4	1011620	S 11302W				
	(5)	100000	S193000W				
	6	100000	N301000W				
Add	2	75000	1042938				
Subtract	5	100000	494000				

Ref Data — Punch — Verify — Calc Date — Chd Date — Plot Date — Chd Date — Dist Co Rte Sec — Item — Sheet — Book

TRAVERSE COMPUTATIONS

* South or West

Problem Type / District / Group / Batch / Traverse	Course	Area in Square Feet: Distance	Bearing	Cosine	Sine	Area in Acres: Latitude / Error of Closure	Departure	Coordinates: North / Progressive	East / Totals
4 13 A 48 16								10000000	20000000
	1	1034220	N004140W	9999265	0141200	103414	* 1253	10103414	19998747
	2	75000	S450000E	7071068	7071068	* 5303	5303	10098111	20004050
	3	75000	N592938E	5076303	8615750	3807	6462	10101918	20010512
	4	1011620	S011302W	9997743	0212429	* 101139	* 2149	10000779	20008363
	5	100000	S193000W	9426415	3338069	* 9426	* 3338	9991353	20005025
	6	100000	N301000W	8645673	5025170	8646	* 5025	9999999	20000000
						* (01) ← Error of closure	* ( )	9999999	20000000
			102947	Sq. ft. ← Area of traverse →		2363 acres			
	2		2406	← Area of circular segments →		1055	9681743 ← Sine of delta		
	5		523			(*) 012	7622920		
			104830	Sq. ft. ← Net area →		2406 acres			

(*) ← Indicates this segment was subtracted

CHPS TRAVERSE SHEET

PROBLEM TYPE 1 All sides & bearings known
2. Two sides unknown
3. 1 side & 1 bearing unknown
4. Type 1 with area
5 Type 2 with area
6. 1 side & its bearing
7 Type 3 with area
8 Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
5	13	A	48	17

STATION	CSE NO.	DISTANCE	BEARING	COS	SIN	N	E
	00					13062072	20941226
	1	?	N374146E				
	2	787260	N815547W				
	3	?	S514924E				
	99					13062072	20941226

TRAVERSE COMPUTATIONS

* South or West

Problem Type / District / Group / Batch / Traverse	Course	Distance (Area in Square Feet)	Bearing	Cosine	Sine	Latitude (Area in Acres) / Error of Closure	Departure	North (Progressive)	East (Totals)	Seq Ck.
513A4817								13062072	20941226	
	1	394900	N374146E	7912650	6114733	31247	24147	13093319	20965373	*
	2	787260	N815547W	1403876	9900966	11052	* 77946	13104371	20887427	
	3	684360	S514924E	6180883	7861087	* 42299	53798	13062072	20941225	*
	99									*
						*	* 01	* 99999999	* 99999998	
		135125				3102				
		135125 S.F.	← area →			3102 acres				

Handwritten notes: "Unknowns" (pointing to the distances of courses 1 and 3, 394900 and 684360); "Error of closure" (pointing to 01); "Error of closure to end coordinates" (pointing to 1).

CHPS TRAVERSE SHEET

PROBLEM TYPE 1 All sides & bearings known
2. Two sides unknown
3. 1 side & 1 bearing unknown
4. Type 1 with area
5 Type 2 with area
6. 1 side & its bearing
7 Type 3 with area
8 Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
6	13	A	48	18

STATION	CSE NO.	DISTANCE	BEARING	COS	SIN	N	E
	00					13042679	26342196
	1	?	?				
	99					13165819	26153648

TRAVERSE COMPUTATIONS

* South or West

Problem Type / District / Group / Batch / Traverse	Course	Distance (Area in Square Feet)	Bearing	Cosine	Sine	Latitude (Area in Acres) / Error of Closure	Departure	North (Progressive)	East (Totals)	Seq Ck.
613A4818								13042679	26342196	
	1	225197	N565106W	5468084	8372578	123140	* 188548	13165819	26153648	*
	99									*
						123140	* 188548	* 99999999	* 99999999	

Handwritten note: "Unknowns" (pointing to 225197 and N565106W)

CHPS TRAVERSE SHEET

PROBLEM TYPE 1 All sides & bearings known
2. Two sides unknown
3. 1 side & 1 bearing unknown
4. Type 1 with area
5 Type 2 with area
6. 1 side & its bearing
7 Type 3 with area
8 Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
6	13	A	48	31 to 37

STATION	CSE NO.	DISTANCE	BEARING (N/S, DEG, MIN, SEC, E/W)	COS	SIN	N	E
	00					19178072	28163510
		?	?				
						19162534	28161015
		?	?				
						19153120	28150379
		?	?				
						19173804	28101679
		?	?				
						19201657	28116389
		?	?				
						19316592	28263945
		?	?				
						19384562	28373440
		?	?				
	99					19374629	28363440

Ref Date

Punch
Verify

Calc Date
Chd. Date
Plot Date
Chd Date

Dist Co Rte Sec.
Item

Sheet
Book

CHPS TRAVERSE SHEET

PROBLEM TYPE 1 All sides & bearings known
2. Two sides unknown
3. 1 side & 1 bearing unknown
4 Type 1 with area
5 Type 2 with area
6. 1 side & its bearing
7 Type 3 with area
8 Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
7	13	A	48	19 20

STATION	CSE NO.	DISTANCE	BEARING (N/S, DEG, MIN, SEC, E/W)	COS	SIN	N	E
	00					13724591	24361015
	1	?	N 04140 W				
	(2)	75000	S 450000 E				
	3	75000	N 592938 E				
	4	1011620	?				
	(5)	100000	S 193000 W				
	6	100000	N 301000 W				
	99					13724591	24361015
Add	2	75000	1042938				
Subtract	5	100000	494000				

Ref Date

Punch
Verify

Calc Date
Chd. Date
Plot Date
Chd Date

Dist Co Rte Sec.
Item

Sheet
Book

TRAVERSE COMPUTATIONS

* South or West

Problem Type / District / Group / Batch / Traverse	Course	Distance (Area in Square Feet)	Bearing	Cosine	Sine	Latitude (Area in Acres) / Error of Closure	Departure	North (Progressive)	East (Totals)	Seq Ch.
7 13 A 48 19								13724591	24361015	
	1	987890	N004140W	9999265	0121200	98782	* 1197	13823373	24359818	*
	2	75000	S450000E	7071068	7071068	* 5303	5303	13818070	24365121	
	3	75000	N592938E	5076303	8615750	3807	6462	13821877	24371583	
	4	1011620	S011832W	9997391	0228424	* 101136	* 2311	13720741	24369272	*
	5	100000	S193000W	9426415	3338069	* 9426	* 3338	13711315	24365934	
	6	100000	N301000W	8645673	5025170	8646	* 5025	13719961	24360909	
	99							* 4630	* 106	*
						* 4630	* 106	99995369	99999893	
			102125			2344				
	2		2406			055	9681743			
	5		523			* 012	7622920			
			104008			2387				

Unknown

This traverse fails to close, which is an indication that the second solution (Trav. # 20) is the acceptable one.

