HIGHWAY RESEARCH BOARD
Bulletin 164

Manpower Potentials in Highway Engineering

National Academy of Sciences—
National Research Council
publication 524

HIGHWAY RESEARCH BOARD

Officers and Members of the Executive Committee

1957

Editorial Staff

FRED BURGGRAF ELMER M. WARD HERBERT P. ORLAND

2101 Constitution Avenue Washington 25, D. C.

HIGHWAY RESEARCH BOARD
Bulletin 164

Manpower Potentials in Highway Engineering

PRESENTED AT THE
Thirty-Sixth Annual Meeting
January 7-11, 1957

1957
Washington, D. C.

Department of Economics, Finance and Administration

Guilford P. St. Clair, Chairman
Chief, Financial and Administrative Research Division, Office of Research
Bureau of Public Roads

COMMITTEE ON HIGHWAY ORGANIZATION AND ADMINISTRATION

Harmer E. Davis, Chairman
Director, Institute of Transportation and Traffic Engineering
University of California, Berkeley

James M. Montgomery, Secretary
Bureau of Public Roads

A. K. Branham, Joint Highway Research Project, Purdue University, Lafayette, Ind.

D. H. Bray, State Highway Engineer, Kentucky Department of Highways, Frankfort

W. A. Bugge, Director, Washington Department of Highways, Olympia

Clint Burnes, Assistant Traffic and Planning Engineer, Minnesota Dept. of Highways

Howard Bussard, Automotive Safety Foundation

Ellis Danner, Professor, University of Illinois, Urbana

Theodore G. Driscoll, Assistant Director, The Council of State Governments, Washington, D. C.

W. L. Haas, Director of Administration, State Highway Commission of Wisconsin

Norman Hebden, Capital Improvements Administrator, Maryland State Planning Commission, Baltimore

A. E. Johnson, Executive Secretary, American Association of State Highway Officials

G. Donald Kennedy, President, Portland Cement Association, Chicago

A. C. Leonard, Chief,Secondary Road Division, Office of Engineering, Bureau of Public Roads

Ralph S. Lewis, USOM/TCP Box 32, Navy 150-c/o FPO, San Francisco, Calif.

Ben F. Ostergren, Manager, County and Municipal Division, American Road Builders' Association

L. R. Schureman, Bureau of Public Roads

Keith L. Seegmiller, Executive Secretary, National Association of County Officials

John E. Stoner, Professor, Department of Government, Indiana University, Bloomington

A. J. Thelen, Executive Secretary, Wisconsin County Boards Association, Madison

W. S. Ward, Daviess County Highway Engineer, Courthouse, Washington, Indiana

Contents

1956 Inventory of State Highway Engineering Manpower

JAMES M. MONTGOMERY, Bureau of Public Roads

During the past few years several attempts have been made to obtain a complete and accurate count of state highway department engineering manpower. Previously reported data were in some cases inconsistent due to variations in the classification methods among the states and also due to different interpretations of the several questionnaire forms used. It was apparent that an accurate tabulation of engineering employees was desirable as part of the over-all effort in connection with the present shortage of engineers.

The present study indicates that previous reports have had a reasonably accurate nationwide total for engineers, but the figures reported for individual states vary widely in some instances from those reported in other studies. In addition, the number of engineering aids employed has not been reported previously. As of March 1956, according to the present study, the states employed 20,551 engineers, which total compares favorably with a figure of 21,229 reported by Professor Danner of the University of Illinois as of December 31, 1955. The states also employed 25,911 engineering aids, or a ratio of approximately 1.3 aids per engineer. As of July 1956, the states estimated that they would employ 21,435 engineers and 30,879 aids, the ratio of aids to engineers increasing to more than 1.4. These ratios are somewhat higher than that of one aid employed for each engineer reported in a study of six selected states made in 1955. The regional pattern for the ratio of engineering aids to engineers shows that in general the New England, Mid-Atlantic, East North Central and Pacific regions employ more engineers than aids, whereas in the remaining regions just the reverse is true.

It was also found that of the total engineers employed about 39 percent were neither registered nor graduates, while an additional 17 percent were registered but not graduates. Only one engineer out of five was both a civil engineering graduate and registered.

●THE TITLE of this paper could just as well be "A Further Analysis of State Highway Engineering Manpower," since the information presented supplements that reported by Campbell and Schureman (1) for the year 1954 and by Lewis (2) for the year 1955. The latter article pointed up the need for better information as to the number of engineers and aids employed in each state, and in fact suggested that no one really knows just how many engineers and aids are employed by the several state highway departments. This lack of knowledge is especially critical today in view of the current dearth of engineers in the face of a greatly accelerated highway program.

To meet this deficiency the Highway Research Board prepared and distributed to each state a form for the presentation of uniform information on the several categories of engineers and engineering aids employed by the state highway departments. This form reproduced as Appendix A, requested actual data as of March 1, 1956, and estimated data as of July 1, 1956.

In most cases the states responded with complete information. In several cases, however, it was necessary to make estimates either for the March or the July figures, and in two cases where only totals were given, it was necessary to estimate the number of employees in the several categories which together comprise the totals. That part of the information which is presented state-by-state in the tables shows only those figures reported by each state. Estimates were made for the missing data, but are reflected here only in national totals. The estimates made are based on those figures which were reported by a state as well as the average change indicated by states reporting complete information. In addition, one state did not respond to the question-

Table 1 -- State highway department engineering employees 1/

As of March 1, 1956

State	Classified as engineers									Classified as engineering aids					Total state engineering employees	Equivalent consultant engineers employed 2/	Total engineering personnel equivalent
	Civil engineers				Other engineers				Total engineers								
	Both a graduate and registered	Graduate only	Registered only	Total	Both a graduate and registered (Other than civil)	Graduate only (Other than civil)	Neither graduate nor registered (In any branch)	Total other		Both a graduate and registered civil engineer	Graduate civil engineer only	Registered engineer only	Neither graduate nor registered	Total engineering aids			
Alabama	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arizona	30	-	23	53	3	-	-	3	56	-	10	1	493	504	560	-	560
Arkansas	42	10	36	88	4	3	42	49	137	4	3	5	375	387	524	-	524
California	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Colorado	20	18	120	158	18	19	134	171	329	-	-	-	438	438	767	1	768
Connecticut	41	75	40	156	2	11	544	557	713	-	-	-	235	235	948	1,350	2,298
Delaware	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Florida	57	57	35	149	3	2	198	203	352	-	-	-	1,183	1,183	1,535	-	1,535
Georgia	58	35	92	185	8	13	375	396	581	1	4	2	1,230	1,237	1,818	-	1,818
Idaho	33	35	36	104	3	3	29	35	139	-	-	-	453	453	592	3/	592
Illinois	306	333	203	842	-	111	101	212	1,054	-	-	-	151	151	1,205	100	1,305
Indiana	270	80	-	350	10	-	-	10	360	-	-	-	169	169	529	3/	529
Iowa	112	18	92	222	-	-	-	-	222	-	-	-	745	745	967	-	967
Kansas	129	23	114	266	11	21	12	44	310	-	-	5	557	562	872	23	895
Kentucky	62	35	148	245	5	9	318	332	577	-	-	-	584	584	1,161	50	1,211
Louisiana	80	-	225	305	-	-	-	-	305	-	-	14	910	924	1,229	75	1,304
Maine	63	33	30	126	10	13	21	44	170	-	-	-	57	57	227	2	229
Maryland	7	36	36	79	1	2	308	311	390	-	1	-	372	373	763	13	776
Massachusetts	-	-	-	-	-	-	-	-	(600)	-	(10)	-	(1,054)	(1,064)	(1,664)	(450)	(2,114)
Michigan	107	156	31	294	7	17	181	205	499	-	-	-	800	800	1,299	-	1,299
Minnesota	196	37	146	379	3	6	217	226	605	-	-	-	635	635	1,240	-	1,240
Mississippi	60	6	21	87	18	-	1	19	106	11	9	4	566	590	696	-	696
Missouri	127	116	137	380	-	-	263	263	643	-	-	-	725	725	1,368	218	1,586
Montana	16	13	64	93	-	11	100	111	204	-	2	-	281	283	487	-	487
Nebraska	27	28	70	125	-	11	105	116	241	-	1	2	222	225	466	40	506
Nevada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Hampshire	43	52	22	117	-	5	93	98	215	-	-	22	98	120	335	25	360
New Jersey	-	-	-	-	-	-	-	-	(425)	-	-	-	-	(77)	(502)	-	(502)
New Mexico	26	-	22	48	-	-	-	-	48	-	30	-	490	520	568	-	568
New York	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
North Carolina	17	124	20	161	-	10	277	287	448	-	-	-	608	608	1,056	-	1,056
North Dakota	28	11	24	63	4	6	46	56	119	-	-	-	45	45	164	2	166
Ohio	336	54	261	651	-	-	-	-	651	-	-	-	1,306	1,306	1,957	3/	1,957
Oklahoma	39	10	38	87	5	14	34	53	140	1	2	-	565	568	708	40	748
Oregon	56	57	48	161	-	55	293	348	509	-	-	-	278	278	787	-	787
Pennsylvania	24	31	51	106	3	16	401	420	526	2	4	2	1,047	1,055	1,581	3/	1,581
Rhode Island	12	6	16	34	1	10	40	51	85	-	-	-	109	109	194	-	194
South Carolina	23	92	2	117	-	11	136	147	264	-	1	-	444	445	709	-	709
South Dakota	14	29	6	49	-	3	32	35	84	-	-	-	363	363	447	-	447
Tennessee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Texas	522	176	215	913	-	-	-	-	913	-	-	-	2,755	2,755	3,668	-	3,668
Utah	-	-	-	-	-	-	-	-	(55)	-	-	-	-	(99)	(154)	-	(154)
Vermont	27	37	17	81	4	12	62	78	159	-	-	-	46	46	205	28	233
Virginia	25	47	62	134	-	-	213	213	347	-	2	-	763	765	1,112	45	1,157
Washington	57	123	50	230	5	42	336	383	613	-	4	-	364	368	981	-	981
West Virginia	32	-	49	81	-	-	-	-	81	-	-	-	191	191	272	12	284
Wisconsin	70	142	50	262	16	27	88	131	393	-	-	-	349	349	742	-	742
Wyoming	35	3	45	83	-	-	10	10	93	-	10	4	151	165	258	-	258
District of Columbia	6	26	4	36	-	3	42	45	81	-	-	-	77	77	158	-	158
Totals for States fully classified	3,235	2,164	2,701	8,100	144	466	5,052	5,662	13,762	19	83	61	21,230	21,393	35,155	2,024	37,179
Estimated grand totals	4,287	3,655	3,477	11,419	182	945	8,005	9,132	20,551	19	107	63	25,722	25,911	46,462	3/2,476	48,938

1/ Detail figures reported by the several State highway departments. Items shown in parentheses are not included in fully classified totals since a complete classification was not given by the State.

2/ Includes engineering aids in Kansas and Missouri

3/ Idaho, Indiana, Ohio and Pennsylvania gave the number of firms employed rather than the equivalent engineering personnel. No estimate has been made for these States.

Table 2. -- State highway department engineering employees 1/

As of July 1, 1956

State	Classified as engineers: Civil engineers: Both a graduate and registered	Classified as engineers: Civil engineers: Graduate only	Classified as engineers: Civil engineers: Registered only	Classified as engineers: Civil engineers: Total	Classified as engineers: Other engineers: Both a graduate and registered (Other than civil)	Classified as engineers: Other engineers: Graduate only (Other than civil)	Classified as engineers: Other engineers: Neither graduate nor registered (In any branch)	Classified as engineers: Other engineers: Total other	Classified as engineers: Total engineers	Classified as engineering aids: Both a graduate and registered civil engineer	Classified as engineering aids: Graduate civil engineer only	Classified as engineering aids: Registered engineer only	Classified as engineering aids: Neither graduate nor registered	Classified as engineering aids: Total engineering aids	Total State engineering employees
Alabama	32	16	11	59	-	-	485	485	544	-	-	-	957	957	1,501
Arizona	33	-	27	60	-	-	-	-	60	-	15	1	663	679	739
Arkansas	50	15	40	105	1	5	50	56	161	10	5	15	375	405	566
California	488	1,001	330	1,819	13	331	1,554	1,898	3,717	-	-	-	1,672	1,672	5,389
Colorado	20	18	120	158	18	19	134	171	329	-	-	-	488	488	817
Connecticut	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Delaware	15	15	6	36	-	-	9	9	45	-	-	-	183	183	228
Florida	-	-	-	-	-	-	-	-	-	-	-	-	(1,283)	(1,283)	-
Georgia	(65)	(46)	(97)	(208)	-	-	-	(418)	(626)	(1)	(4)	(2)	(1,546)	(1,553)	(2,179)
Idaho	(33)	(48)	(36)	(117)	-	-	-	(35)	(152)	-	-	-	(500)	(500)	(652)
Illinois	(306)	(350)	(203)	(859)	-	-	-	(216)	(1,075)	-	-	-	(251)	(251)	(1,326)
Indiana	273	94	-	367	10	-	-	10	377	-	-	-	235	235	612
Iowa	112	18	92	222	-	-	-	-	222	-	-	-	745	745	967
Kansas	(136)	(33)	(114)	(283)	-	-	-	(44)	(327)	-	-	(5)	(745)	(750)	(1,077)
Kentucky	(55)	(34)	(148)	(237)	-	-	-	(340)	(577)	-	-	-	(746)	(740)	(1,323)
Louisiana	90	-	225	315	-	-	-	-	315	-	-	14	950	964	1,279
Maine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maryland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Massachusetts	-	-	-	-	-	-	-	-	(610)	-	(20)	-	(1,180)	(1,200)	(1,810)
Michigan	(107)	(166)	(31)	(304)	-	-	-	(194)	(498)	-	-	-	(1,000)	(1,000)	(1,498)
Minnesota	(193)	(40)	(146)	(379)	-	-	-	(226)	(605)	-	-	-	(650)	(650)	(1,255)
Mississippi	60	13	21	94	19	-	1	20	114	11	9	4	566	590	704
Missouri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montana	(21)	(17)	-	-	-	-	-	-	(246)	-	(8)	-	(405)	(413)	(659)
Nebraska	-	-	-	-	-	-	-	-	(255)	-	-	-	-	(300)	(555)
Nevada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New Hampshire	(55)	(70)	(26)	(151)	-	-	-	(144)	(295)	-	-	(28)	(144)	(172)	(467)
New Jersey	-	-	-	-	-	-	-	-	(425)	-	-	-	-	(77)	(502)
New Mexico	29	-	25	54	-	-	-	-	54	-	35	-	500	535	589
New York	208	170	141	519	21	77	711	809	1,328	-	18	3	854	875	2,203
North Carolina	(17)	(128)	(20)	(165)	-	-	-	(293)	(458)	-	-	-	(683)	(683)	(1,141)
North Dakota	(28)	(16)	(24)	(68)	-	-	-	(56)	(124)	-	-	-	(200)	(200)	(324)
Ohio	336	54	261	651	-	-	-	-	651	-	-	-	1,579	1,579	2,230
Oklahoma	(43)	(12)	(40)	(95)	-	-	-	(60)	(155)	(2)	(5)	-	(600)	(607)	(762)
Oregon	(72)	(72)	(58)	(202)	-	-	-	(383)	(585)	-	-	-	(333)	(333)	(918)
Pennsylvania	-	-	-	-	-	-	-	-	(566)	(3)	(4)	(3)	(1,056)	(1,066)	(1,632)
Rhode Island	(12)	(6)	(16)	(34)	-	-	-	(51)	(85)	-	-	-	(111)	(111)	(196)
South Carolina	(23)	(98)	(2)	(123)	-	-	-	(149)	(272)	-	(1)	-	(469)	(470)	(742)
South Dakota	(14)	(33)	(6)	(53)	-	-	-	(35)	(88)	-	-	-	(527)	(527)	(615)
Tennessee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Texas	522	196	215	933	-	-	-	-	933	-	-	-	3,255	3,255	4,188
Utah	-	-	-	-	-	-	-	-	(58)	-	-	-	(120)	(120)	(178)
Vermont	(26)	(37)	(17)	(80)	-	-	-	(98)	(178)	-	-	-	(91)	(91)	(269)
Virginia	26	49	62	137	-	-	213	213	350	-	2	-	877	879	1,229
Washington	(58)	(124)	(50)	(232)	-	-	-	(386)	(618)	-	(6)	-	(457)	(463)	(1,081)
West Virginia	32	-	49	81	-	-	-	-	81	-	-	-	220	220	301
Wisconsin	(75)	(150)	(55)	(280)	-	-	-	(131)	(411)	-	-	-	(675)	(675)	(1,086)
Wyoming	38	3	47	88	-	-	10	10	98	-	16	4	165	185	283
District of Columbia	(6)	(26)	(4)	(36)	-	-	(45)	(81)	-	-	-	-	(77)	(77)	(158)
Totals for States fully classified	2,364	1,662	1,672	5,698	82	432	3,167	3,681	9,379	21	100	41	14,284	14,446	23,825
Estimated grand totals	4,418	3,908	3,574	11,900	180	983	8,372	9,535	21,435	27	150	82	30,620	30,879	52,314

1/ Detail figures reported by the several State highway departments Items shown in parentheses are not included in fully classified totals since a complete classification was not given by the State naire at all and one other state could not supply any data, so that it was necessary to make complete estimates for these states. In spite of these and perhaps other shortcomings it is believed that the present inventory of state highway engineering manpower is about as accurate as can be obtained.

