Six-State Classification Study of Engineering Personnel

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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 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
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.