TRAVERSE COMPUTATIONS

* South or West

Problem Type / District / Group / Batch / Traverse	Course	Distance (Area in Square Feet)	Bearing	Cosine	Sine	Latitude (Area in Acres) / Error of Closure	Departure	North (Progressive)	East (Totals)	Seq Ch.
7 13 A 48 20								13724591	24361015	
	1	1034230	N004140W	9999265	0121200	103415	* 1253	13828006	24359762	*
	2	75000	S450000E	7071068	7071068	* 5303	5303	13822703	24365065	
	3	75000	N592938E	5076303	8615750	3807	6462	13826510	24371527	
	4	1011620	S011302W	9997743	0212429	* 101139	* 2149	13725371	24369378	*
	5	100000	S193000W	9426415	3338069	* 9426	* 3338	13715945	24366040	
	6	100000	N301000W	8645673	5025170	8646	* 5025	13724591	24361015	
	99							*	*	*
						*	*	99999999	99999999	
			102947	Sq Ft	Area of traverse	2363 acres				
	2		2406		Area of circular segments	055	9681743	Sum of Delta	See note on traverse #19	
	5		523		" " "	* 012	7622920			
			104830	Sq Ft.	Net area	2406 acres				

Indicates the area was subtracted

CHPS TRAVERSE SHEET

PROBLEM TYPE
1. All sides & bearings known
2. Two sides unknown
3. 1 side & 1 bearing unknown
4. Type 1 with area
5. Type 2 with area
6. 1 side & its bearing
7. Type 3 with area
8. Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
8	13	A	48	21

STATION	CSE NO.	DISTANCE	BEARING	FUNCTIONS COS	FUNCTIONS SIN	COORDINATES N	COORDINATES E
	00					10000000	20000000
	1	683379	N374146E				
	2	?	?				
	3	562899	S704958E				
	99					10000000	20000000

Ref Date

Punch

Verify

Calc Date
Chd Date
Plot Date
Ckd Date

Dist Co Rte Sec

Item

Sheet

Book

TRAVERSE COMPUTATIONS

* South or West

Problem Type	District	Group	Batch	Traverse	Course	Distance (Area in Square Feet)	Bearing	Cosine	Sine		Latitude (Area in Acres) (Error of Closure)		Departure	North Progressive	East Totals	Seq Ck
8	13	A	48	21												
														10000000	20000000	
					1	683379	N374146E	7912650	6114733		54073		41787			
														10054073	20041787	
Unknowns					2	1014070	S692709W	3509938	9363815	*	35592	*	94956			*
														10018481	19946831	
					3	552899	S704958E	328[illegible]263	9445643	*	18481		53169			
														10000000	20000000	
					99											*
														*	*	
												*		99999999	99999999	
							182364				4187					
							182364	Sq. Ft	Area		4187		acres			

CHPS TRAVERSE SHEET

PROBLEM TYPE
1 All sides & bearings known
2 Two sides unknown
3 1 side & 1 bearing unknown
4 Type 1 with area
5 Type 2 with area
6 1 side & its bearing
7 Type 3 with area
8 Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
9	13	A	48	3 4

STATION	CSE NO.	DISTANCE	BEARING	COS	SIN	COORDINATES N	COORDINATES E
	00					13035733	20802897
	1	199510	N755838W				
	2	1217750	?				
	3	1218330	?				
	4	199510	N573207W				
	99					13035733	20802897

TRAVERSE COMPUTATIONS

Problem Type	District	Group	Batch	Traverse	Course	Area in Square Feet or Distance	Bearing	Cosine	Sine	Latitude Or Area in Acres (Error of Closure)	Departure Or Sine of Delta (Error of Closure)	Coordinates North Progressive	Coordinates East Totals	[illegible]
9	13	A	4J	3								13035733	20802897	
					1	199510	N755838W	2423076	9701995	4834	* 19356			
												13040567	20783541	
					2	1217750	N322751E	8437273	5367720	102745	65365			*
												13143312	20848906	
					3	1218330	S135120W	9709025	2394750	* 118288	* 29176			*
												13025024	20819730	
					4	199510	N573207W	5367802	8437221	10709	* 16833			
												13035733	20802897	
					99									*
												*	*	
										*	*	99999999	99999999	
							230414			529				
							230414			529				

TRAVERSE COMPUTATIONS

Problem Type	District	Group	Batch	Traverse	Course	Area in Square Feet or Distance	Bearing	Cosine	Sine	Latitude Or Area in Acres (Error of Closure)	Departure Or Sine of Delta (Error of Closure)	Coordinates North Progressive	Coordinates East Totals	[illegible]
9	13	A	48	4								13035733	20802897	
					1	199510	N755838W	2423076	9701995	4834	* 19356			
												13040567	20783541	
					2	1217750	S140119W	9702030	2422935	* 118146	* 29505			*
												12922421	20754036	
					3	1218330	N323750E	8421650	5392200	102603	65695			*
												13025024	20819731	
					4	199510	N573207W	5367802	8437221	10709	* 16833			
												13035733	20802898	
					99									*
												*	1	
										*	01	99999999	1	
							243011			5579				
							243011			5579				