NUMBER OF ENGINEERING EMPLOYEES

Tables 1 and 2 present the results of the 1956 study of state highway department engineering manpower in summary form. As shown in Table 1, the estimated total number of engineering employees as of March 1, 1956, was 46,462, consisting of 20,551 employees classified as engineers and 25,911 employees classified as engineering aids. The ratio of aids to engineers was therefore 1.26.

According to Table 2, the corresponding estimated total number of engineering employees as of July 1, 1956, was 52,314, consisting of 21,435 engineers and 30,879 aids. The increase in total engineering employees, then, was 12.6 percent; engineers and aids increased 4.3 and 19.2 percent, respectively. The ratio of aids to engineers increased to 1.44.

Table 3 presents summary information on engineers and aids employed. Although the July figures show substantial increases over those of March, it must be remembered that these can be attributed in large part to temporary employees hired for the summer construction season only. Also, some of the increases estimated by the states may reflect some wishful thinking. Several states did not estimate increases, and one showed an estimated decrease, for the period indicated.

It is obvious that additional technical talent should be obtained to modernize our highway plant, but finding and keeping such talent is another matter indeed. Several states mentioned during the course of the study that they are losing engineers faster than they are recruiting them. Maine, for example, lost 24 members of its engineering staff between January and October; three of these retired, but the rest went to private industry. To replace them the state has been able to recruit only one engineering aid (a college graduate just returned from service) and three high school graduates. Similarly, New Hampshire lost more than 15 engineering employees during the early part of 1956.

Table 4 shows the number of engineering employees assigned to maintenance work. Some states did not complete this part of the form, but estimates have been made for the missing information. The total of 1,298 engineers as of March 1, 1956 is approximately 13 percent greater than the 1,151 reported by Campbell and Schureman for 1954. Total engineering employees assigned to maintenance as of March 1, 1956 was 2,082 as compared with 2,164 for July 1, 1956.

The information pertaining to consultants shown in Table 1 (similar information is not included in Table 2 because only one figure was requested for consultants) is also open to some question. Some of the states reported the number of consulting firms retained rather than the equivalent engineering employees, and some did not report this item at all. Accordingly, the engineering effort expended through consultants is undoubtedly greater than that indicated.

The data reported as to the number of engineers and aids employed by the state highway departments, however, is probably as good as can be obtained in view of the widely varying employee classification plans of the several states. The total number of engineering aids has not been reported in recent years, so far as is known, and the total number of engineers is believed to be a better figure than has been available previously.

For purposes of comparison, and to emphasize the uncertainty which has existed with respect to the number of engineers employed by state highway departments, Table 5 shows the number of engineers reported as employed by the state highway departments in a number of previous studies. It should be noted that Danner's data as of December 31, 1955, compare favorably with the March 1, 1956, figures of this study in total, although wide variations exist in individual states. New Mexico and Utah are two cases in point; in each case the figures reported to Danner are approximately three times as large as those reported to the Highway Research Board only two months later.

Table 3.--State highway department engineering personnel

State	March 1, 1956			July 1, 1956		
	Engineers	Aids	Total	Engineers	Aids	Total
Alabama	-	-	-	544	957	1,501
Arizona	56	504	560	60	679	739
Arkansas	137	387	524	161	405	566
California	-	-	-	3,717	1,672	5,389
Colorado	329	438	767	329	488	817
Connecticut	713	235	948	-	-	-
Delaware	-	-	-	45	183	228
Florida	352	1,183	1,535	-	-	-
Georgia	581	1,237	1,818	626	1,553	2,179
Idaho	139	453	592	152	500	652
Illinois	1,054	151	1,205	1,075	251	1,326
Indiana	360	169	529	377	235	612
Iowa	222	745	967	222	745	967
Kansas	310	562	872	327	750	1,077
Kentucky	577	584	1,161	577	746	1,323
Louisiana	305	924	1,229	315	964	1,279
Maine	170	57	227	-	-	-
Maryland	390	373	763	-	-	-
Massachusetts	600	1,064	1,664	610	1,200	1,810
Michigan	499	800	1,299	498	1,000	1,498
Minnesota	605	635	1,240	605	650	1,255
Mississippi	106	590	696	114	590	704
Missouri	643	725	1,368	-	-	-
Montana	204	283	487	246	413	659
Nebraska	241	225	466	255	300	555
Nevada	-	-	-	-	-	-
New Hampshire	215	120	335	295	172	467
New Jersey	425	77	502	425	77	502
New Mexico	48	520	568	54	535	589
New York	-	-	-	1,328	875	2,203
North Carolina	448	608	1,056	458	683	1,141
North Dakota	119	45	164	124	200	324
Ohio	651	1,306	1,957	651	1,579	2,230
Oklahoma	140	568	708	155	607	762
Oregon	509	278	787	585	333	918
Pennsylvania	526	1,055	1,581	566	1,066	1,632
Rhode Island	85	109	194	85	111	196
South Carolina	264	445	709	272	470	742
South Dakota	84	363	447	88	527	615
Tennessee	-	-	-	-	-	-
Texas	913	2,755	3,668	933	3,255	4,188
Utah	55	99	154	58	120	178
Vermont	159	46	205	178	91	269
Virginia	347	765	1,112	350	879	1,229
Washington	613	368	981	618	463	1,081
West Virginia	81	191	272	81	220	301
Wisconsin	393	349	742	411	675	1,086
Wyoming	93	165	258	98	185	283
District of Columbia	81	77	158	81	77	158
Totals for States reporting	14,842	22,633	37,475	18,749	27,481	46,230
Estimated grand totals	20,551	25,911	46,462	21,435	30,879	52,314

Table 4.--State highway department engineering employees assigned to maintenance

State	March 1, 1956			July 1, 1956		
	Engineers	Aids	Total	Engineers	Aids	Total
Alabama	-	-	-	-	-	-
Arizona	-	-	-	-	-	-
Arkansas	28	-	28	37	-	37
California	-	-	-	71	-	71
Colorado	-	-	-	-	-	-
Connecticut	-	-	-	-	-	-
Delaware	-	-	-	5	7	12
Florida	33	-	33	-	-	-
Georgia	27	5	32	27	5	32
Idaho	42	-	42	42	-	42
Illinois	85	1	86	85	10	95
Indiana	21	16	37	21	25	46
Iowa	36	-	36	36	-	36
Kansas	11	-	11	11	-	11
Kentucky	30	-	30	30	-	30
Louisiana	46	-	46	46	-	46
Maine	2	-	2	-	-	-
Maryland	26	-	26	-	-	-
Massachusetts	53	37	90	53	37	90
Michigan	17	-	17	17	-	17
Minnesota	20	-	20	20	-	20
Mississippi	10	41	51	10	41	51
Missouri	36	-	36	-	-	-
Montana	11	-	11	12	-	12
Nebraska	-	-	-	-	-	-
Nevada	-	-	-	-	-	-
New Hampshire	12	-	12	18	-	18
New Jersey	6	-	6	6	-	6
New Mexico	11	10	21	11	10	21
New York	-	-	-	131	20	151
North Carolina	36	48	84	36	48	84
North Dakota	6	-	6	6	-	6
Ohio	35	26	61	35	26	61
Oklahoma	11	-	11	11	-	11
Oregon	27	2	29	27	2	29
Pennsylvania	28	-	28	30	-	30
Rhode Island	4	-	4	4	-	4
South Carolina	54	-	54	54	-	54
South Dakota	1	-	1	1	-	1
Tennessee	-	-	-	-	-	-
Texas	17	300	317	17	300	317
Utah	7	6	13	7	6	13
Vermont	23	1	24	25	1	26
Virginia	-	-	-	-	-	-
Washington	9	-	9	9	-	9
West Virginia	15	90	105	15	90	105
Wisconsin	21	33	54	21	50	71
Wyoming	5	-	5	5	-	5
District of Columbia	2	-	2	2	-	2
Totals for States reporting	864	616	1,480	994	678	1,672
Estimated grand totals	**1,298**	**784**	**2,082**	**1,336**	**828**	**2,164**

Table 5.--Comparison of number of engineers reported employed by State highway departments in recent years

State	Highway Research Board March 1, 1956		Prof. Danner Dec. 31, 1955	Campbell-Schureman 1954 1/	Information from State highway departments 1950
	Civil graduate and/or registered	Total engineers			
Alabama	-	-	403	403	665
Arizona	53	56	53	59	504
Arkansas	88	137	120	69	233
California	-	-	3,451	3,388	2,462
Colorado	158	329	328	147	248
Connecticut	156	713	402	163	526
Delaware	-	-	70	67	52
Florida	149	352	693	137	540
Georgia	185	581	524	329	993
Idaho	104	139	130	63	75
Illinois	842	1,054	1,002	1,131	857
Indiana	350	360	368	316	312
Iowa	222	222	336	360	212
Kansas	266	310	317	338	364
Kentucky	245	577	617	252	1,047
Louisiana	305	305	309	276	284
Maine	126	170	174	68	125
Maryland	79	390	350	165	397
Massachusetts	-	2/ (600)	702	742	877
Michigan	294	499	601	407	572
Minnesota	379	605	530	247	466
Mississippi	87	106	111	111	259
Missouri	380	643	702	470	491
Montana	93	204	214	85	145
Nebraska	125	241	239	245	230
Nevada	-	-	89	76	65
New Hampshire	117	215	237	200	103
New Jersey	-	2/ (425)	420	479	551
New Mexico	48	48	124	73	132
New York	-	-	1,377	1,839	1,856
North Carolina	161	448	437	284	2,726
North Dakota	63	119	63	61	61
Ohio	651	651	636	654	537
Oklahoma	87	140	115	115	222
Oregon	161	509	495	452	656
Pennsylvania	106	526	480	300	235
Rhode Island	34	85	73	43	198
South Carolina	117	264	241	230	200
South Dakota	49	84	91	79	87
Tennessee	-	-	216	560	366
Texas	913	913	922	875	1,904
Utah	-	2/ (55)	175	78	176
Vermont	81	159	158	153	50
Virginia	134	347	360	376	500
Washington	230	613	966	206	256
West Virginia	81	81	226	76	399
Wisconsin	262	393	398	422	328
Wyoming	83	93	92	74	204
District of Columbia	36	81	92	48	114
Totals for States reporting to Highway Research Board	8,100	13,762	-	-	-
Totals including estimates	11,419	20,551	21,229	17,791	24,862

1/ Registered professional engineers or those qualified to register.

2/ Not included in totals for States reporting since information as to graduates or registered was not reported.

GRADUATE AND REGISTERED ENGINEERS

Referring again to Tables 1 and 2, of the 20,551 engineers employed as of March 1, 1956, approximately 21 percent were both civil engineering graduates and registered civil engineers. An additional 17 percent were registered civil engineers but were not civil engineering graduates, and another 18 percent were civil engineering graduates but not registered civil engineers. Still another 5 percent were graduates of or registered in branches of engineering other than civil, so that approximately 39 percent of all employees classified as engineers were neither registered engineers nor engineering graduates. A similar situation exists with respect to engineers employed as of July 1, 1956, but since the July figures are based on estimates, they are probably of less interest than the March figures.

Including those classified as engineers and also those classified as aids, 9,195 engineering graduates were employed by the 48 state highway departments and the District of Columbia as of March 1, 1956. Of this total, 8,068 were civil engineering graduates and 1,127 were engineering graduates in branches other than civil. In the past it was the practice in many states to employ young graduate engineers as engineering aids during their initial assignments, and apparently about one-third of the states still follow this procedure to some degree, as 126 of the engineering graduates employed were classified as aids.

Table 6 shows for each state the percentage of graduate and registered civil engineers included in the total number of classified engineers employed. Only 38.6 percent of the total classified engineers employed by all states are graduate civil engineers, and only 37.8 percent are registered civil engineers; the percentages for indivídaul states vary from 10.5 to 97.2 in the case of graduate engineers and from 8.3 to 100 percent in the case of registered engineers. The columns of Table 6 are non-additive, because some engineers are both graduates and registered, but from Table 1 it can be seen that only 55.6 percent of all classified engineers employed are civil engineering graduates and/or registered civil engineers; probably this is one of the most significant findings of the present study.

There seems to be little relation between the percentage of civil engineering graduates and either the amount of capital outlay or the geographical location of a particular state. Texas, for example, has one of the highest percentages of graduate civil engineers, 76.5, whereas Pennsylvania has one of the lowest, 10.5; Ohio, adjacent to Pennsylvania, shows a percentage of 59.9. Of the states with low capital outlays, Maine, for example, has 56.5 percent graduate civil engineers, but Montana has only 14.2 percent. Similarly, there appears to be little relation between the percentage of registered civil engineers and either the amount of capital outlay or geographical location.

It is interesting to note that in three states (Louisiana, New Mexico, and West Virginia) 100 percent of the employees classified as engineers are registered civil engineers. In these same states the percentages of graduate civil engineers are 26.2, 54.2, and 39.5, respectively. Several other states show more than 90 percent of their engineer employees as registered, and probably require registration as a prerequisite to classification as an engineer, except in the case of young graduate engineers without the experience necessary for registration.

RATIO OF AIDS TO ENGINEERS

As stated previously, the ratio of aids to engineers for state highway department engineering employees was 1.26 in March 1956 and 1.44 in July. There were wide variations among the states, as shown in Table 7. In March the variation was from 10.83 in New Mexico to 0.14 in Illinois, and in July it was from 11.32 in Arizona to 0.18 in New Jersey. Unfortunately there is no obvious explanation for these wide variations.