CHPS TRAVERSE SHEET

PROBLEM TYPE
1 All sides & bearings known
2 Two sides unknown
3 1 side & 1 bearing unknown
4 Type 1 with area
5 Type 2 with area
6 1 side & its bearing
7 Type 3 with area
8 Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
0	13	A	48	1/2

STATION	CSE. NO.	DISTANCE	BEARING (N/S, DEG, MIN, SEC, E/W)	FUNCTIONS COS	FUNCTIONS SIN	COORDINATES N	COORDINATES E
	00					19178072	23469172
	1	199510	N755838W				
	2	1217750	?				
	3	1218330	N323753E				
	4	199510	?				
	99					19178072	23469172

TRAVERSE COMPUTATIONS

Problem Type	District	Group	Batch	Traverse	Course	Area in Square Feet or Distance	Bearing	Cosine	Sine	Latitude Or Area in Acres	Departure Or Sine of Delta	Coordinates North Progressive	Coordinates East Totals	Seq Ck or Unknown
0	13	A	4 ıı	1										
												19178072	23469172	
					1	199510	N755838W	2423076	9701995	4834	¥ 19356			
												19182906	23449816	
					2	1217750	S140122W	9701995	2423076	118146	ς 29507			*
												19064760	23420309	
					3	1218330	N323753E	8421571	5392322	102603	65696			
												19167363	23486005	
					4	199510	N573212W	5367597	8437351	10709	, 16833			*
												19178072	23469172	
					99									*
												*	*	
										¥	*	99999999	99999999	

TRAVERSE COMPUTATIONS

Problem Type	District	Group	Batch	Traverse	Course	Area in Square Feet or Distance	Bearing	Cosine	Sine	Latitude Or Area in Acres	Departure Or Sine of Delta	Coordinates North Progressive	Coordinates East Totals	Seq Ck or Unknown
0	13	A	48	2										
												19178072	23469172	
					1	199510	N755838W	2423076	9701995	4834	* 19356			
												19182906	23449816	
					2	1217750	S323826W	8420709	5393670	* 102543	* 65681			*
												19080363	23384135	
					3	1218330	N323753E	8421571	5392322	102603	65696			
												19182966	23449831	
					4	199510	S754800E	2453074	9694453	, 4894	19341			*
												19178072	23469172	
					99									*
												*	*	
										*	*	99999999	99999999	

TRAVERSE COMPUTATIONS

* South or West

Problem Type / District / Group / Batch / Traverse	Course	Distance	Bearing	Cosine	Sine	Latitude	Departure	North Progressive	East Totals
C 1 3 A 5 0 1 0								19178072	26432961
	1	2200000	N450000E	7071068	7071068	155563	155563	19333635	26588524
	2	3000000	N720118W	3086573	9511733	92597	* 285352	19426232	26303172
	3	2800000	S273617E	8861654	4633691	* 248126	129743	19178106	26432915
						34	* 46	19178106	26432915
	99							19178072	26432961

TRAVERSE COMPUTATIONS

Problem Type / District / Group / Batch / Traverse	Course	Distance	Bearing	Cosine	Sine	Latitude Or Area in Acres	Departure Or Sine of Delta	North Progressive	East Totals	Seq. Balance
C 1 3 A 5 0 1 0								19178072	26432961	
	1	2200020	N450014E			155554	155576	19333326	26588537	
	2	2999800	N720123W			92584	* 285335	19426210	26303202	
	3	2800180	S273623E			* 248138	129759	19178072	26432961	
	99							*	*	*
						*	*	99999999	99999999	

CHPS TRAVERSE SHEET

PROBLEM TYPE
1. All sides & bearings known
2. Two sides unknown
3. 1 side & 1 bearing unknown
4. Type 1 with area
5. Type 2 with area
6. 1 side & its bearing
7. Type 3 with area
8. Type 6 with area

PROB TYPE	DIST	GROUP LETTER	BATCH NO	TRAV NO
C T	13	A	50	11

STATION	CSE NO.	DISTANCE	BEARING	COS	SIN	N	E
	00					20163529	113462 12
	1	62340				+ 2905	− 5516
	2	211395				− 20631	+ 4608
	3	29160				− 1313	+ 2604
	4	1011620				+ 101139	+ 2149
	5	645				000	+ 65
	6	136244				+ 11759	+ 6881
	99					20257353	11351702

TRAVERSE COMPUTATIONS

Problem Type / District / Group / Batch / Traverse	Course	Distance	Bearing	Cosine	Sine	Latitude Or Area in Acres	Departure Or Sine of Delta	North Progressive	East Totals	Seq. Balance
C 1 3 A 5 0 1 1								20163529	11346212	
	1	62320	N621412W			2903	* 5514	20166432	11340698	
	2	211450	S123604E			* 20636	4613	20145796	11345311	
	3	29160	S631300W			* 1314	* 2603	20144482	11342708	
	4	1011380	N011356E			101115	2175	20245597	11344883	
	5	650	N900000W				* 65	20245597	11344818	
	6	136230	N302110E			11756	6884	20257353	11351702	
	99							*	*	*
						93824	5490	99999999	99999999	

TRAVERSE COMPUTATIONS

Problem Type	District	Group	Batch	Traverse	Course	Area in Square Feet or Distance	Bearing	Cosine	Sine	Latitude Or Area in Acres (Error of Closure)	Departure Or Size of Delta (Error of Closure)	Coordinates North (Progressive)	Coordinates East (Totals)	[illegible]
T	13	A	50	11										
												20163529	11346212	
					1	62260	N621150W			2904	* 5507			
												20166433	11340705	
					2	211460	S123631E			* 20636	4616			
												20145797	11345321	
					3	29130	S631232W			* 1313	* 2600			
												20144484	11342721	
					4	1011360	N011311E			101113	2153			
												20245597	11344874	
					5	650	N900000W				* 65			
												20245597	11344809	
					6	136280	N302303E			11756	6893			
												20257353	11351702	
					99									
														*
												*	*	
										93824	5490	99999999	99999999	

Appendix B

Instructions for Calculation of Earthwork Data by Punched Cards

The tabulating section of the California Highway Planning Survey is now prepared to compute elevations, earthwork quantities, and mass diagram ordinates from data supplied by the districts. This service is being furnished with the intention of relieving engineering personnel from monotonous routine plotting of cross sections and calculating of earthwork data, giving them more time for actual engineering work. In preparing this service every attempt was made to make as few changes as possible in the normal approach to the problem by the engineer. The changes that do occur have been found necessary to mechanically process the data.

It is not intended to eliminate all plotting of cross sections. However, it is believed that only representative and critical sections need be plotted, and these to a much smaller scale than previously since they are not needed for quantities.

It is believed that considerable engineering time will be saved if full use is made of this service. It will be possible, for example, to use terrain data submitted for one "P" line for subsequent "P" lines and the final line. It will also be possible to process at one time several alternate lines if roadbed data is furnished. It should be unnecessary to resubmit roadbed data for subsequent lines if it would require the engineer to recopy information already available in notes previously submitted, since instructions can be given to the tabulating section to re-use portions of the roadbed data.

The necessary information, where computation of end areas is involved, is to be furnished on the Earthwork Data Sheet, Form WH-67, which may be obtained on requisition in pads of 50 sheets. Samples of this form properly filled out, are attached.

Fill in the identification blocks in the upper right hand corner of each sheet as follows:

District, County, Route, Section

Record the district in arabic numerals.

In District IV and VII, for ease in distribution, separate district numbers for use by sections submitting this work are assigned as follows:

District IV. 24 - Design - J. C. Black; 34 - Design - W. P. Smith; 44 - Design - A. E. Simmons; 54 - Design - J. A. Spence; 64 - Surveys; 74 - Administration - H. S. Miles; 84 - Construction.

District VII. 7 - Design A - J. E. Eckhardt; 17 - Design B - E. G. Hanson; 27 - Design C - L. S. Van Voorhis; 37 - R/W Engineering; 47 - Surveys; 57 - Construction.

Headquarters departments will use District 13. Division of Water Resources will use District 73.

Other sections or districts desiring special district number assignments for this work may request them from the tabulation section.

Only one county, route, and section or city may be indicated on any one sheet. Place the section or start the city in the left square of the coding blocks assigned.

Group, Line

Group and line are district designations to aid in identification and segregation of the work. Each shall consist of one letter only.

When stationing is repeated within a project, a new line letter should be assigned.

Date, Sheet, Recorder, Party

These lines are for district use as desired.

TERRAIN NOTES

Terrain notes, or original ground cross sections, may be submitted as true elevations, as rod readings, or as a difference in elevation from center or offset line. Check the appropriate box on each sheet to show the method used therein.

Sections may read either up or down the page. If there is insufficient room for all points on one line, they may be continued on the next line. Do not crowd the work. Additional lines must also be labeled as to station and all points must appear on the proper side of centerline.

A space has been provided immediately to the right of the station column for carrying the HI and elevations. If the space is used for this purpose, no cross section points should be recorded therein on that page, if not, the space may be used for additional points.

Rod readings and/or elevations may be expressed to tenths or hundredths of a foot. Horizontal distances shall be expressed to the nearest one-tenth foot and must always be from centerline. Where distances are to the even foot, the zero tenths should be shown. Use a line under the decimal figures in lieu of a decimal point.

No two horizontal distances are to be identical. In case of vertical faces, the second point shown should be one-tenth foot farther from centerline.

The thousands or hundreds of feet may be omitted from the notes if desired. However, at any one section the terrain and roadbed notes must be on the same basis.

Whenever possible a section should be shown at an equation.

Terrain notes should be submitted in sufficient widths to cover any line changes which appear probable. However, we are not prepared to handle sections extending beyond 999.9 feet either side of the centerline. It will not be necessary to resubmit terrain notes when sending in subsequent line or grade changes provided reference is made in the transmittal to the previously submitted terrain notes. Supplemental terrain notes may be submitted in the event additional cross sections are taken or it becomes necessary to cover a wider area. These notes are to be submitted in the same form as the original notes. Be sure to fully identify group, line, station, and right or left of centerline.

It is recommended that the original field notes be taken on this new form, WH-67, in the form prescribed herein so as to avoid the necessity for recopying the notes. Two sets of notes may be made by using carbon, one set to be retained in the district and one to be submitted for computations.

Elevations

Sample 1. When this box is checked, the elevation and distance of each point must be given, with no reductions necessary in Headquarters.

If additional figures are included, the top figure at any one point will be taken as the elevation and the bottom figure as the horizontal distance.

Rod Readings

Sample 2. The HI will be shown near the centerline. The notes will clearly indicate the points to which each HI applies. The HI must be repeated on each sheet.

Rod readings will be considered as negative unless marked "plus."

Where the elevations of any points on this sheet are determined by another method, notes for those points will be reduced in the district, the elevations circled, and the correct horizontal distance from centerline inserted below, as shown in the sample.

Difference from Elevation at Centerline

Sample 3. The HI for the centerline elevation will be shown below the centerline. The notes will clearly indicate the stations to which each HI applies. The HI must be repeated on each sheet.

The elevation of points other than the centerline will be shown as plus or minus from centerline elevation. Where the elevations of any points on this sheet are determined by another method, notes for these points will be reduced in the district, the elevations circled, and correct horizontal distance from centerline inserted below.

Difference from Elevation at Centerline and Δ

Sample 4. Where the notes contain setup points in addition to centerline, check the box labeled "Diff. from Elev. at ℄" and draw a Δ around ℄ as shown in Sample 4 attached. Elevations will be shown as plus or minus from centerline until a new setup is reached. Place a Δ below this point to which subsequent differences apply. All horizontal distances are to be reduced to distance from centerline in the district, and recorded as shown on the sample.

Difference from Elevation at Offset Line

Sample 5. If an offset line is used as the base, its distance right or left of centerline should be shown in the blank in front of the checked box. For example, an offset line 90 feet right of the centerline would be recorded as "90R." This offset distance will apply to all sections on the page.

The notes for points on this offset line must be reduced to true elevation. The notes for points other than the offset line will be shown as plus or minus from the elevation at the offset line. Where the elevations of any points on this sheet are determined by another method, notes for these points will be reduced in the district, the elevations circled, and the correct distances from centerline inserted below.