A regional pattern is apparent, however, as indicated by Tables 8 and 9. In March the New England, Middle Atlantic, East North Central and Pacific regions each employed more engineers than aids, whereas in each of the other regions the reverse was true. In July the same situation prevailed, except in the case of the East North Central region, which then employed more aids than engineers although the ratio of aids to

Table 6.--Percentages of graduate and registered civil engineers among total classified engineers employed

As of March 1, 1956

State	Graduate civil engineers		Registered civil engineers	
	Number 1/	Percentage	Number 1/	Percentage
Alabama	-	-	-	-
Arizona	30	54.6	53	94.6
Arkansas	52	38.0	78	56.9
California	-	-	-	-
Colorado	38	11.6	140	42.6
Connecticut	116	16.3	81	11.4
Delaware	-	-	-	-
Florida	114	32.4	92	26.1
Georgia	93	16.0	150	25.8
Idaho	68	48.9	69	49.6
Illinois	639	60.6	509	48.3
Indiana	350	97.2	270	75.0
Iowa	130	58.6	204	91.9
Kansas	152	49.0	243	78.4
Kentucky	97	16.8	210	36.4
Louisiana	80	26.2	305	100.0
Maine	96	56.5	93	54.7
Maryland	43	11.0	43	11.0
Massachusetts	-	-	-	-
Michigan	263	52.7	138	27.7
Minnesota	233	38.5	342	56.5
Mississippi	66	62.3	81	76.4
Missouri	243	37.8	264	41.1
Montana	29	14.2	80	39.2
Nebraska	55	22.8	97	40.2
Nevada	-	-	-	-
New Hampshire	95	44.2	65	30.2
New Jersey	-	-	-	-
New Mexico	26	54.2	48	100.0
New York	-	-	-	-
North Carolina	141	31.5	37	8.3
North Dakota	39	32.8	52	43.7
Ohio	390	59.9	597	91.7
Oklahoma	49	35.0	77	55.0
Oregon	113	22.2	104	20.4
Pennsylvania	55	10.5	75	14.3
Rhode Island	18	21.2	28	32.9
South Carolina	115	43.6	25	9.5
South Dakota	43	51.2	20	23.8
Tennessee	-	-	-	-
Texas	698	76.5	737	80.7
Utah	-	-	-	-
Vermont	64	40.3	44	27.7
Virginia	72	20.7	87	25.1
Washington	180	29.4	107	17.5
West Virginia	32	39.5	81	100.0
Wisconsin	212	53.9	120	30.5
Wyoming	38	40.9	80	86.0
District of Columbia	32	39.5	10	12.3
Totals for States reporting	5,399	39.2	5,936	43.1
Estimated grand totals	7,942	38.6	7,764	37.8

1/ Columns one and three are not additive since 4,287 engineers are both graduates and registered.

Table 7.--Ratio of aids to engineers among State highway department employees

State	March 1, 1956	July 1, 1956
Alabama	-	1.76
Arizona	9.00	11.32
Arkansas	2.82	2.52
California	-	0.45
Colorado	1.33	1.48
Connecticut	0.33	-
Delaware	-	4.07
Florida	3.36	-
Georgia	2.13	2.48
Idaho	3.26	3.29
Illinois	0.14	0.23
Indiana	0.47	0.62
Iowa	3.36	3.36
Kansas	1.81	2.29
Kentucky	1.01	1.29
Louisiana	3.03	3.06
Maine	0.34	-
Maryland	0.96	-
Massachusetts	1.77	1.97
Michigan	1.60	2.01
Minnesota	1.05	1.07
Mississippi	5.57	5.18
Missouri	11.13	-
Montana	1.39	1.68
Nebraska	0.93	1.18
Nevada	-	-
New Hampshire	0.56	0.58
New Jersey	0.18	0.18
New Mexico	10.83	9.91
New York	-	0.66
North Carolina	1.36	1.49
North Dakota	0.38	1.61
Ohio	2.01	2.43
Oklahoma	4.06	3.92
Oregon	0.55	0.57
Pennsylvania	2.01	1.88
Rhode Island	1.28	1.31
South Carolina	1.69	1.73
South Dakota	4.32	5.99
Tennessee	-	-
Texas	3.02	3.49
Utah	1.80	2.07
Vermont	0.29	0.51
Virginia	2.20	2.51
Washington	0.60	0.75
West Virginia	2.36	2.72
Wisconsin	0.89	1.64
Wyoming	1.77	1.89
District of Columbia	0.95	0.95
Totals	1/ 1.26	1/ 1.44

1/ Includes estimates for States not reporting information.

Table 8.- Ratio of aids to engineers among State highway department engineering employees by region

As of March 1, 1956

Region	Number of engineers	Number of aids	Ratio of aids to engineers
New England	1,942	1,631	0.84
Middle Atlantic	2,224	1,819	0.82
East North Central	2,957	2,775	0.94
West North Central	2,224	3,300	1.48
South Atlantic	2,587	5,023	1.94
East South Central	1,429	2,209	1.55
West South Central	1,495	4,634	3.10
Mountain	1,009	2,562	2.54
Pacific	4,684	1,958	0.42
Total	20,551	25,911	1.26

Table 9.- Ratio of aids to engineers among State highway department engineering employees by region

As of July 1, 1956

Region	Number of engineers	Number of aids	Ratio of aids to engineers
New England	2,088	1,929	0.92
Middle Atlantic	2,319	2,018	0.87
East North Central	3,012	3,740	1.24
West North Central	2,291	4,053	1.77
South Atlantic	2,686	5,801	2.16
East South Central	1,469	2,597	1.77
West South Central	1,564	5,231	3.34
Mountain	1,086	3,042	2.80
Pacific	4,920	2,468	0.50
Total	21,435	30,879	1.44

engineers in this region was still below the national average. The variations among regions are not nearly so extreme as those among states.

In the individual regions there were some states which did not fall into the pattern of their regions. In the West North Central region, for example, which in March employed 1.48 aids per engineer and in July 1.77, North Dakota's ratio was 0.38 in March and 1.61 in July, but South Dakota's was 4.32 in March and 5.99 in July. In general, the highly populated regions employed more engineers than aids, although some of the highly populated states within these regions employed more aids than engineers.

It might be noted that the July ratios of aids to engineers showed slight decreases over the March ratios in five states (Arkansas, Mississippi, New Mexico, Oklahoma, and Pennsylvania). In Illinois, Vermont, and Wisconsin, however, the July ratios were almost double those for March, and in North Dakota the July ratio was more than four times that for March.

CONCLUSION

This 1956 inventory of engineering manpower was undertaken primarily to obtain an accurate tabulation of the engineers and aids employed by the several state highway departments. In view of uncertainties which existed in connection with previous studies, ERRATUM

HRB BULLETIN 164

Manpower Potentials in Highway Engineering

* * * *

In the paper "1956 Inventory of State Highway Engineering Manpower," by James A. Montgomery, Table 7, page 10, the March 1, 1956, value for Missouri should be 1.13 instead of 11.13 as shown. This change does not affect the column total.

it was felt that such a summary was necessary as a basis for further studies of manpower requirements in connection with the ever-expanding highway program.

It is believed that the data presented satisfy these requirements. As already noted, a few states did not furnish complete information, so that some estimates had to be made. Also, there may be certain inconsistencies or inaccuracies inherent in the data because of the different classification plans in use by the several states, the lack of standard definitions for engineers and aids, and the complexities of the professional engineering registration laws in the different states. Nevertheless, the picture portrayed is probably as good a one as can be obtained in view of the existing difficulties.

The analysis of the ratio of aids to engineers is in a sense beyond the scope of an inventory. It was undertaken in an effort to increase the value of the basic information. The wide variations which exist among the states cannot be explained at this time, but do suggest the need for additional detailed studies, perhaps in the individual states. They also furnish the states with information which should be useful for comparative purposes.

It has been pointed out that a regional pattern exists with respect to the ratio of aids to engineers, and the tentative conclusion of an earlier study that a combination of aids and engineers is the best indication of engineering effort has been confirmed. Both of these are significant findings. With the continuing cooperation of the states, they can be further explored to a point where it can be determined whether or not a particular state is making the best possible use of its engineering manpower.

REFERENCES

1. Campbell, M. Earl and Schureman, L. R., "Engineering Personnel Needs for Highway Departments." Highway Research Board Bulletin 106 (1955).

2. Lewis, R. S., "A Six-State Classification Study of Engineering Personnel." Public Roads, Vol. 29, No. 2 (June 1956).

Appendix A

Highway Research Board
2101 Constitution Avenue
Washington 25, D. C.

SUMMARY OF ENGINEERING EMPLOYEES

Please read accompanying instructions carefully before completing form.

A. Employees Classified as Engineers:

	3/1/56 (Actual)*1 Total	Mtnce Only	7/1/56 (Estimated)*2 Total	Mtnce Only
1. Both a civil engineering graduate and registered as a civil engineer	____	( )	____	( )
2. Civil engineering graduate only, but not registered	____	( )	____	( )
3. Registered only, (as a civil engineer)	____	( )	____	( )
4. Neither a civil engineering graduate nor registered as a civil engineer. (These may be registered in other branches.)	____	( )	____	( )
5. .... Grand totals	____	( )	____	( )

6. Of the employees classified as engineers (in item 4 above)

   a. How many are graduates from other branches of engineering, or other sciences ________ (______), and how many of these are registered ________ (______)

   b. How many are doing design or other work requiring the exercise of independent engineering judgment, i.e., are in "responsible charge", as opposed to high-grade inspecting, surveying, and similar work? ________ (______)

B. Employees Classified as Engineering Aids or Equivalent:

	3/1/56 (Actual)		7/1/56 (Estimated)	
1. Both a civil engineering graduate and registered	____	( )	____	( )
2. Civil engineering graduate only	____	( )	____	( )
3. Registered only	____	( )	____	( )
4. Neither a civil engineering graduate nor registered	____	( )	____	( )
5. .... Grand totals	____	( )	____	( )

C. Remarks:

D. Number of equivalent consulting engineers employed ____ : ( )

*1. See instructions.
*2. Show breakdown if available - otherwise total only.

INSTRUCTIONS FOR SUMMARY OF ENGINEERING EMPLOYEES
(Include both permanent and temporary employees)

Recent studies of state highway department employees have, because of non-uniformity in the method of reporting used, made it difficult to determine the number of employees in each of the various classes. It is the purpose of the attached form to obtain information based on a uniform system of classification for the different categories of engineers and for sub-professional people as well. Actual data as of March 1, 1956 and estimated data as of July 1, 1956 are requested.

Most States have graded classification plans for engineering employees, i.e., Engineer I, II, III, IV, V, etc., or Junior Engineer, Assistant Engineer, etc., and should report under the first major heading of the form all employees classified as engineers by such plans. In those States which do not have a graded classification plan, job titles may be related to specific duties, i.e. junior engineer of final plans, senior instrumentman, junior designer, senior designer, etc., and the job titles which are included in the engineering category will be a matter of judgment.

States with graded classification plans usually classify their sub-professional employees as Engineering Aid I, II, III, etc., or A, B, C, etc., and these should be reported under the second major heading of the form, "Employees classified as engineering aids or equivalent." For States without a graded classification plan, such titles as rodman, chainman, instrumentman, laboratory assistant, inspector, computer, draftsman, etc. should be included here. In any event, all technical employees should be included under one of the two major headings.

Under each heading, provision is made for indicating the professional qualifications of the employees included in the March 1 tabulation. The first line will include those employees who are both civil engineering graduates and also registered professional engineers, the second line those who are civil engineering graduates but not registered engineers, the third line those who are registered engineers but not civil engineering graduates, and the fourth line those who are neither. It is realized that there will be very few civil engineering graduates or registered engineers among the engineering aids, but in some States the item may be significant.

Also, since in relating the number of engineering employees to program or capital-outlay amounts it is desirable to exclude those employees assigned to maintenance, provision has been made for showing such employees separately in each case. Thus, if there are 653 employees in a particular category, and 87 of these are assigned to maintenance, the entry would be 653 (87).

Any necessary or desirable explanations of the data submitted can be made under the "Remarks" heading, and continued on the back of the form. The completed form should be forwarded to the Highway Research Board as soon after March 1 as is feasible.

Purpose of Inventory: (1) Determination of engineering requirements for construction and for maintenance; (2) To relate the requirements to an expanded construction and maintenance program; (3) To determine the number of aides required in terms of those classified as engineers; (4) To determine the best utilization of engineers.

A Study of Local Road Administration and Engineering Manpower

WAYNE H. SNOWDEN, Associate Engineer
Institute of Transportation and Traffic Engineering
University of California, Berkeley

● THE engineering manpower situation has given impetus to studies centered on local road agencies, as it has to practically all aspects of engineering. As a result the general nature of local studies, as carried out in California were discussed (1) at the 1956 annual meeting of the Highway Research Board.

The shortage of engineers tends to concentrate such studies on immediate means of increasing availability and productivity of the technical working force. The increase of productivity, at least, is a desirable long-term objective. Nevertheless, regardless of the circumstances that give rise to these studies, the studies deal with one or more phases of engineering administration and thus provide opportunity for developing a better understanding of road management, to which current manpower availability is more or less incidental.

Studies of engineering manpower in California county road departments have been conducted with these dual purposes of immediate and long-term usefulness. This paper presents, specifically, information about the numbers of technical personnel per unit of construction and about jobs filled in relation to salaries paid in California county road departments. More generally, however, it is intended to deal with some features of finding and reporting facts about local road administration, and to discuss some fundamentals of the engineering manpower situation which are often passed over, especially in the present atmosphere of concentration on immediate corrective measures.

Considerable information about engineering manpower in California county road departments has been gathered by both the California State Division of Highways and the Institute of Transportation and Traffic Engineering, University of California. This work began in 1955 and is continuing. Most of the information is of a statistical nature; that is, it concerns numbers of individuals, amounts of salary, etc., rather than how individuals behave or what they say and think. Being of this nature, it avoids many of the problems in psychology and semantics that are so common and so perplexing to students of administration.

This is not, however, to say that it avoids all of them. And both because those that remain are likely to be slighted by investigators who incline to the engineering point of view, and because these remaining problems place special importance on how findings are reported, they are referred to first.

NATURE OF ADMINISTRATIVE FACTS

Administrative facts of the type here considered, however quantitative, are of a different order than facts of nature, however qualitative. Administration is concerned with organizing and guiding human effort. The study of administration is concerned with evaluating, and presumably influencing, this organizing and guiding activity, which is itself a human effort. Some aspects of administration can be numerically expressed. A county road department may have 15 authorized engineering positions—something that can be recorded, tabulated, added, and generally handled as a number. But the number conceals a history of law and custom, an environment of human intention, past and present, which make it what it is today and may make it something else tomorrow. It is by no means of the same class as a number representing the density of a soil.

There is a temptation, however, to attribute to administrative numbers a sort of natural validity that they do not have and to overlook the human connotations that they do. Especially is there a disposition to regard an average of such numbers as acquiring a validity not present in the humbers from which it was derived, much as if human vagaries were a random distribution around some desirable mean. The possibility of these human connotations attaching to numbers developed in administrative studies should keep everyone on guard against definite statements of correlation, which, however impressive in mathematical expression, may rest on a relationship that, functionally, is tenuous or even non-existent.

REPORTING OF ADMINISTRATIVE FACTS

An even more important consideration may be the manner in which administrative studies become useful. The soil density, already selected for example, may be fed into scientific channels of communication with assurance that it will be dispassionately extracted and directly utilized by anyone having need of it. The results of administrative study, however, are primarily useful to the administrations they to some extent portray, and they are useful, not as independent facts on which to base a new design, but as guides by which the administrations may alter themselves. In such a situation it is unrealistic to expect a neutral view of administrative findings by the very individuals to whom the findings may have some use.