ROADBED NOTES

Roadbed or template notes may be submitted as true elevations or as a difference in elevation from centerline or offset line. Check the appropriate box on each sheet to show the method used therein.

Sections may read either up or down the page. If there is insufficient room for all points on one line, they may be continued on the next line or on an additional sheet. Each line must be labeled as to station and all points must appear on the proper side of centerline.

Elevations or differences in elevations may be expressed to tenths or hundredths of a foot. Horizontal distances shall be expressed to the nearest one-tenth foot and must be measured from the same centerline as the corresponding terrain notes. Where distances are to the even foot, the zero tenths should be shown. Use a line under the decimal figures in lieu of a decimal point.

No two horizontal distances are to be identical. In case of vertical faces, the second point shown should be one-tenth foot farther from centerline. In the case of a vertical match line, the same effect may be obtained by offsetting the top and bottom of the line by at least one-tenth. It is recommended that the roadbed hinge point be set in one-tenth of a foot from the desired match line and the catch point on existing ground be set one-tenth outside the match line. This should give the same quantity as a vertical match line and has the advantage that you do not have to determine and specify cut or fill for the match line. The elevation at the point where the match line touches original ground need not be given. As an example, the roadbed notes which include a match line 100 feet right of the centerline might be written as follows:

$$\frac{88^{5}}{0} \quad \frac{88^{8}}{19^{0}} \quad \frac{89^{6}}{55^{0}} \quad \frac{90^{0}}{99^{9}} \quad \frac{}{100^{1}}$$

Roadbed notes may be given to subgrade or finished grade. In the latter case, a tabulation of yards per station correction may be submitted as discussed below.

If requested in the transmittal sheet, computed catch points will be checked against any specified minimum distance from centerline and revised where necessary before computing areas.

In recording elevations the thousands and hundreds of feet may either be shown or omitted but must correspond with the terrain notes for each cross section. In general, no inspection or adjustment of datum between the two sets of notes will be made in Headquarters.

Elevations

Sample 6. Where preliminary quantities are to be computed, notes will be shown as in Sample 6. Elevation of the catch point need not be shown. In cases where the horizontal position of the catch point is set and the slope is variable, this distance will appear with the elevation blank at the last point in the section, as shown at the right side of this sample. In cases where both horizontal position and elevation are unknown, the slope will be shown beyond the hinge point and will be indicated as plus for cut or minus for fill. This situation is shown at the left side of this sample. Where the elevation and distance from centerline of the catch point is given it should be identified by an X below the distance from centerline as in Sample 7.

Sample 7. Where final quantities are to be computed after slope stakes have been set, the notes will be shown as in Sample 7. Catch points will be identified by an X below their distance from centerline. Notes for points beyond the X will be disregarded in the computations. In case additional figures are shown at any point, the top figure will be taken as the elevation and the bottom figure as the distance from centerline.

Difference from Elevation at Centerline or Offset Line

Sample 8. As an alternate to either of the preceding methods of showing roadbed notes, they may be indicated as plus or minus from the elevation at centerline or an offset line. In many cases this method will save computation or writing time. If an offset line is used as the base, its distance from centerline and right or left should be shown in the blank in front of the checked box. This offset distance will apply to all sections on the page. Where the template is sufficiently uniform, points may be shown to apply to all sections on the sheet by arrows, as shown in Sample 8. If notes read up the page, the difference from elevation at centerline and distance from ℄ should appear at each end of the ditto arrows. Points must be repeated on succeeding sheets. Additional non-uniform points may also be shown. If expressed in elevation rather than difference from centerline, the elevation must be circled as shown.

Stations need not be consecutive. If desired, notes may be segregated by types of typical section to facilitate writing.

CONTOUR AREA NOTES

Where planimetered areas have been obtained in the district from a contour-grading plan and quantities and mass-diagram ordinates are desired, the information may be submitted on the regular Quantity Sheet, Form WH-29, as shown in Sample 9, or on a similar district form. Indicate district, county, route, section, group, and line in the same manner as on terrain and roadbed notes. Stationing at the beginning and ending of each area shall be shown in the "Sum Reading" columns. Elevations of the contour areas will be shown in the "Station" column, and planimetered areas in the "Planimeter Reading" columns. Be sure that the elevation of the zero area point is shown at the beginning and end of each group of areas.

Additional quantities to be added should be identified by the beginning station of the area to which it applies.

Between station limits, more than one volume of excavation or embankment may be included provided each volume starts and ends with zero in the area column and occurs on the same sheet. Otherwise, attention should be drawn to this item in the transmittal.

TRANSMITTAL SHEET

A transmittal sheet similar to the one shown in Sample 11 should be used. The identification information in the upper right is to be filled in in the same manner as for individual sheets. Where a job contains more than one county, route, or section, each section should have a separate transmittal sheet. A separate transmittal sheet should also be used for each group or line.

If mass-diagram ordinates are to be continuous through separate transmittals, this fact should be indicated on the subsequent transmittal sheets on the line "start with mass diagram ordinate."

If contour area notes are transmitted, check the applicable box and circle the scale.

If terrain or roadbed notes, or both, are attached, check whether each is complete, a part of the job, or the final transmittal where portions have previously been sent in.

When roadbed notes are transmitted, indicate whether they are to be used with enclosed terrain notes or with terrain notes previously submitted. If the latter, be sure to fully identify the desired combination.

The mass-diagram ordinate to be used at the beginning of the line should be shown in the space provided. The capacity of listing for mass-diagram ordinate is from +9,999,999 to -9,999,999. If a mass diagram is not desired, indicate by checking the box provided.

Shrinkage factors to be applied are to be indicated by station limits.

Amounts to be added or subtracted from computed quantities for subgrade, slope rounding, ditches, etc., should be tabulated by station. Indicate whether these quantities are to be added to or subtracted from the cut or fill quantities. The mass diagram sheet, Form WH-30, is suggested as a convenient form for this tabulation. A sample of such a tabulation is shown in Sample Sheet 10. These quantities will be added following their listed station. For example, quantities given to be added at station 31 will be shown between stations 31 and 32.

Quantities which have been computed separately for divided highways, frontage roads, or other parallel construction may, when requested, be combined to give a final quantity and mass diagram tabulation. Stationing on the parallel lines must be identical or an equation given. Such combination of additional lines and miscellaneous quantities should be fully explained on the transmittal sheet.

Equations affecting the length of any lines should be listed on the transmittal sheet, as well as appearing in the notes.

Time will be saved on large projects by sending in the terrain notes or a portion of them as soon as possible. The roadbed notes may also be forwarded in portions. Instructions to calculate and combine should be sent with the final lot of roadbed notes.

In general we will be able to make horizontal and vertical shifts in roadbed notes previously submitted where the template remains the same without the necessity of new roadbed notes being submitted. Certain portions of the roadbed notes, defined either longitudinally or laterally also may be replaced with other notes without the necessity of rewriting the whole job or all of the cross section template. If you are unsure how to handle special problems of this sort, it is suggested that you request additional information on your particular job from the tabulating section of the Planning Survey.

Zero area for both cut and fill may be specified at any station.

TABULATIONS

The following tabulations will be furnished:

1. A tabulation of reduced notes for terrain and roadbed containing elevations and distances from centerline to tenths of a foot.
2. A tabulation of catch point elevations and distances from centerline.
3. A tabulation showing stations, end areas, quantities, shrinkage factors, and mass-diagram ordinates.

Sample Earthwork Data Sheets

EARTHWORK DATA SHEET

☐	PUNCHED
☐	VERIFIED

(SAMPLE #1)

ROADBED NOTES ☐ ROD READINGS ☐
TERRAIN NOTES ☑ ELEVATIONS ☑
DIFF FROM ELEV AT { ℄ ☐ / ____ ☐ }

DIST: 13 | CO: SAM | RTE: 30 | SEC: C | GROUP: B | LINE: A

Date______________ Sheet____of____
Recorder______________
Party______________

WH 67

STATION	+	+	HI		-	ELEV																				
625				$109^{5}/120^{0}$																		$79^{8}/120^{0}$		$79^{3}/100^{0}$		
625			$107^{4}/79^{0}$		$106^{4}/62^{0}$		$99^{5}/53^{0}$		$96^{3}/32^{0}$		$96^{0}/20^{0}$		$99^{3}/0$		$95^{0}/20^{0}$		$95^{3}/34^{0}$		$97^{8}/42^{0}$		$89^{3}/51^{0}$		$78^{9}/60^{0}$		$77^{5}/86^{0}$	
	50																							$80^{3}/120^{0}$		
	50		$108^{4}/120^{0}$		$106^{1}/81^{0}$		$105^{3}/61^{0}$		$99^{1}/51^{0}$		$95^{5}/24^{0}$		$98^{6}/0$		$94^{5}/21^{0}$		$95^{6}/30^{0}$		$98^{1}/45^{0}$		$81^{5}/50^{0}$		$82^{1}/73^{0}$		$82^{3}/89^{0}$	
624				$107^{5}/120^{0}$																		$94^{1}/120^{0}$		$94^{0}/100^{0}$		
624			$105^{2}/98^{0}$		$103^{1}/85^{0}$		$98^{1}/63^{0}$		$96^{3}/45^{0}$		$96^{2}/24^{0}$		$97^{5}/0$		$97^{2}/20^{0}$		$97^{1}/31^{0}$		$95^{0}/45^{0}$		$95^{2}/50^{0}$		$96^{9}/79^{0}$		$95^{2}/89^{0}$	

EARTHWORK DATA SHEET

☐	PUNCHED
☐	VERIFIED

(SAMPLE #2)

ROADBED NOTES ☐ ROD READINGS ☑
TERRAIN NOTES ☑ ELEVATIONS ☐
DIFF FROM ELEV AT { ℄ ☐ / ____ ☐ }

DIST: 13 | CO: SAM | RTE: 30 | SEC: C | GROUP: B | LINE: A

Date______________ Sheet____of____
Recorder______________
Party______________

WH 67

STATION	+	+	HI		-	ELEV																				
626 / 626	9112 / 5518																									
	50																						$12^{1}/150^{0}$		$9^{6}/120^{0}$	
								(78^{3})																		
	50							0^{5}/50 75^{0}		$+5^{2}$	$0^{9}/25^{0}$		$1^{9}/18^{0}$		$2^{5}/12^{5}$		$3^{6}/0$		$6^{9}/25^{0}$		$8^{2}/50^{0}$		$9^{2}/100^{0}$		$9^{2}/110^{0}$	
TP		1^{09}	80^{41}		13^{31}	79^{32}										HI	80^{4}									
626									$1^{9}/100^{0}$		$3^{2}/60^{0}$		$6^{1}/25^{0}$		$7^{2}/12^{5}$		$9^{8}/0$		$10^{9}/12^{5}$		$12^{3}/25^{0}$		$1^{5}/48^{0}$		$3^{8}/100^{0}$	
625	50								$+0^{6}/100^{0}$		$1^{8}/62^{0}$		$2^{8}/24^{0}$		$4^{3}/12^{5}$		$6^{0}/0$		$5^{8}/13^{0}$		$7^{2}/25^{0}$		$8^{9}/51^{0}$		$9^{3}/108^{0}$	
USC+GS #38	BM	3^{48}	92^{63}			1289^{21}										HI	92^{6}									