These general considerations are especially relevant to the study of local road administration. The larger an organization, the more it assumes an abstract pattern that can be viewed without reference to individuals. A large organization often can create the means of looking at itself objectively, and examine and correct its shortcomings without proclaiming them to the public at large. County road departments, however, are in the main so small that a collection of particular individuals, rather than an abstract pattern, is the explanation of its administration—a situation that severely limits an organization's capacity for objective self-appraisal. This limitation, in fact, is one major reason for the collective study of county road administrations by external agencies. But external study normally makes information available to anyone who wishes to look at it, and unless findings about local road administration are presented with considerable care they are all too likely to be taken as representing a great deal more than they actually do, to become the vehicle for unfounded conclusions about a particular agency, and in general to do more harm than good.

This danger applies to the comparatively simple matter of the engineering manpower situation. To illustrate, there is the actual case of a county with a staff of 48 engineers and another county with a higher rate of annual road construction, but with a staff of only 2 engineers. The first county reports several positions vacant, over and above the 48. The second county reports all two authorized positions filled. From this bit of information, one could draw various and conflicting conclusions about the manpower situation, according to the assumption from which he proceeded. Merely to identify the agencies with special reference to these numbers would be to place one or both in the position of having to defend themselves against questions to which there are no real answers so far.

The difficulty here emphasized is that there is not a sound, or even a roughly agreed upon basis for measuring engineering manpower requirements. What is the optimum number of engineers for doing a given kind and amount of road work? What does the organization stand to lose as it departs one way or the other from this optimum number? How is the value in the roadway plant measured and up to what point is this value enhanced by additional engineering?

The objection might be raised that although specific answers cannot be given to the questions as stated, usable guides to manpower requirements can nevertheless be derived from current practice as a whole. After all, according to this objection, the nation is continuously engaged in a tremendous amount of roadbuilding, and this is being accomplished with an ascertainable amount of engineering effort, whether optimum or otherwise. Hence, it can be said that so much construction takes so much engineering and in this way engineering needs are expressed on a unit-of-construction base.

Useful as this may be for broad appraisal, it does not solve the question of how to report findings at the local level, as another example may indicate. Data obtained by the California State Division of Highways show that California county road departments, taken together, had on the job, per million dollars of construction in 1956, about 4 registered civil engineers, 4 non-registered engineers, 14 assistant and junior engineers, and 10 engineering aids. According to broad-based measures, this might be considered enough. Yet such over-all appraisal would be neither consoling nor useful to the large number of California counties that now have work waiting for engineers and technicians that they are unable to lure onto the payroll. Nor can it be said that the better-staffed counties do not need every engineer they have.

As one considers the curiosities of administrative facts, the ways in which these facts may be bent to certain purposes, and—in the current engineering manpower situation—the dearth of information on some very fundamental matters, the question of just what is being found out, and why, is brought into prominence.

CURRENT REPORTING IN CALIFORNIA

As has been mentioned, the attempt in California has been to develop fundamental information at the same time that facts about the current situation have been collected. In reporting findings, the attempt has been to challenge the thinking of all concerned with local road administration, and to do so without exposing any agency to criticism which would certainly not be justified on the basis of facts now known—with the possible exception of the fact that a good many county road departments are offering salaries far below the going wage for the class of technical personnel they are trying to attract.

It is, of course, impossible to accommodate all the foregoing considerations in selecting a given reporting method. In the California work, statistical refinement has been sacrificed, perhaps at the risk of criticism for grouping and averaging numbers, in order to present certain pictures of county road administration in a way that it is hoped will be understandable and thought provoking to the most people concerned, and to do so without arousing irrational criticism of the agencies reported on.

Data so far available permit two somewhat unrelated statements. One is of the numbers of engineers in California county road departments per unit of annual construction. The other is a comparison of salaries and engineering jobs open. Both are presented by groups of counties, the groups being made up of counties ranked according to annual rate of road construction. The reasons for resorting to such grouping were several. In the first place, California counties run through an 80-to-1 range of sizes, if size is measured by annual rate of road construction in dollars. Size is to some extent correlated with factors such as degree of urbanization, population, and population density, all of which bear on the kind of road system with which the county road department is concerned. Grouping by size should retain distinctions associated with size, while tending to average out other variations which, when counties are taken individually, frequently obscure central tendencies of some importance. Grouping also reduces the number of reported bits of information, and while this may obscure some relationships which might be discerned in the basic data, it facilitates quick general comparisons which may very well be the most useful, as well as all that can be justified on the basis of data so far available. And finally, grouping eliminates strict county-by-county comparison, thus forestalling conclusions about engineering in a particular county which might be suggested by a more detailed presentation, but which would actually not be warranted without evaluation of many factors which in the present state of knowledge are unstudied.

California's 57 counties (excluding San Francisco because it is a combined city-county) have been grouped as shown in Table 1. This grouping, which is based on annual rates of road construction expressed in round numbers, happily sets aside (in Group I) California's two unusually large counties, while producing four remaining groups of somewhat the same numbers of counties.

DISTRIBUTION OF ENGINEERING PERSONNEL

Numbers of engineering personnel engaged in work connected with construction (that is, less the numbers equivalent to time spent on maintenance, right-of-way, and non-engineering activities) were computed for each of these county groups. The results are shown in Figure 1, which gives the numbers of engineers per million dollars of

TABLE 1

GROUPING OF CALIFORNIA COUNTIES FOR STUDY OF ROAD ADMINISTRATION

Group	Millions of Dollars of Road Construction per Year[1]		Number of Counties in Group
	Per County	Group Total	
I	Over 2	11.016	2
II	1 to 2	11.344	9
III	½ to 1	10.979	16
IV	¼ to ½	5.192	14
V	Under ¼	2.168	16

[1] Average for fiscal years 1953-4 and 1954-5 as reported to the California State Comptroller.

construction for each county group. At the same time, the areas of the bars, portray the distribution of engineering personnel among the 57 counties. Although the latter serves to emphasize where engineering personnel are located, and hence to aid in evaluating county-by-county reports of shortages, it is the numbers at work per unit of construction that calls attention to more fundamental questions of engineering manpower utilization.

Why should the Group II counties (with annual construction programs ranging from $1 million to $2 million) have on a unit of construction basis less than one-third as many engineers as the counties in Group I, less than one-half as many as the counties in Group V, and for that matter less than any other group? Immediately one looks for reasons to explain away this seemingly odd situation. The first fact is that the two large counties in Group I are contending with extensive urbanization and engaged in major construction of highways to accommodate heavy traffic. It is concluded that, dollar for dollar, they must have to put more engineering time than other counties into such things as preliminary planning, utility relocation, and the design of complicated structures. A look at the Group V counties (with annual construction programs under $250,000 per year) shows that each engineer in this group counts high on a unit-of-construction basis because the levels of construction are low. But there is still no explanation for the extreme variations here shown and for the steady trend toward more and more engineers per unit of construction as progress is made toward smaller county groups, Group I excepted.

This last is particularly amazing, because it is a common assumption, doubtless reached because of the known cases of small counties with very minimum technical staffs, that there is a consistent decline in engineering availability as counties become smaller. In California, at least, such an assumption would also correspond with need—need here being thought of in terms of the kind of structures being engineered—as there is a consistent shift in road system standards as the counties become smaller, the smaller counties (in terms of construction dollars) being so, not because they are geographically small, but because they are most rural and least developed.

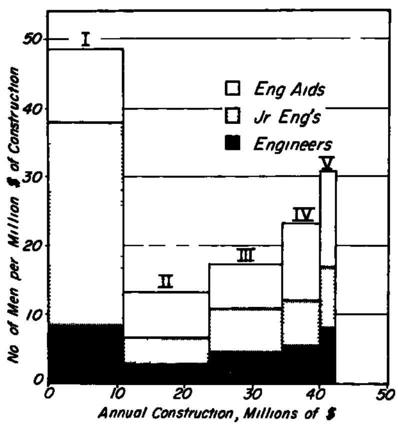

Figure 1. Distribution of engineering personnel among California county road departments—counties arranged in five groups ranked according to annual rate of road construction. Areas in the diagram are proportional to numbers of individuals.

Whatever the reasons for the peculiar shape of Figure 1, it cannot be explained in terms either of engineering time put into maintenance or of outside engineering services performed for the counties. The first is excluded from Figure 1, as already mentioned. The second has been separately examined in reports of California counties covering engineering services performed for them by the State Division of Highways and by private firms, and the total engineering accomplished in this way does not at all change the picture.

TABLE 2

PERCENT JOBS FILLED AND SALARIES IN CALIFORNIA COUNTY ROAD DEPARTMENTS

County Group	No. of Positions	No. of Vacancies	Percent Vacancies	Percent Filled	Average Salary[1]
		(a) Senior Engineering Grades[2]			
I	106	14	13	87	675
II	38	7	18	82	620
III	41	7	17	83	640
IV	23	3	13	87	655
V	19	3	16	84	580
		(b) Junior Engineering Grades[3]			
I	133	18	14	86	500
II	36	16	40	60	470
III	70	17	24	76	450
IV	11	4	36	64	438
V	10	5	50	50	426
		(c) Technician Grades[4]			
I	410	32	8	92	431
II	124	4	3	97	402
III	144	21	15	85	395
IV	57	15	26	74	331
V	46	7	15	85	378

[1] Per month. [2] 261 positions. [3] 320 positions. [4] 860 positions.

As Figure 1 is viewed as a whole—as representing engineering in a large aggregate of county road systems—it is hard to escape the conclusion that, whatever the shortcomings in visualization, one is looking at an unreasonable distribution of engineering personnel.

POSITION VACANCIES AND SALARIES

A second matter examined on the same group basis in California has been the relation between jobs open and salaries. Here the relation of manpower to construction level is ignored. Authorized positions are taken as the basis, percent vacancies are computed, and these percent vacancies are compared with salaries. The results are given in Table 2.

The average salary for a given grade level in a given county was taken as the payroll for that level divided by the number of individuals. For a county group, the average salary as tabulated is the unweighted, arithmetic mean of the individual county averages. This process leaves something to be desired as a statistical procedure, and further, starting salary rather than average for the grade may be the more decisive influence in filling vacancies. Therefore, information is now being collected on first-step salaries for jobs filled and on salaries being offered for jobs not filled. So far, however, it appears that although this latter form of reporting may serve to avoid criticism, and will certainly reduce the absolute size of the stated salaries, it will not significantly affect the relationships here shown, because of the very close correlation between a starting or step-one salary and the average actually being paid.

The relationship is not clear in rank correlations of percent jobs filled against salary for counties taken as individual units, probably because of the considerable number of counties in which there is only one position in a given grade, with the result that the position must appear as either zero or 100 percent filled. In the grouped data, however, not only is there a general salary decline from large to small counties, as might be expected, but more importantly there are many cases in which both salaries and positions filled move with or contrary to this general trend.

The importance of such a showing is against two rather common points of view. One is that counties are committed to a certain range of salaries because of their size. The data show three cases where this is not true even for counties taken as groups. The prevailing salaries for senior engineering positions in Group III counties are higher than those in Group II, although the counties in Group III are smaller, and the same applies to Group IV in comparison to Group III. Salary variations among individual counties of similar size cannot be seen in the grouped data, but they are sizeable and numerous, offering further evidence that various salary levels can be established, however difficult a change may seem in any individual case.

The second often-heard view is that salary offers no particular promise of holding engineering personnel in smaller counties because the salary, even if increased, would still be below salaries offered by larger agencies; in other words, it would still fail to meet the competition. The data seem to deny this. If Group I is excluded where the highest salaries in this field are found, and a move is made from one to another of the remaining groups for each of the remaining job classifications, there are nine salary changes to examine, involving twelve cases of below-maximum salaries, and in eight of these nine changes the salaries and percent jobs filled move up or down together. Perhaps the most definite indication that even a relatively small salary increase will keep technical personnel on the job is to be seen in the status of Group IV counties in comparison with the groups on either side. In the case of senior engineers, the Group IV salaries are higher than both the average salaries in the 16 somewhat larger counties of Group III and the average salaries in the 16 somewhat smaller counties of Group V, and the percent jobs filled is also higher; in the case of junior engineers Group IV salaries are intermediate and so are percent jobs filled; and in the case of technician grades Group IV salaries are lower and so are percent jobs filled.

STATUS QUO AND FURTHER STUDY

Despite the statistical shortcomings already alluded to, it is felt that the data developed so far should be promptly reported so they may help in correcting salary inequities, especially in the case of individual counties where present salaries are far below the prevailing mean for similar job classifications in organizations of similar size. At the same time, more detailed information is being obtained on this fundamental to maintaining adequate staff.

In regard to the previously discussed distribution of engineering manpower among counties, an attempt is also being made to use the information so far obtained as a guide to further study along definitely constructive lines. Here the proposal is not to attempt premature inferences about optimum engineering staff, but rather to look closely at that sizeable group of sizeable counties (Group II) where the most work is being done with the fewest relative numbers of technical personnel.

The specific information presented in this paper may, of course, be peculiar to California. It is hoped, however, that the considerations raised by these findings and these methods of presentation may stimulate attention to some neglected fundamentals of engineering manpower in local road administration.

REFERENCE

1. Local Highway Engineering Manpower: Appraisal and Action, Wayne H. Snowden, Highway Research Board Bulletin 134, p. 25, (1956).

Graduate Degrees in Highway Engineering as Related to Other Majors in Civil Engineering

ROBLEY WINFREY, Chief, Personnel and Training
U. S. Bureau of Public Roads

●ENROLLMENTS at engineering colleges for the master and doctor degrees are materially greater than they were prior to World War II. There are many indications that these enrollments will continue to increase, both in numbers as well as in percentage of undergraduate enrollment. College administrations are stressing graduate work; industry is paying an attractive starting salary differential to holders of the master and doctor degrees; and students themselves are realizing that the standard 4-year curriculum does not give them the depth or specialization of education they desire.

The numbers of civil engineering bachelor graduates who enroll for graduate degrees and whether they undertake their further education in subject areas specifically related to highway engineering are important considerations to the employers of highway and bridge engineers.

Reports of engineering enrollment and numbers of graduates that appear in the Journal of Engineering Education and in publications of the U.S. Office of Education generally itemize by the major departments of engineering such as ceramic, civil, electrical, mechanical, etc. Such reports are useful to employers of civil engineers, but of even greater usefulness would be reports showing the subdivision of the graduate enrollment and degrees by major subject within civil engineering. By mail questionnaire of October 22, 1956, an attempt to gather such statistics was undertaken. The information, together with other available information on enrollment and number of degrees is presented in this paper.

Before presenting the statistical tables on enrollments and degrees it is well to mention that numerical information on college enrollments, numbers of degrees conferred, and curricula offered is most difficult to collect. Further, once collected the information may be at difference with other reports. Contributing to these discrepancies are differences in the reporting dates, sources of information, and interpretations of what is wanted by those supplying the information. College enrollments change each day of the school year. Many special and unclassified students enroll for short periods or long periods. Degrees are conferred on graduating groups in official ceremonies two to five times a year and to individuals at other times. Specific curricula are offered in the catalog but draw no students or no student graduates in a specific curriculum in a given year. Because of these differences, the reader is cautioned not to be concerned with apparent discrepancies found in the tables (Table 4, for instance) presented.

ENROLLMENTS AND NUMBERS OF GRADUATES

The number of institutions enrolling students in undergraduate, master, and doctor programs is given in Table 1 for the years of 1950 to 1956. For the graduate degrees, not all of the institutions offering graduate degrees graduate students each year. Therefore, the number of schools graduating masters or doctors in a given year may be less than the number of schools offering work leading to such degrees and also less than the number of schools enrolling students for these degrees. In 1956, out of 37 schools enrolling students in a doctors program, only 20 conferred such degree.