EARTHWORK DATA SHEET

	PUNCHED
	VERIFIED

ROADBED NOTES ☐ ROD READINGS ☐
TERRAIN NOTES ☑ ELEVATIONS ☐
DIFF. FROM ELEV. AT ℄ ☑ / ____ ☐

DIST	CO	RTE	SEC	GROUP	LINE
13	SAM	30C		B	A

Date____ Sheet___of___
Recorder____
Party____

SAMPLE 3

WH 97

STATION	+	+	HI	−	ELEV									
628						-2^{1} / 78^{0}	-3^{2} / 100							
628						-1^{8} / 63^{0}	-0^{9} / 50^{0}	$+0^{3}$ / 25^{0}	$+1^{6}$ / 15^{0}	5^{1} / 0	$+1^{8}$ / 15^{0}	$+3^{9}$ / 25^{0}	$+6^{3}$ / 50^{0}	$+7^{4}$ / 100^{0}
TP		6^{23}	76^{33}	10^{31}	70^{10}				HI	76^{3}				
	50					-3^{8} / 100^{0}	-2^{6} / 70^{0}	$+0^{2}$ / 25^{0}	$+1^{3}$ / 15^{5}	9^{1} / 0	$+3^{5}$ / 12^{5}	$+6^{3}$ / 25^{0}	$+8^{3}$ / 70^{0}	$+1^{3}$ / 100^{0}
627						-1^{5} / 71^{0}	-1^{9} / 89^{0}	-2^{6} / 100^{0}	-3^{1} / 110^{0}				-2^{3} / 100^{0}	-1^{9} / 80^{0}
627						-0^{6} / 50^{0}	$+0^{9}$ / 37^{0}	$+1^{8}$ / 24^{0}	$+2^{1}$ / 10^{0}	8^{4} / 0	$+3^{8}$ / 12^{5}	$+2^{1}$ / 24^{0}	-4^{6} / 50^{0}	-1^{3} / 60^{0}
									HI	80^{4}				

EARTHWORK DATA SHEET

	PUNCHED
	VERIFIED

ROADBED NOTES ☐ ROD READINGS ☐
TERRAIN NOTES ☑ ELEVATIONS ☐
DIFF. FROM ELEV. AT Δ ☑ / ____ ☐

DIST	CO	RTE	SEC	GROUP	LINE
13	SAM	30C		B	A

Date____ Sheet___of___
Recorder____
Party____

(Sample # 4)

WH 97

STATION	+	+	HI	−	ELEV									
630						$+3^{1}$ / 50^{0} / 100^{0} Δ	-1^{6} / 20^{0} / 120^{0}	-2^{3} / 50^{0} / 150^{0}					$+1^{3}$ / 10^{0} / 135^{0}	-1^{6} / 75^{0} / 125^{0} Δ
630						$+3^{2}$ / 25^{0} / 75^{0}	$+1^{3}$ / 15^{0} / 65^{0}	-2^{1} / 50^{0} Δ	-1^{8} / 25^{0}	9^{2} / 0	$+3^{6}$ / 25^{0}	$+2^{2}$ / 50^{0} Δ	$+1^{6}$ / 24^{0} / 74^{0}	$+1^{8}$ / 50^{0} / 100^{0}
	50												-2^{2} / 50^{0} / 100^{0}	-2^{1} / 25^{0} / 75^{0}
629	50					-2^{4} / 50^{0} / 100^{0}	-1^{2} / 25^{0} / 75^{0}	$+3^{6}$ / 50^{0} Δ	$+2^{1}$ / 12^{0}	8^{5} / 0	$+2^{5}$ / 13^{0}	$+2^{4}$ / 24^{0}	$+3^{7}$ / 50^{0} Δ	-1^{2} / 10^{0} / 60^{0}
		2^{29}	72^{60}		70^{31}				HI	72^{6}				

	PUNCHED
	VERIFIED

EARTHWORK DATA SHEET

SAMPLE 5

- ROADBED NOTES ☐
- TERRAIN NOTES ☑
- ROD READINGS ☐
- ELEVATIONS ☐
- DIFF. FROM ELEV AT { ℄ ☑ / 90R ☐ }

DIST	CO.	RTE	SEC	GROUP	LINE
1	3 5	A M 3 0 C		B	A

Date______ Sheet___of___
Recorder______
Party______

WN 67

STATION	+	+	HI	-	ELEV	Cross-section entries
TBM#2				6^{01}	70^{31}	
629						-10^{2} 135 / 45^{0}; -3^{8} 60^{0}; -5^{2} 110^{0}
						68^{1}
629						-10^{2} 130 / 40^{0}; -6^{9} 110 / 20^{0}; -5^{3} 90 / 0^{0}; -2^{9} 87 / 3^{0}; -1^{8} 50 / 40^{0}; -1^{6} 37 / 53^{0}; -0^{3} 15 / 75^{0}; 8^{2} 90^{0}; $+0^{2}$ 10 / 100^{0}
						70^{2}
628	50					-12^{6} 200 / 110^{0}; -10^{4} 150 / 60^{0}; -3^{8} 115 / 25^{0}; -4^{9} 90 / 0^{0}; -2^{8} 86 / 4^{0}; -1^{7} 37 / 53^{0}; -0^{3} 14 / 76^{0}; 6^{1} 90^{0}; $+0^{2}$ 10 / 100^{0}
						HI 76^{3}

	PUNCHED
	VERIFIED

EARTHWORK DATA SHEET

SAMPLE 6

- ROADBED NOTES ☑
- TERRAIN NOTES ☐
- ROD READINGS ☐
- ELEVATIONS ☑
- DIFF. FROM ELEV AT { ℄ ☐ / ____ ☐ }

DIST	CO.	RTE	SEC	GROUP	LINE
1	3 5	A M 3 0 C		B	A

Date______ Sheet___of___
Recorder______
Party______

WN 67

STATION	+	+	HI	-	ELEV	Entries
	50					89^{55}
						82^{0}; 61^{0}
	50		-2:1			89^{57} 58^{0}; 88^{3} 57^{0}; 88^{8} 19^{5}; 90^{25} 18^{0}; 88^{45} 0; 90^{25} 18^{0}; 88^{8} 19^{5}; 88^{34} 55^{0}; 89^{62} 55^{2}; 89^{57} 58^{2}
625			-2:1			88^{57} 58^{0}; 87^{3} 57^{0}; 87^{8} 19^{5}; 89^{25} 18^{0}; 87^{45} 0; 89^{25} 18^{0}; 87^{8} 19^{5}; 87^{34} 55^{0}; 88^{62} 55^{2}; 88^{57} 58^{0}; 82^{0}

EARTHWORK DATA SHEET

	PUNCHED
	VERIFIED

(SAMPLE #7)