Of recent years the number of colleges accredited in civil engineering by the Engineering Council for Professional Development (Table 2) has been about 80 percent of all schools granting the bachelor degree in civil engineering. These schools, however, conferred about 90 percent of the total number of first degrees.

Table 2 shows that the peak of post-war bachelor degrees came in the 1949-50 school year with 7,772 degrees awarded. The number then decreased to a low of

TABLE 1

NUMBER OF COLLEGES AND UNIVERSITIES ENROLLING STUDENTS IN CIVIL ENGINEERING BY DEGREE - FALL 1956[1]

Fall of	Schools with Civil Engineering enrollment by degree		
	B. S.	M. S.	PhD.
1956	168	93	37
1955	167	95	35
1954	166	98	36
1953	169	90	32
1952	161	90	28
1951	159	88	30
1950	153	90	30

[1] Includes building engineering and construction, and transportation engineering.

TABLE 2

NUMBER OF DEGREES IN CIVIL ENGINEERING

Year	Number of Schools and BS Degrees						Number M. S. Degrees	Number PhD. Degrees
	Accredited		Not Accredited		Total			
	Schools	Degrees	Schools	Degrees	Schools	Degrees		
1955-56	130	3,825	38	402	168	4,227	822	59
1954-55	129	3,492	32	350	161	3,868	683	29
1953-54	129	3,532	32	424	161	3,955	560	43
1952-53	131	3,375	27	358	158	4,400	560	32
1951-52	131	4,868	27	486	158	5,354	571	43
1950-51	130	6,450	25	616	155	7,060	658	51
1949-50	125	7,265	21	507	146	7,772	709	32
1948-49	-	-	-	-	-	6,400	743	34
1947-48	-	-	-	-	-	3,271	897	53
1946-47	-	-	-	-	-	3,658	555	26
1945-46	-	-	-	-	-	900	1,486	17
1944-45	-	-	-	-	-	644	49	10
1943-44	-	-	-	-	-	1,479	---	--
1942-43	-	-	-	-	-	1,758	100	14
1941-42	-	-	-	-	-	-----	---	--
1940-41	-	-	-	-	-	1,430	239	26
1939-40	-	-	-	-	-	-----	300	9
1938-39	-	-	-	-	-	-----	---	--
1937-38	-	-	-	-	-	1,572	---	--

3,868 in 1954-55. College enrollments and numbers of graduations are now increasing primarily because of increase in the birth rate following the depression period in the 1930's. The heavy birth rate of the post-war period starting in 1946 will be a strong factor in reaching new highs in civil engineering bachelor degrees by 1970.

The peak of the number of master degrees came in 1945-46 with 1,486, which reflects the unusually large number of graduates who returned to college immediately after World War II for graduate work. A secondary peak of 897 was reached in 1947-48. From 1948 to 1951 the master degrees were about 10 percent of the bachelors. For the past three years, however, this percentage has averaged about 16 percent. From other sources there is indication that the number of bachelor graduates who return for graduate work is still on the increase. Prospective employers of civil engineering graduates, then, need to realize that roughly 15 percent of the bachelor

TABLE 3

CLASSIFICATION OF STUDENTS ENROLLED FOR GRADUATE WORK IN CIVIL ENGINEERING - FALL 1956

(Summary of Tables 4 and 5)

Civil Engineering Subject Major	Percentage Enrolled in Subject Major	
	M. S. Candidates	PhD. Candidates
1. Structures	47.22	36.75
2. Soils	10.53	14.13
3. Highways	9.76	4.95
4. Sanitation	9.13	15.20
5. Hydraulics	8.04	13.43
6. General	4.79	.35
7. Engineering Mechanics	3.13	8.48
8. Municipal	2.11	-----
9. Irrigation	1.91	2.47
10. Construction	1.85	-----
11. Materials	.83	1.06
12. Surveying	.38	.35
13. Fluid Mechanics	.32	2.83
Total	100.00	100.00
Questionnaire study:		
Number of schools reporting	75	32
Number of graduate students reported	1,567	283
Preliminary Report, U.S. Office of Education:		
Number of schools enrolling graduate students	93	37
Number of graduate students enrolled	2,314	259

graduates are not available for employment for another year or two after their first degree. Further, when they are available with graduate degrees, higher salaries will be in order and a higher level of specialized assignments will be expected.

The doctors degrees 1950-51 to 1955-56 averaged slightly less than 1 percent of the bachelors degrees and about 7 percent of the masters. With the increased weight the college administrations are giving doctors degrees as a qualification for a teaching position, it may be expected that the number of degrees at the doctors level will increase somewhat.

Usable returns were received from 75 schools reporting enrollments of master degree students and 32 schools enrolling doctor degree students in the fall of 1956. The possible total number of schools was 93 for the master and 37 for the doctor degrees. Total enrollment (Table 6) in the fall of 1956 was 2,314 for the master degree and 259 for the doctors degree. The questionnaire returns included 1,567 master degree students and 283 doctors candidates, or a percentage of 68 and 109, respectively, of the total enrollments in all schools.

In Table 3 is summarized by percentage the enrollments in the separate majors within civil engineering as obtained by questionnaire. Structural engineering is by far the leader with 47.22 percent at the masters level and 36.75 percent at the doctors. Soils and highways are second and third, respectively, in the masters and third and

TABLE 4

NUMBER OF MS CANDIDATES IN THE VARIOUS CIVIL ENGINEERING SPECIALTIES - FALL 1956

State	Institution	Enrollment reported by U S Office Ed	Total	Enrollment Reported from HRB Questionnaire Study												
				Structures	Soils	Highways	Sanitation	Hydraulics	General	Engineering Mechanics	Municipal	Irrigation	Construction	Materials	Surveying	Fluid Mechanics
				1	2	3	4	5	6	7	8	9	10	11	12	13
Ala	Alabama Poly	8	10	1	1	2	2	1	-	3	-	-	-	-	-	-
	Univ Alabama	5	6	4	-	2	-	-	-	-	-	-	-	-	-	-
Ariz	Univ Arizona	3	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Ark	Univ Arkansas	2	2	-	-	-	1	-	1	-	-	-	-	-	-	-
Calif	California Tech	15	16	3	1	-	1	1[1]	10	-	-	-	-	-	-	-
	Stanford	60	50	21	-	1	-	6	5	-	-	-	17	-	-	-
	Univ California	35	73	35	1	20	13	2	-	-	-	2	-	-	-	-
Colo	Colorado A and M	6	34	-	-	-	-	-	6	-	-	28	-	-	-	-
	Univ Colorado	77	33	23	-	-	-	10	-	-	-	-	-	-	-	-
	Univ Denver	3	3	3	-	-	-	-	-	-	-	-	-	-	-	-
Conn	Yale	18	17	10	-	-	-	-	-	7	-	-	-	-	-	-
Dela	Univ Delaware	4	8	8	-	-	-	-	-	-	-	-	-	-	-	-
Fla	Univ Florida	8	11	3	1	2	1	-	-	4	-	-	-	-	-	-
Ga	Georgia Tech	25	38	12	8	2	3	5	-	-	8[2]	-	-	-	-	-
Idaho	Univ Idaho	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-
Ill	Illinois Inst Tech	47	22	16	1	-	4	-	-	-	1[2]	-	-	-	-	-
	Northwestern	43	21	10	6	-	4	-	-	1	-	-	-	-	-	-
	Univ Illinois	107	111	91	3	7	5	4	-	-	-	-	-	-	1	-
Ind	Notre Dame	5	3	3	-	-	-	-	-	-	-	-	-	-	-	-
	Purdue	60	71	17	3	33	9	2	-	-	-	-	-	7	-	-
Iowa	Iowa St Coll	26	34	7	18	7	1	-	-	-	1	-	-	-	-	-
	St Univ Iowa	6	25	3	-	-	3	19	-	-	-	-	-	-	-	-
Kan	Kansas State Coll	7	5	2	-	2	-	-	-	-	-	-	-	-	1	-
	Univ Kansas	30	9	6	-	-	2	-	-	1	-	-	-	-	-	-
Ky	Univ Kentucky	18	18	11	1	6	-	-	-	-	-	-	-	-	-	-
La	Tulane	19	18	18	-	-	-	-	-	-	-	-	-	-	-	-
Maine	Univ Maine	3	2	-	1	-	1	-	-	-	-	-	-	-	-	-
Md	Johns Hopkins	10	3	1	-	-	-	-	-	-	-	-	-	-	-	2
	Univ Maryland	4	4	2	-	1	-	-	-	-	-	-	-	1	-	-
Mass	Harvard	10	21	3	7	-	10	-	-	-	1	-	-	-	-	-
	Mass Inst Tech	57	61	18	13	4	-	11	13	-	-	-	-	-	2	-
	Northeastern	67	11	10	-	-	1	-	-	-	-	-	-	-	-	-
	Univ Massachusetts	9	4	4	-	-	-	-	-	-	-	-	-	-	-	-
Mich	Michigan M and T	4	5	2	-	-	-	-	-	-	3[2]	-	-	-	-	-
	Michigan State Univ	17	20	5	3	3	5	-	-	-	-	-	4	-	-	-
	Univ Mich	54	54	30	3	5	5	3	5	-	-	-	3	-	-	-
	Wayne Univ	29	28	18	-	-	1	-	7	-	1	-	1	-	-	-
Minn	Univ Minnesota	31	50	24	4	3	7	12	-	-	-	-	-	-	-	-
Miss	Mississippi St Coll	2	3	2	-	-	1	-	-	-	-	-	-	-	-	-
Mo	Missouri Mines	17	18	2	1	7	2	1	-	-	-	-	2	3	-	-
	Wash Univ (St L)	8	10	10	-	-	-	-	-	-	-	-	-	-	-	-
Mont	Montana St Coll	4	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Neb	Univ of Nebraska	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
N J	Rutgers	2	5	1	1	-	3	-	-	-	-	-	-	-	-	-
	Stevens	4	8	2	-	-	-	-	-	4	-	-	-	-	-	2
N Mex	New Mexico A and M	6	8	2	-	-	1	-	5	-	-	-	-	-	-	-
	Univ N Mexico	15	10	-	-	-	-	-	10	-	-	-	-	-	-	-
N Y	Clarkson	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
	Columbia	100	183	115	48	1[3]	-	12	-	6	-	-	-	-	-	1
	Cornell	17	26	13	1	6	1	3	2	-	-	-	-	-	-	-
	Rensselaer	25	24	18	6	-	-	-	-	-	-	-	-	-	-	-
	Syracuse	2	4	2	1	1	-	-	-	-	-	-	-	-	-	-
N C	North Carolina St Coll	16	17	5	2	3	5	-	-	-	2	-	-	-	-	-
N Dak	Univ North Dakota	8	8	5	-	-	3	-	-	-	-	-	-	-	-	-
Ohio	Case	31	19	12	-	-	4	-	-	1	2[2]	-	-	-	-	-
	Ohio St Univ	16	19	6	4	4	3	1	-	-	-	-	1	-	-	-
Okla	Oklahoma A and M	17	20	11	-	8	-	1	-	-	-	-	-	-	-	-
Ore	Oregon State	7	7	2	-	1	2	2	-	-	-	-	-	-	-	-
Pa	Bucknell	2	2	-	-	-	-	1	1	-	-	-	-	-	-	-
	Drexel	27	30	15	6	3	-	-	-	6	-	-	-	-	-	-
	Pa State Univ	9	11	4	-	-	6	1	-	-	-	-	-	-	-	-
	Univ Pittsburgh	28	26	12	7	-	-	7[1]	-	-	-	-	-	-	-	-
R I	Univ Rhode Island	3	2	2	-	-	-	-	-	-	-	-	-	-	-	-
S Dak	South Dakota St Coll	3	3	-	-	2	1	-	-	-	-	-	-	-	-	-
Tenn	Univ Tennessee	12	14	3	-	2	3	1	5	-	-	-	-	-	-	-
Texas	Univ Houston	14	18	8	6	-	-	-	4	-	-	-	-	-	-	-
	Univ Texas	27	13	5	2	1	3	2	-	-	-	-	-	-	-	-
Utah	Utah St Ag Coll	2	6	-	-	-	-	5	-	-	-	-	-	1	-	-
Va	Univ of Virginia	3	3	1	-	1	-	-	-	-	-	-	-	1	-	-
	Virginia Poly	15	15	9	-	-	4	-	1	-	1	-	-	-	-	-
Wash	Univ Washington	50	39	20	5	5	6	3	-	-	-	-	-	-	-	-
	Washington St Coll	2	2	-	-	-	1	1	-	-	-	-	-	-	-	-
Wisc	Univ Wisconsin	56	71	14	-	7	15	6	-	15	13	-	-	-	1	-
Wyo	Univ Wyoming	9	8	4	-	-	-	3	-	-	-	-	1	-	-	-
D C	Catholic Univ	17	9	8	-	-	-	-	-	1	-	-	-	-	-	-
	Total	1,509	1,567	740	166	153	143	126	75	49	33	30	29	13	5	5

[1] Candidates for M S in Water Power and Supply
[2] Candidates for M S in City Planning
[3] Candidate for M S in Transportation

TABLE 5

NUMBER OF PhD CANDIDATES ENROLLED IN THE VARIOUS CIVIL ENGINEERING SPECIALTIES
FALL 1956

State	Institution	Enrollment reported by U. S. Office Ed.	Total	Enrollment Reported from HRB Questionnaire Study												
				Structures	Soils	Highways	Sanitation	Hydraulics	General	Engineering Mechanics	Municipal	Irrigation	Construction	Materials	Surveying	Fluid Mechanics
				1	2	3	4	5	6	7	8	9	10	11	12	13
Calif	California Tech	2	2	-	1	-	1	-	-	-	-	-	-	-	-	-
	Stanford	7	9	6	-	-	-	3	-	-	-	-	-	-	-	-
	Univ Calif	16	20	6	-	5	6	2	-	-	-	1	-	-	-	-
Colo	Colorado A and M	-	6	-	-	-	-	-	-	-	-	6	-	-	-	-
	Univ Colorado	1	3	3	-	-	-	-	-	-	-	-	-	-	-	-
Conn	Yale	6	6	2	-	-	-	-	-	4	-	-	-	-	-	-
Fla	Univ Florida	4	5	2	-	-	3	-	-	-	-	-	-	-	-	-
Iowa	Iowa St Coll	13	14	4	8	-	2	-	-	-	-	-	-	-	-	-
	St Univ Iowa	3	13	-	-	-	2	10	1	-	-	-	-	-	-	-
Ill	Illinois Inst Tech	6	3	2	1	-	-	-	-	-	-	-	-	-	-	-
	Northwestern	8	14	5	6	-	2	-	-	-	-	-	-	-	-	1
	Univ Illinois	38	42	30	5	1	2	4	-	-	-	-	-	-	-	-
Ind	Purdue	16	18	4	5	4	2	-	-	-	-	-	-	3	-	-
Md	Johns Hopkins	4	5	2	-	-	-	-	-	-	-	-	-	-	-	3
Mass	Harvard	4	9	-	4	-	4	1	-	-	-	-	-	-	-	-
	Mass Inst Tech	23	23	11	3	1	-	8	-	-	-	-	-	-	-	-
Mich	Michigan State	-	4	2	1	1	-	-	-	-	-	-	-	-	-	-
	Univ Mich	15	15	13	-	-	2	-	-	-	-	-	-	-	-	-
Minn	Univ Minnesota	5	13	4	1	-	3	5	-	-	-	-	-	-	-	-
Mo	Washington Univ (St L)	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-
N J	Stevens Inst	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2
N Y	Columbia	13	18	-	2	-	-	-	-	14	-	-	-	-	-	2
	Cornell	7	5	2	-	-	1	1	-	-	-	-	-	-	1	-
	Rensselaer	2	1	-	-	-	1	-	-	-	-	-	-	-	-	-
Ohio	Ohio State Univ	2	1	-	1	-	-	-	-	-	-	-	-	-	-	-
Okla	Oklahoma A and M	1	2	2	-	-	-	-	-	-	-	-	-	-	-	-
Ore	Oregon State	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-
Pa	Pennsylvania State	2	2	-	-	1	1	-	-	-	-	-	-	-	-	-
Texas	Univ Texas	4	2	-	-	-	2	-	-	-	-	-	-	-	-	-
Va	Virginia Poly	1	3	-	1	-	2	-	-	-	-	-	-	-	-	-
Wash	Univ Washington	2	2	1	1	-	-	-	-	-	-	-	-	-	-	-
Wisc	Univ Wisconsin	13	19	2	-	1	6	4	-	6	-	-	-	-	-	-
	Total	220	283	104	40	14	43	38	1	24	0	7	0	3	1	8

sixth in the doctors listing. Because soils engineering is closely related to highway engineering, the combination of the two would provide a total percentage of 20. 29 masters and 19. 08 doctors of all civil engineering graduate majors available for the highway field. Many of the structural majors would also be available for highway bridge engineering. Over-all, whether the graduate degree candidate elects to remain in educational pursuits or to enter the noneducation field, the highway industry has a good opportunity to obtain a fair share of those who are awarded graduate degrees.

Tables 4 and 5 present the data summarized in Table 3, institution by institution, for the 75 which returned the questionnaire. These tables indicate the high degree of specialization of graduate enrollment. Many of the schools have their one or two majors which attract most of their graduate students. For instance, at the University of California, 68 out of 73 master degree students are majoring in structures, highways,

TABLE 6

CIVIL ENGINEERING ENROLLMENTS AND DEGREES IN THE UNITED STATES AND OUTLYING PARTS, BY LEVEL AND BY INSTITUTION 1956

U.S. Department of Health, Education, and Welfare - Office of Education

Institution	Enrollment Fall 1956			Degrees 1955-56		
	B.S.	M.S. [2]	PhD.	B.S.	M.S.	PhD.
Civil - Grand Total	28,312	2,314	259	4,227	822	59
Alabama	469	13	-	64	1	-
[1] Ala Poly	314	8	-	40	-	-
[1] Ala Univ	155	5	-	24	-	-
Arizona	223	3	-	16	3	-
[1] Ariz Univ	223	3	-	16	3	-
Arkansas	166	2	-	19	3	-
[1] Ark Univ	166	2	-	19	3	-
California	1,222	255	25	255	115	4
[1] Calif Tech	20	15	2	11	20	1
Coll of the Pacif	40	-	-	2	-	-
Fresno St Coll	110	-	-	9	-	-
Loyola Univ	32	-	-	5	-	-
San Jose St Coll	91	-	-	16	-	-
[1] Santa Clara	92	-	-	20	-	-
[1] Stanford	131	60	7	36	31	-
[1] Univ Calif	381	35	16	106	34	3
[1] Univ So Calif	325	145	-	50	30	-
Colorado	619	86	1	89	10	1
[1] Colo A and M	91	6	-	18	-	-
Colo Coll	4	-	-	3	-	-
[1] Colo Univ	469	77	1	50	10	1
[1] Univ Denver	55	3	1	18	-	-
Connecticut	96	28	6	34	9	-
[1] Conn Univ	48	10	-	19	3	-
[1] Yale	48	18	6	15	6	-
Delaware	73	4	-	15	5	-
[1] Univ Dela	73	4	-	15	5	-
Florida	394	8	4	66	6	-
[1] Univ Fla	133	8	4	38	6	-
Univ Miami	261	-	-	28	-	-
Georgia	417	25	1	73	11	-
[1] Ga Tech	417	25	1	73	11	-
Idaho	149	1	-	25	-	-
[1] Idaho Univ	149	1	-	25	-	-
Illinois	1,099	198	52	149	110	10
Bradley	148	1	-	12	-	-
[1] Ill Inst Tech	141	47	6	22	5	-
[1] Northwestern	84	43	8	14	16	-
[1] Ill Univ	726	107	38	101	89	10
Indiana	1,236	65	16	270	36	5
Evansville	7	-	-	-	-	-
Ind Tech	286	-	-	47	-	-

Table 6 continued

Institution	Enrollment Fall 1956 B.S.	Enrollment Fall 1956 M.S.	Enrollment Fall 1956 PhD.	Degrees 1955-56 B.S.	Degrees 1955-56 M.S.	Degrees 1955-56 PhD.
Indiana (continued)						
[1] Notre Dame	175	5	-	33	1	-
[1] Purdue	416	60	16	109	35	5
[1] Rose Poly	39	-	-	14	-	-
Tri-State Coll	210	-	-	57	-	-
Valparaiso	103	-	-	10	-	-
Iowa	500	32	16	72	28	2
[1] Iowa St Coll	370	26	13	59	28	2
[1] St Univ Iowa	130	6	3	13	-	-
Kansas	533	37	-	49	3	-
[1] Kansas St Coll	265	7	-	30	1	-
Mun Univ Wichita	101	-	-	2	-	-
[1] Univ Kansas	167	30	-	17	2	-
Kentucky	580	37	-	69	11	-
[1] Univ Ky	548	18	-	59	10	-
[1] Univ Louisville	32	19	-	10	1	-
Louisiana	385	48	-	56	2	-
[1] La Poly	133	-	-	10	-	-
[1] La St Univ	117	29	-	22	2	-
[1] S W La Inst	66	-	-	7	-	-
[1] Tulane	69	19	-	17	-	-
Maine	119	3	-	25	2	-
[1] Maine Univ	119	3	-	25	2	-
Maryland	361	14	4	55	8	2
[1] Johns Hopkins	137	10	4	25	6	2
[1] Univ Md	224	4	-	30	2	-
Massachusetts	854	143	27	174	63	3
Bradford Durfee	31	-	-	4	-	-
Harvard	-	10	4	-	12	-
[1] Mass Inst Tech	173	57	23	52	39	3
Merrimack Coll	54	-	-	6	-	-
[1] Univ Mass	96	9	-	17	-	-
[1] Northeastern	335	67	-	59	12	-
[1] Tufts Univ	71	-	-	26	-	-
[1] Worcester	94	-	-	10	-	-
Michigan	1,485	104	15	179	73	6
Detroit Inst	69	-	-	7	-	-
[1] Detroit Univ	182	-	-	30	-	-
Lawrence Inst	147	-	-	5	-	-
[1] Mich M and T	384	4	-	48	1	-
[1] Mich St Univ	300	17	-	40	8	-
[1] Mich Univ	238	54	15	37	62	6
[1] Wayne Univ	165	29	-	12	2	-
Minnesota	359	31	5	39	23	6
[1] Univ Minn	359	31	5	39	23	6
Mississippi	442	3	-	40	3	-
[1] Miss St Coll	362	2	-	29	3	-
[1] Univ Miss	80	1	-	11	-	-

Table 6 continued

Institution	Enrollment Fall 1956 B. S.	Enrollment Fall 1956 M. S.	Enrollment Fall 1956 PhD.	Degrees 1955-56 B. S.	Degrees 1955-56 M. S.	Degrees 1955-56 PhD.
Missouri	890	42	4	100	11	-
[1] Mo Mines	427	17	-	44	2	-
[1] Univ of Mo	292	17	3	34	7	-
St Louis Univ	54	-	-	4	-	-
[1] Wash Univ (St L)	117	8	1	18	2	-
Montana	154	4	-	19	1	-
[1] Mont St Coll	154	4	-	19	1	-
Nebraska	170	-	-	37	1	-
[1] Univ of Neb	170	-	-	37	1	-
Nevada	142	2	-	15	1	-
[1] Univ of Nev	142	2	-	15	1	-
New Hampshire	180	-	-	15	-	-
[1] Dartmouth	51	-	-	4	-	-
[1] Univ N H	129	-	-	11	-	-
New Jersey	325	75	-	79	29	-
[1] Newark	246	56	-	51	15	-
[1] Princeton	42	13	-	14	12	-
[1] Rutgers	37	2	-	14	2	-
Stevens	-	4	-	-	-	-
New Mexico	213	21	-	34	1	-
[1] New Mex A and M	127	6	-	10	1	-
[1] Univ N Mex	86	15	-	24	-	-
New York	2,699	428	36	450	113	3
[1] Brooklyn Poly	367	140	-	57	20	-
[1] City Coll of N Y	696	78	-	84	10	-
[1] Clarkson	196	-	-	30	-	-
[1] Columbia	68	100	13	17	34	1
[1] Cooper Union	100	-	-	19	-	-
[1] Cornell	281	17	-	41	12	-
[1] Manhattan Coll	377	-	-	77	-	-
[1] N Y Univ	227	66	13	35	19	1
[1] Rensselaer	242	25	2	70	15	1
Syracuse	86	2	1	11	3	-
[1] Union Coll	59	-	-	9	-	-
North Carolina	694	16	-	83	6	-
[1] Duke Univ	76	-	-	25	-	-
[1] N C State Coll	618	16	-	58	6	-
North Dakota	241	8	-	45	4	-
[1] N Dak Ag Coll	155	-	-	30	-	-
[1] Univ N Dak	86	8	-	15	4	-
Ohio	1,150	47	2	165	1	-
Antioch	10	-	-	2	-	-
[1] Case	123	31	-	30	-	-
[1] Fenn Coll	47	-	-	19	-	-
[1] Ohio Northern	82	-	-	7	-	-
[1] Ohio State Univ	250	16	2	29	1	-
[1] Ohio Univ	118	-	-	24	-	-
[1] Univ Akron	20	-	-	3	-	-

Table 6 continued

	Enrollment Fall 1956			Degrees 1955-56		
	B.S.	M.S.	PhD.	B.S.	M.S.	PhD.
Ohio (continued)						
[1] Univ Cincinnati	150	-	-	21	-	-
[1] Univ Dayton	124	-	-	10	-	-
[1] Univ Toledo	91	-	-	10	-	-
Youngstown	135	-	-	10	-	-
Oklahoma	320	30	1	25	10	-
[1] Okla A and M	172	17	1	11	4	-
[1] Univ Okla	148	13	-	14	6	-
Oregon	158	7	1	24	2	1
[1] Ore State	158	7	1	24	2	1
Pennsylvania	1,751	181	21	321	44	9
[1] Bucknell	109	2	-	20	1	-
[1] Carnegie	238	31	3	41	-	3
[1] Drexel	270	27	-	49	2	-
[1] Lafayette	101	-	-	18	-	-
[1] Lehigh	111	39	13	34	18	5
Pa Mil College	47	-	-	13	-	-
[1] Pa State Univ	442	9	2	68	8	-
[1] Swarthmore	12	-	-	5	-	-
[1] Univ Penn	73	45	3	13	10	1
[1] Univ Pittsburgh	237	28	-	27	5	-
[1] Villanova	111	-	-	33	-	-
Rhode Island	95	3	-	23	-	-
[1] Brown	5	-	-	6	-	-
[1] Univ R I	90	3	-	17	-	-
South Carolina	675	-	-	101	2	-
[1] Citadel	308	-	-	42	-	-
[1] Clemson	200	-	-	36	2	-
S C State Coll	6	-	-	2	-	-
[1] Univ S C	161	-	-	21	-	-
South Dakota	186	3	-	41	-	-
[1] S Dak Mines	122	-	-	20	-	-
[1] S Dak St Coll	64	3	-	21	-	-
Tennessee	528	12	-	64	1	-
Tenn Ag and Ind	77	-	-	5	-	-
Tenn Poly	104	-	-	5	-	-
[1] Univ Tenn	188	12	-	24	1	-
[1] Vanderbilt	159	-	-	30	-	-
Texas	1,586	140	6	192	35	3
Lamar St Tech	136	-	-	8	-	-
Prairie View	14	-	-	3	-	-
[1] Rice Inst	33	-	-	7	-	-
[1] Southern Meth	115	63	-	9	1	-
[1] Tex A and M	329	36	2	86	21	2
[1] Tex Tech	205	-	-	27	-	-
Tex Western	145	-	-	10	-	-
Univ Houston	253	14	-	7	2	-
[1] Univ Texas	356	27	4	35	11	1

Table 6 continued

	Enrollment Fall 1956			Degrees 1955-56		
	B.S.	M.S.	PhD.	B.S.	M.S.	PhD.
Utah	569	3	-	59	2	-
Brigham Young	184	-	-	4	-	-
[1] Univ Utah	138	1	-	18	2	-
[1] Utah St Ag Coll	247	2	-	37	-	-
Vermont	216	-	-	24	-	-
[1] Norwich	117	-	-	15	-	-
[1] Univ Vermont	99	-	-	9	-	-
Virginia	879	18	1	117	5	-
[1] Univ of Va	121	3	-	18	1	-
[1] Va Military Inst	305	-	-	65	-	-
[1] Va Poly	453	15	1	34	4	-
Washington	603	52	2	93	9	-
Gonzaga	70	-	-	5	-	-
St Martins	26	-	-	5	-	-
Seattle	68	-	-	10	-	-
[1] Univ Wash	225	50	2	51	7	-
Walla Walla	20	-	-	-	-	-
[1] Wash St Coll	194	2	-	22	2	-
West Virginia	122	-	-	11	1	-
[1] W Va Univ	122	-	-	11	1	-
Wisconsin	835	56	13	96	11	4
[1] Marquette	195	-	-	34	-	-
[1] Univ Wisc	495	56	13	50	11	4
Wisc Inst Tech	148	-	-	12	-	-
Wyoming	155	9	-	26	4	-
[1] Univ Wyo	155	9	-	26	4	-
Dist of Columbia	292	17	-	26	3	-
Catholic Univ	74	17	-	14	3	-
[1] Geo Wash Univ	107	-	-	7	-	-
[1] Howard Univ	111	-	-	5	-	-
[1] Alaska - U of	91	-	-	4	-	-
[1] Hawaii - U of	425	-	-	46	-	-
Puerto Rico - U of	187	-	-	59	-	-

[1] Undergraduate curriculum accredited by the Engineers' Council for Professional Development.
[2] Includes Pre-doctoral (professional) degree.

or sanitation. At the University of Illinois, 91 out of 111 masters candidates are majoring in structures. At the State University of Iowa, 10 of 13 doctors are majoring in hydraulics. University of Michigan has 13 out of 15 doctors in structural engineering.

There were reported 32 schools enrolling students for masters degrees in highway engineering and 7 schools for the doctors degrees. Of the 32 schools only 11 enrolled 5 or more students for the masters degree. Of the total 153 students, 33 are enrolled at Purdue University and 20 at the University of California.

There are 11 schools out of 36 enrolling 5 or more students for the masters degree in soils. These 11 schools account for 123 out of the total of 166 students. Columbia

University enrolled 48, Iowa State College 18, and Massachusetts Institute of Technology 13.

At the doctors level only two schools, University of California and Purdue University, have an enrollment in highways of more than one student. In soils, Iowa State College, Northwestern University, University of Illinois, and Purdue University are the only schools enrolling 5 or more candidates for the doctors degree.

The civil engineering enrollments, fall of 1956, by institution and the number of degrees awarded in the 1955-56 school year are given in Table 6. These statistics are from reports of the U. S. Office of Education. As pointed out earlier there are differences in Table 6 and the information reported from the questionnaire study. Table 6 is useful in comparing graduate enrollment in civil engineering with undergraduate enrollment. Also, Table 6 affords opportunity to study the enrollment and numbers of graduates in civil engineering in each of the 168 schools offering civil engineering.