ROADBED NOTES ☑ TERRAIN NOTES ☐ ROD READINGS ☐ ELEVATIONS ☑ DIFF. FROM ELEV. AT ℄ ☐ ____ ☐

DIST.	CO.	RTE.	SEC.	GROUP	LINE
13	5 AM	30	C	B	A

Date________ Sheet____of____
Recorder________
Party________

WH 67

STATION	+	1	2	3	4	5	6	7	8	9	10	11	12
626 / 626	91.12 / 55.18												
	50	73^{4} / 110^{3} X											
	50	90^{5} / 61^{0}	90^{6} / 58^{0}	90^{3} / 57^{0}	90^{8} / 19^{5}	92^{25} / 18^{0}	90^{45} / 0	92^{25} / 18^{0}	90^{8} / 19^{5}	90^{3} / 55^{0}	91^{6} / 55^{7}	90^{6} / 58^{0}	88^{6} / 82^{0} X
626		70^{0} / 112^{6} X	90^{6} / 58^{0}	89^{8} / 57^{8}	89^{8} / 19^{5}	91^{25} / 18^{0}	89^{45} / 0	91^{25} / 18^{0}	89^{8} / 19^{5}	89^{3} / 55^{0}	90^{6} / 55^{7}	89^{6} / 58^{0}	87^{3} / 82^{0} X

EARTHWORK DATA SHEET

	PUNCHED
	VERIFIED

(SAMPLE #8)

ROADBED NOTES ☑ TERRAIN NOTES ☐ ROD READINGS ☐ ELEVATIONS ☐ DIFF. FROM ELEV. AT ℄ ☑ ____ ☐

DIST.	CO.	RTE.	SEC.	GROUP	LINE
13	5 AM	30	C	B	A

Date________ Sheet____of____
Recorder________
Party________

WH 67

STATION	+	1	HI	2	3	4	5	6	7	8	9	10	11	12
627		−2:1 ↓		$+1^{14}$ / 58^{0} ↓	-0^{15} / 57^{0} ↓	$+0^{35}$ / 19^{5} ↓	$+1^{8}$ / 18^{0} ↓	91^{45} / 0	$+1^{8}$ / 18^{0} ↓	$+0^{35}$ / 19^{5} ↓	-0^{11} / 55^{0} ↓	$+1^{12}$ / 55^{7} ↓	$+1^{14}$ / 58^{0} ↓	−2:1 ↓
	50		(93^{5}) / 68^{0}					92^{45} / 0						
628			(94^{5}) / 68^{0}	$+1^{04}$ / 58^{0}				93^{45} / 0						
635				$+1^{14}$ / 58^{0} ↓				90^{65} / 0						82^{0} ↓
	50							89^{15} / 0						
636								87^{65} / 0						
	50							86^{15} / 0						
637								84^{65} / 0						

FORM WH 29A

QUANTITY SHEET STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS—DIVISION OF HIGHWAYS

Dist 13 County SAM Route 30 Section C Group B Line A Sheet No

Date
Date

(Sample #9)

STATION	EXCAVATION: PLANIMETER READING	EXCAVATION: SUM READING	EXCAVATION: LENGTH FEET	EXCAVATION: QUANTITY CUBIC YARDS	STATION CUBIC YARDS	EMBANKMENT: PLANIMETER READING	EMBANKMENT: SUM READING	EMBANKMENT: LENGTH FEET	EMBANKMENT: QUANTITY CUBIC YARDS	STATION CUBIC YARDS
42	0	~~88~~			20	0	88			
44	1.04				22	12.95				
46	3 50				24	13.09				
48	5 10				26	13.84				
50	5 14				28	14.50				
52	5.05				30	14.86				
54	4.96				32	15.21				
56	4.81				34	15.13				
58	4.76				36	14.94				
60	4.53				38	14.86				
62	4.20				40	13.52				
64	3.87				42	9.20				
66	2.80				44	3.25				
68	1.91				46	0.05				
70	0.79				46 3/	0				
72	0 02									
72 5/	0									
		92					92			
45 5/	0									
46	0.50									
48	1.15									
50	1.25									
52	1.36									
54	1.52									
56	1.48									
58	1.32									
60	0 75				none					
62	0									
45 8/	0									
46	0 04									
48	0 95									
50	1.21									
52	1.37									
54	1 50									
56	1.61									
58	1.38									
60	1.10									
62	0.78									
64	0.25									
66	0									
		96					96			
		TOTAL CU YDS					TOTAL CU YDS			

Calculated by
Checked by

SAMPLE 10

MASS DIAGRAM SHEET

CALCULATED BY *Additions for Quantities* ____ 19__

CHECKED BY ____ 19

Dist	13
	SAM
Route	30
Sec.	C

Sta	Exc C.Y	Swell or Shrinkage %	Applied Exc C.Y.		Emb C.Y		Algebraic Sum		Group Line	B A
	←	Cut	→		←	Fill →				
	Subgrade	Ditch	Slope	Round	Subgrade		Front Rd			
650	+32		+5							
651	↓		↓							
652	↓		↓							
653	↓		↓							
654	↓		↓							
655	↓		↓							
656	↓		↓							
657	↓		↓				+36			
658	↓		↓				+34			
659	+16									
660		+16			-30					
661		+78			-34					
662		+35			↓					
663					↓					

☐	Punched
☐	Verified

(SAMPLE #11)

Dist.	Co.	Rte.	Sec.	Group	Line
13	SAM	30	C	B	A

FROM: District 13

TO: CHPS Tabulating Section

Enclosed are the following data for yardage calculations

Contour Area Sheets ☐ Map Scale 1" = 50' - 100'

Terrain Notes - Complete ☐ Partial ☐ Final ☑

Roadbed Notes - Complete ☑ Partial ☐ Final ☐

To be combined with enclosed terrain notes ☐

To be combined with terrain notes for *Group B, Line A - part enclosed and part* previously submitted.

Start with Mass Diagram ordinate *100,000*

Do not calculate Mass Diagram ☐

Shrinkage factors to be used are:

0.85	from Station	625	to Station	651
0.90	" "	651	" "	690
	" "		" "	
	" "		" "	
	" "		" "	
	" "		" "	
	" "		" "	
	" "		" "	
	" "		" "	
	" "		" "	

Remarks: *Equation 626+55.18 BK = 626+91.12 Ah*
Run quantities for Group B Line A, then run final tabulation combining this with Group B, Line B

THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the ACADEMY and the government, although the ACADEMY is not a governmental agency.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government designated by the President of the United States, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY-COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.