SUMMARY

This study of the number of graduate students in civil engineering indicates that a reasonable percentage are majoring in highway engineering. Although not a complete coverage and a study whose accuracy is questionable in spots, this study does indicate that about 10 percent of the civil engineering graduate students at the masters level and 5 percent at the doctors level are majoring in highway engineering. For the 1955-56 school year these percentages would indicate that about 80 master degrees and 3 doctor degrees were awarded with majors in highway engineering.

In soils engineering, the percentages are about 10 and 14, which would produce for the 1955-56 school year about 80 graduates with masters degrees and 9 with the doctors degree.

With the trend upward in civil engineering enrollments at all class levels, there will be available increasing numbers of civil engineering graduates for entry into highway work.

Turnover and Factors in the Retention of Highway Engineering Personnel

ELLIS DANNER, Professor of Highway Engineering
University of Illinois

●IN DEVELOPING its program of research, the Highway Research Board Committee on Education and Training of Highway Engineering Personnel found that the education and training problems were complicated by the apparently high rate of turnover of engineering personnel in the highway departments. The effectiveness of education and training programs in the highway field would be greatly reduced if a considerable number of the persons developed by these programs were lost to other engineering fields. Some definite information on the extent of turnover of engineering personnel seemed desirable as a starting point.

The verification of a high rate of turnover in the face of a greatly expanded highway program emphasized the need for immediate study of the causes of turnover so that corrective measures might be initiated. To meet the engineering manpower requirements for the national highway program it is equally, if not more important, to retain the experienced personnel already in the highway departments than it is to recruit additional engineering staff. The real problem is to obtain the true reasons for engineers leaving the highway departments and not merely assumed or commonly stated reasons. If highway departments are to take effective action to make highway engineering a reasonably attractive career, they must have factual information on the favorable and unfavorable factors affecting highway engineering employment or time and effort will be wasted. A pilot study was initiated to see how this factual information could be obtained.

TURNOVER OF ENGINEERING PERSONNEL IN 1955

To get specific data on the turnover situation for 1955, a questionnaire was developed (See Appendix A) and sent to the 48 state highway departments and the District of Columbia. The data obtained are given in Table 1.

Engineering losses for 1955 were approximately 10 percent of the entire engineering staffs of the state highway departments at the end of the year. Total additions of engineering personnel were somewhat greater than the losses, but a large number of these were promotions from preprofessional grades and therefore were not additions to total available staff. The number of new personnel hired in the preprofessional grades was not included in the data. Considerably fewer new engineering personnel were hired than were lost, although the states desired to increase their engineering staffs by an average of about 20 percent for 1956. This 1956 estimate was based on needs for the normal 1956 program and did not include additional requirements for the expanded National Highway Program, which became a reality in 1956. Indications are that most of the state highway departments employed all of the engineering personnel that they could attract in 1955, therefore, it appears unlikely that they could fill their estimated requirements for 1956, because of relatively little increase in the available supply or in their ability to attract engineers from other employers.

The total of 1,760 for those departing on leave (mostly military leave) and those resigning was made up mostly of younger engineers. This number is only slightly less than the total (1,843) of new engineering personnel hired and those returning from leave. A real training problem exists when the highway departments in an expanding program lose almost as many experienced engineers each year (not counting the normal losses from death, retirement, and dismissal) as they add new and inexperienced personnel. Furthermore, the increased manpower needs of the expanded highway program are still to be met.

Serious and concerted attention to the problem of making highway engineering a more attractive career in all of the highway departments to reduce losses seems justified.

TABLE 1

SUMMARY OF DATA FROM STATES ON TURNOVER OF HIGHWAY ENGINEERING PERSONNEL FOR PERIOD JANUARY 1 THROUGH DECEMBER 31, 1955
(Total Number of States Reporting and D C - 49)

State	New HEP Hired	Returning from Leave	Promoted from Preprofessional Grades	Total Additions	Deaths or Retired	Dismissed or Separated	Departed on Leave	Resigned	Total Losses	Net Gain + or Net Loss -	Total HEP Dec 31, 1955	Desired Additional HEP for 1956
Alabama	67	5	14	86	2	0	37	36	75	+11	403	60
Arizona	5	0	6	11	2	0	0	5	7	+ 4	53	17
Arkansas	7	0	5	12	1	1	2	2	6	+ 6	120	100
California	416	42	235	693	39	63	62	285	449	+244	3451	410
Colorado	16	0	26	42	12	1	1	11	25	+17	328	50
Connecticut	21	1	23	45	8	0	4	14	26	+19	402	0
Delaware	0	0	0	0	0	0	0	0	0	0	70	15
Florida	30	5	15	50	5	0	10	20	35	+15	693	50
Georgia	31	2	71	104	3	1	3	11	18	+86	524	160
Idaho	20	0	8	28	3	2	4	29	38	-10	130	20
Illinois	145	21	5	171	20	3	51	141	215	-44	1002	400
Indiana	75	2	0	77	1	0	17	26	44	+33	368	172
Iowa	30	3	0	33	4	0	15	0	19	+14	336	50
Kansas	9	0	0	9	2	0	10	18	30	-21	317	98
Kentucky	16	1	6	23	3	0	6	50	59	-36	617	100
Louisiana	50	0	5	55	3	2	4	11	20	+35	309	109
Maine	15	3	3	21	2	0	11	9	22	- 1	174	21
Maryland	4	1	0	5	2	0	2	20	24	-19	350	30
Massachusetts	26	1	20	47	12	0	3	35	50	- 3	702	110
Michigan	38	15	0	53	7	0	26	41	74	-21	601	174
Minnesota	21	1	65	87	15	0	13	35	63	+24	530	50
Mississippi	7	3	0	10	0	0	1	13	14	- 4	111	47
Missouri	71	1	6	78	15	2	7	34	58	+20	702	40
Montana	12	3	6	21	0	0	2	5	7	+14	214	26
Nebraska	17	2	22	41	4	3	2	17	26	+15	239	40
Nevada	3	0	0	3	0	0	1	1	2	+ 1	89	20
New Hampshire	16	0	8	24	4	0	0	9	13	+11	237	79
New Jersey	16	0	5	21	9	0	2	21	32	-11	420	140
New Mexico	15	2	12	29	2	1	2	10	15	+14	124	35
New York	14	5	97	116	41	0	10	72	123	- 7	1377	650
North Carolina	17	1	14	32	4	2	2	30	38	- 6	437	50
North Dakota	3	0	3	6	0	1	2	2	5	+ 1	63	20
Ohio	99	6	32	137	12	0	46	18	76	+61	636	200
Oklahoma	3	0	2	5	2	0	0	7	9	- 4	115	50
Oregon	33	8	36	77	8	3	6	46	53	+24	495	50
Pennsylvania	5	0	9	14	3	10	0	0	13	+ 1	480	130
Rhode Island	4	0	0	4	1	0	0	0	1	+ 3	73	87
South Carolina	13	0	0	13	3	1	1	16	21	- 8	241	80
South Dakota	15	0	2	17	1	0	0	2	3	+14	91	15
Tennessee	30	6	18	54	5	6	5	18	34	+20	216	50
Texas	93	10	0	103	4	2	34	57	97	+ 6	922	100
Utah	8	0	14	22	3	1	0	10	14	+ 8	175	25
Vermont	12	0	7	19	1	0	0	12	13	+ 6	158	57
Virginia	9	5	20	34	2	0	7	17	26	+ 8	360	60
Washington	48	4	32	84	7	7	2	38	54	+30	966	0
West Virginia	19	0	8	27	2	3	0	49	54	-27	226	100
Wisconsin	38	2	1	41	6	0	11	29	46	- 5	398	60
Wyoming	11	2	10	23	4	0	1	10	15	+ 8	92	28
Dist of Columbia	7	0	10	17	0	0	1	2	3	+14	94	30
Totals	1,680	163	881	2,724	289	115	426	1,334	2,164	+560	21,229	4,465[1]

[1] Estimate based on needs for the normal 1956 program and does not include requirements for an expanded National Highway Program which has since become a reality

Unfavorable employment conditions in any of the highway departments become generally known and make more difficult the problem of attracting and retaining engineering personnel in other highway departments. Thus, the efforts should be directed toward improving engineering employment conditions in all highway departments up to at least certain minimum desirable standards.

PROCEDURE FOR STUDYING FACTORS IN RETENTION OF ENGINEERING PERSONNEL

Any highway department that wishes to change its organization and administration to improve its engineering career opportunities needs specific information on what engineering employees consider as important favorable and unfavorable employment conditions. A proper remedy can't be prescribed unless the correct diagnosis is made. How can the factual information be obtained?

Several state highway departments have a policy of interviewing each person who submits a resignation, as to his reasons for leaving. As a part of this Committee study some persons who have left highway departments have been questioned about this procedure and it appears likely that only partially complete and sometimes incorrect information may be obtained when a senior person in the highway department conducts such an interview. Many engineers, when they have decided to leave, don't wish to make an issue of their reasons for leaving; they don't wish to offend someone, or they may not have clearly in their own minds the specific combination of factors which caused them to make their decision. They give a reason which comes first to mind—it may or may not be the primary reason, and usually it is only one of several real reasons. Dependable information from persons not planning to resign, at least immediately, is even more difficult to obtain.

While this conclusion is not verified by specific studies, there seems to be general agreement that true and complete information can best be obtained from the engineering personnel concerned by someone outside the highway department who has their confidence. Staff members of the engineering colleges in a state may know personally a number of the engineers in the highway department and may be able to conduct an effective study. In any case the information given must be treated with confidence and the person giving it must be assured that what he says will not be associated with him personally in the study or otherwise.

After some personal interviews indicated that both present and former highway engineers have developed either a favorable or unfavorable attitude toward highway employment as a composite feeling, usually without any particular analysis of the reasons, some help in determining specific reasons was needed. It was decided to try a comprehensive questionnaire which would first establish factual information about highway employment from the point of view of the particular engineer, and would then give him a guide for selecting the favorable and unfavorable factors in order of their importance. The questionnaire used and the letter of transmittal are shown as Appendix B. It was realized that the questionnaire was quite lengthy and would require considerable time to complete. It would be useless if a reasonable number of engineers could not be sufficiently made aware of its importance to be willing to fill it out accurately and completely.

For the pilot study 136 questionnaires were mailed out, 68 to engineers still employed by highway departments, and 68 to engineers no longer employed. This was done on a paired basis, that is, for each engineer selected at random who had formerly worked for a highway department, a present employee was selected who had started to work with that highway department at approximately the same time and in the same subdivision of the department. With only a few exceptions none of those selected had started to work for the highway departments more than 10 years ago. Former employees returned 21 questionnaires, of which 15 were complete and 6 were incomplete or were received too late to be included here. Present employees returned 40 questionnaires, of which 37 were complete. No followup to the original letter of transmittal urging the return of the questionnaires has been sent out as yet. Inadequate forwarding addresses for former employees reduced the percentage of those returns. It is believed that with suitable followup letters a sufficiently high percentage of return of these questionnaires can be obtained to justify their use in spite of the length.

Only a partial analysis has been made of the data obtained to date. The most effective procedure for tabulating, classifying, and interpreting the great amount of data made available by these completed questionnaires is yet to be studied. Some business machine method may provide the most effective means of processing the data to its fullest utilization. Hand methods of tabulation and analysis were used to obtain the information presented in this report covering the 15 complete questionnaires from engineers no longer employed and 37 questionnaires from engineers still employed.

SUMMARY OF EMPLOYMENT EVALUATION DATA

1. The average length of highway department employment by those no longer employed was 3 years.

2. The average monthly salary increase at the time of changing employment by those no longer employed by the highway department was $65.

3. The present average monthly salary of those no longer employed is $624, whereas the present monthly salary of those still employed is $555.

4. The favorable and unfavorable employment factors for both those no longer employed and those still employed by the highway department are shown in Tables 2, 3, 4, and 5. The score shown was computed as a composite value after assigning a value of 10 to the most important of the ten factors as marked by each engineer, and 1 to the least important, with proper scale values between these two. The score indicates something of the relative importance of the factors listed.

TABLE 2

FAVORABLE EMPLOYMENT FACTORS LISTED BY THOSE NO LONGER EMPLOYED BY THE HIGHWAY DEPARTMENT

		Score
1.	Reasonable assurance of continued employment even in depression.	59
2.	Interesting and enjoyable work.	55
3.	Steady future highway development and the corresponding demand for engineering services offer a high degree of security of employment in the highway engineering field.	39
4.	Good bosses or supervisors, well-trained, know their job and how to handle people.	31
5.	Doing type of work on which the engineer makes important decisions and does independent work.	30
6.	Expanded highway program and prospective retirements indicate good opportunities for advancement for some years to come.	27
7.	Associates friendly and helpful.	27
8.	Good opportunity to learn and gain valuable experience in my field of interests.	27
9.	The technical and engineering staff below a few top level positions are free from transfer or removal for political considerations.	25
10.	Liked the community and people in the area.	22
11.	Salary levels satisfactory for starting and for the first few years of engineering work.	21
12.	Challenging and stimulating work most of the time.	20
13.	Work of the highway department essential to national economy, feel that total accomplishment is important.	20
14.	Satisfactory sick leave and compensation policies in effect.	20
15.	Amount of paid vacation allowed per year satisfactory.	18

TABLE 3

FAVORABLE EMPLOYMENT FACTORS LISTED BY THOSE STILL EMPLOYED BY THE HIGHWAY DEPARTMENT[1]

		Score
1. (3)	Steady future highway development and the corresponding demand for engineering services offer a high degree of security of employment in the highway engineering field.	162
2. (2)	Interesting and enjoyable work.	136
3. (1)	Reasonable assurance of continued employment even in depression.	113
4.	Retirement plan including deductions and benefits satisfactory.	102
5. (6)	Expanded highway program and prospective retirements indicate good opportunities for advancement for some years to come.	100
6. (12)	Challenging and stimulating work most of the time.	87
7. (13)	Work of the highway department essential to national economy; feel that total accomplishment is important.	62
8. (10)	Liked the community and people in the area.	52
9.	Progress in increased responsibility reasonably regular and certain.	50
10.	Promotions generally made from lower engineering grades and not from outside the highway department.	49
11.	Wide choice of employment and employers in the highway field.	44
12.	Good working hours.	40
13.	Adequate housing available in assigned area.	38
14. (7)	Associates friendly and helpful.	35
15. (15)	Amount of paid vacations allowed per year satisfactory.	35

[1] Numbers in parentheses indicate corresponding position of the same item in Table 2.

TABLE 4

UNFAVORABLE EMPLOYMENT FACTORS LISTED BY THOSE NO LONGER EMPLOYED BY THE HIGHWAY DEPARTMENT

	Score
1. The chances of getting up to a reasonably comfortable living salary in later years are too slim to make a career with the highway department attractive.	58
2. Engineering salary scale in general too low as compared with private industry and other opportunities.	49
3. Salary progress too slow, either adjustments not given often enough or the amount of adjustments too small.	36
4. Too much political interference in general with the work and operations of the highway department.	34
5. Undesirable and unnecessary changes in highway department policies occur with changes in administration.	24
6. Rate of advancement very slow and discouraging after first few years of employment.	21
7. No pay given for overtime work.	21
8. Services used below the level of professional engineering talent.	21
9. No recognition or consideration given for overtime work.	20
10. Other employees dissatisfied and disgruntled with the highway department, continued talk of all the things that are wrong.	20
11. Members of the legislative group responsible for laws and regulations of the highway department show little respect or consideration for the technical and engineering staff.	19
12. Chief engineer removed and replaced with changes in administration.	19
13. Salary levels too low for older engineers in technical work not classified as supervisory or administrative in nature.	18
14. Not assigned to duties that I was informed I would have.	17
15. No distinction made between good and poor work and hence no encouragement to do good work.	17

TABLE 5

UNFAVORABLE EMPLOYMENT FACTORS LISTED BY THOSE STILL EMPLOYED BY THE HIGHWAY DEPARTMENT[1]

	Score
1. (2) Engineering salary scale in general too low as compared with private industry and other opportunities.	121
2. Economic remuneration not in line with the responsibility of the work.	117
3. (6) Rate of advancement very slow and discouraging after first few years of employment.	95
4. (1) The chances of getting up to a reasonably comfortable living salary in later years are too slim to make a career with the highway department attractive.	90
5. (3) Salary progress too slow, either adjustments not given often enough or the amount of adjustment too small.	81
6. Too much consideration given to years of service and not enough to qualifications and ability in making selections for promotion.	78
7. (7) No pay given for overtime work.	77
8. Only a relatively few administrative positions offer any desirable future.	62
9. (9) No recognition or consideration for overtime work.	57
10. Very seldom am I informed about personnel actions affecting me until they have become effective.	57
11. Financial reward not adequate for education and training required.	56
12. (13) Salary levels too low for older engineers in technical work not classified as supervisory or administrative in nature.	53
13. Away from home too much.	48
14. (8) Services used below the level of professional engineering talent.	36
15. (4) Too much political interference in general with the work and operation of the highway department.	34

[1] Numbers in parentheses indicate corresponding position of the same item in Table 4.

5. Questions N-14, N-15, and N-16 were designed to find out the attitude of those still employed toward continuing employment with the highway department. These were marked as true statements by the following numbers of men still employed:

N-14 (Satisfied)	14
N-15 (Dissatisfied, but no decision to move)	9
N-15 and N-16	7
N-16 (Dissatisfied and looking for another job)	4
None of the three	3

6. The average over-all ratings given the highway department as a prospective career organization in item S are (a) by those no longer employed, 5.7; (b) by those still employed, 6.4.

7. For the question in item T as to whether the engineer thought that the highway department could be made into an excellent prospect as a career organization, 43 answered yes, 6 answered no, and 3 did not answer.

CONCLUSIONS OF THIS PRELIMINARY STUDY

1. The rate of turnover of highway engineering personnel is sufficiently high to justify coordinated and intensive study aimed at making highway departments more attractive career organizations.

2. The employment evaluation studies based on a questionnaire method and conducted by personnel outside the highway departments are practical and will give useful information for evaluating employment conditions and prescribing corrective measures.

3. This research should be continued, with several additional highway departments participating in parallel studies to develop effective procedures and to check the findings of this preliminary study.

4. Indications from the preliminary study are that salary levels in the highway departments, particularly for the higher grades, are not sufficiently high relative to other fields, to offer attractive career opportunities to young engineers, and this is a major factor to engineers in considering highway employment. However, a number of other factors influence the decision of engineers to leave highway employment and it is usually the effect of the combination of factors that results in the final decision for a change.

APPENDIX A

QUESTIONNAIRE TO STATE HIGHWAY DEPARTMENTS

Data on Turnover of Highway Engineering Personnel - 1955

(Note: The information given below should include only the highway or civil engineering personnel in the professional grades, that is, the personnel in highway or civil engineering positions that require graduation from an engineering college or equivalent engineering training and experience. Whether or not the persons are registered or licensed under state laws as professional engineers is not to be considered in your tabulation. Do not include preprofessional or subprofessional personnel, that is, rodmen, engineering aides, draftsmen, laboratory technicians, etc. who hold positions not requiring education and experience equivalent to the requirements for the professional grades. (See paper No. 761 of the American Society of Civil Engineers, August, 1955, for listing of requirements of professional grades of engineering position). No doubt most of you have some other professional engineering classifications such as chemical, electrical, mechanical, and landscape engineers, but as this number is relatively small do not include these persons in your report.

Name and address ______________________________

of organization ______________________________

____

(Please give data for the period January 1 through December 31, 1955)

1. ADDITIONS TO HIGHWAY ENGINEERING PERSONNEL:
   a. New personnel hired during the year ________
   b. Personnel returning from military or other leave ________
   c. Personnel promoted from preprofessional grades ________
   d. Total additions ________
2. LOSSES OF HIGHWAY ENGINEERING PERSONNEL:
   a. Personnel deaths or retirements ________
   b. Personnel dismissed or separated for cause ________
   c. Personnel going on military or other leave ________
   d. Personnel resigning to go into other work ________
   e. Total losses ________
3. Net gain ______ Net Loss ______
4. Total number of highway engineering personnel on duty with your organization as of December 31, 1955 ________
5. Estimated number of additional highway engineering personnel that you would like to have in your organization for 1956 if you could employ them ________

Name of person making report ______________________________

Date ____________ Title ______________________________

(Mail to. Highway Research Board
Committee on Education and Training of Highway Engineering Personnel
201 Civil Engineering Hall
University of Illinois
Urbana, Illinois

APPENDIX B

QUESTIONNAIRE TO INDIVIDUALS

To: Selected Engineering Employees and Former Employees of the ______________ ____________________ Highway Department.

Dear Sir:

With the approval by Congress of the Federal-Aid Highway Act of 1956 we are entering upon a long-range highway development program of immense proportions. The planning, design, construction, and maintenance of these highways will challenge our engineering capabilities to the limit.

In general, highway departments are understaffed for this enlarged program because of their inability to retain sufficient engineers in career positions. How can highway departments attract and hold the engineering personnel that they will need for years to come? The Highway Research Board is conducting a study aimed at providing some of the answers to this question. This study is being undertaken in several states.

Apparently changes must be made in the organization and operation of highway departments if they are to offer real career opportunities. What are these necessary changes? Only substantial factual information can be helpful in determining what these changes should be and in persuading the administrative authorities to make these change And only you people who have worked or are still working in the highway department can provide this factual information.

Will you be willing to contribute to this study by filling out the three parts of the enclosed questionnaire and returning them to me? It will take some time and careful thought on your part to be sure of the correct answers and only the correct and truthful answers will be of any value. I hope that you have sufficient interest in professional engineering development to give us the data that is needed. I assure you that your answers will be handled in a confidential manner and will not be associated with you in any way.

May I depend upon you to help by filling out and returning the enclosed items to me within the next week or two?

Very sincerely,

Encls.

Study of Factors in Retention of Highway Engineering Personnel

PART I

Identification Data

Highway Department: ______________________________

Date ______________

1. Name ______________ Confidential File No. ______________

2. Present mailing address ______________________________

____

3. Business telephone number ______________________________

4. Present employer ______________________________

____
Signature

(Please return completed Parts I, II, and III in the enclosed stamped and addressed envelope to ______________________________ ______________. Parts II and III will be kept and used separately from Part I, will be identified by confidential file number only, and will not in any way be associated with your name in any of the studies and reports. Only the addressee above will have access to this identification data in Part I or will have any opportunity of associating Parts II and III with your name and that will be done only for the purpose of checking and verifying the return of this report. Access to Part II will also be limited to the addressee to prevent any possibility of identification from personal data shown therein.)

I hereby certify that the material returned by you will be treated in a confidential manner to prevent the data furnished from being associated in any way with you or your name by anyone except the undersigned.

Date ______________ ______________________________
Name and Title

Study of Factors in Retention of Highway Engineering Personnel

PART II

Confidential Personal Data

Highway Department: ____________________

Confidential File No. ____________ Date ____________

1. Business of your present employer ____________________
2. Your present position and duties ____________________
____
3. Present monthly salary or income from above employment:
Total $________ Regular monthly salary $________ Average monthly overtime pay $________ Average monthly expenses or other allowances $________ Average monthly bonus or share in profits $________ Average monthly commission $________
4. Year of graduation from high school ____________________
5. Home town and state at time of entering college ____________________
6. B.S degree.
Branch of engineering ____________ Major or option, if any ____________
Institution ____________ Date received ____________
7. M. S. degree:
Major field of study ____________________
Institution ____________ Date received ____________
8. Employment by ____________ Highway Department·
a. How hired· (1) If personal interview, by whom? ____________
(2) Contact through friend? ____________
(3) Correspondence contact only? ____________
b. Date of starting work ____________
c. Monthly salary at time of starting work $ ____________
d. Bureau or district to which assigned when starting work ____________
e. Position classification and duties now if still employed or just before resignation if no longer employed ____________
____
____
f. Present monthly salary and expenses if still employed by the Highway Department or just before resignation if no longer employed. Total $________
Regular monthly salary $________ Average monthly expenses or other allowances $________
g. Bureau or district to which assigned now if still employed or just before resignation if no longer employed ____________
h. Effective date of resignation if no longer employed ____________
i. Amount of temporary employment with the Highway Department before graduation (summers, vacations, etc.) Total in months ____________
j. At the time of accepting employment how long did you expect to stay with the Highway Department? ____________
____
9. Employment immediately after leaving the ____________ Highway Department.
a. Business of new employer ____________
b. Monthly salary or income when starting new employment:
Total $________ Regular monthly salary $________ Average monthly overtime pay $________ Average monthly expenses or other allowances $________
Average monthly bonus or share in profits $________ Average monthly commissions $________
c. Other benefits received with new employment ____________
d. Are you presently working for the same employer that hired you immediately after leaving the Highway Department? ____________
e. Did you actively seek new employment or did the opportunity come to you unsolicited? ____________
10. Additional comments about personal data:

PART III

Confidential Employment Evaluation Data

Highway Department: ______________________________

Confidential File No. ______________ Date ______________________

Please place the proper marks in Columns (1), (2), and (3) in accordance with the instructions below:

Column (1): Evaluation of attitudes and conditions affecting employment with the highway department.

a. Mark in the brackets in Column (1) for each numbered statement listed on the following sheets whether, according to your personal knowledge, experience, best judgment, and feelings, each statement is True (T), False (F), Unknown (U), or Not Applicable (N) as far as you are concerned.

Column (2): Favorable factors for employment with the highway department.

a. After marking all items in Column (1), go through the entire list of statements and select the ten conditions that you consider most favorable and important to employment as an engineer with the highway department (they may be either true or false statements as worded, as long as the actual conditions existing are favorable). Mark those ten conditions in the appropriate brackets in Column (2) with a (1) for the condition that you consider the most important favorable condition (having the greatest influence on your staying with the highway department) and rating the others (2), (3), (4), etc., in order of importance down to (10) for the one of the selected ten favorable conditions that you consider of the least importance.

b. In addition to the above ten rated favorable factors, mark in Column (2) with an (F) any other favorable conditions which you think important enough to have some influence on your decision about a career with the highway department.

Column (3): Unfavorable factors for employment with the highway department.

a. Go through the entire list of statements again and select the ten conditions that you consider most unfavorable and important to employment as an engineer with the highway department (they may be either true or false statements as worded, as long as the actual conditions existing are unfavorable). Mark these ten conditions in the appropriate brackets in Column (3) with a (1) for the condition that you consider the most important unfavorable condition (having the greatest influence on your leaving the highway department) and rating the others (2), (3), (4), etc., in order of importance down to (10) for the one of the selected ten unfavorable conditions that you consider of the least importance.

b. In addition to the above ten rated unfavorable factors mark in Column (3) with a (U) any other unfavorable conditions which you think important enough to have some influence on your decision about a career with the highway department.

Notes:

1. In marking Column (1) you will find some statements that have essentially the same meaning as other statements in the list with a different wording or you will find some statements that mean just the opposite of other statements in the list. Please mark each statement individually on its own merits as it is stated and do not be concerned about the apparent duplication in statements. Answer each item on the basis of average or normal conditions and not for the exceptional case.
2. Please complete both Columns (2) and (3) regardless of whether you are still employed by the highway department or have resigned and accepted other employment.

3. All answers given should reflect your own personal views and those of your family and should not be the ideas of other engineers or associates except as those ideas have molded your own opinions.

Employment Evaluation Statements

(1) (2) (3)

A. Assignment and characteristics of work

( ) ( ) ( ) 1. Not assigned to duties that I was informed I would have.
( ) ( ) ( ) 2. People hired for engineering jobs and assigned to duties for which they are not qualified.
( ) ( ) ( ) 3. Consideration given to likes and abilities in assigning to duties.
( ) ( ) ( ) 4. Work too standardized and little opportunity to use new ideas.
( ) ( ) ( ) 5. Prefer technical to non-technical or administrative work if responsibility and pay are commensurate.
( ) ( ) ( ) 6. Interesting and enjoyable work.
( ) ( ) ( ) 7. Dislike for the kind of work assigned to me.
( ) ( ) ( ) 8. Training and ability effectively utilized generally.
( ) ( ) ( ) 9. Challenging and stimulating work most of the time.
( ) ( ) ( ) 10. Appointment or promotion to a position based on merit and qualifications.
( ) ( ) ( ) 11. Services used below the level of professional engineering talent.
( ) ( ) ( ) 12. Special or advanced education and training encouraged and effectively used.
( ) ( ) ( ) 13. Boredom with too much routine work.
( ) ( ) ( ) 14. Assigned an aim or work goal for each job that was understood.
( ) ( ) ( ) 15. Not enough variety in type of work assigned over a period of time.
( ) ( ) ( ) 16. Progress in increased responsibility reasonably regular and certain.
( ) ( ) ( ) 17. Doing type of work on which the engineer makes important decisions and does independent work.
( ) ( ) ( ) 18. Moved around to different types of work too much and not given the opportunity of staying with a particular job.
( ) ( ) ( ) 19. No distinction made between good and poor work and hence no incentive or encouragement to do good work.
( ) ( ) ( ) 20. Not the type of work available that I would want to do for very many years.

B. Working conditions

( ) ( ) ( ) 1. General geographical location of the work not desirable.
( ) ( ) ( ) 2. Disliked the immediate local area where assigned.
( ) ( ) ( ) 3. Satisfactory office conditions, space, lighting, etc.
( ) ( ) ( ) 4. Too much overtime work required.
( ) ( ) ( ) 5. Paid for overtime work.
( ) ( ) ( ) 6. Working under pressure too much of the time.
( ) ( ) ( ) 7. Adequate supporting help, clerical, stenographic, etc., provided for work.
( ) ( ) ( ) 8. Punching a time clock or an equivalent check on working hours required.
( ) ( ) ( ) 9. Too much work and not enough engineering staff to permit doing a good job.
( ) ( ) ( ) 10. Assigned a job and given considerable freedom in time and manner of getting the job done.
( ) ( ) ( ) 11. Too little higher level long-range planning resulting in too much uncertainty about what is to be done from day to day.
( ) ( ) ( ) 12. Good working hours.
( ) ( ) ( ) 13. General attitude prevails that the important thing is to get a job done with little apparent interest in being sure that it is a good engineering job.
( ) ( ) ( ) 14. No recognition or consideration for overtime work.

( ) ( ) ( ) 15. Pleasant surroundings and atmosphere for work.
( ) ( ) ( ) 16. Co-workers who are well known and have influence.

C. Living conditions

( ) ( ) ( ) 1. Adequate housing available in assigned area.
( ) ( ) ( ) 2. Away from home too much.
( ) ( ) ( ) 3. Good shopping facilities easy to reach.
( ) ( ) ( ) 4. Few recreational facilities available within a reasonable distance.
( ) ( ) ( ) 5. Good schools in the community for the children.
( ) ( ) ( ) 6. Required either to move too often or to live away from the family during the week.
( ) ( ) ( ) 7. Liked the community and the people in the area.
( ) ( ) ( ) 8. Living too expensive in assigned area.

D. Direct compensation

( ) ( ) ( ) 1. Financial reward adequate for education and training required.
( ) ( ) ( ) 2. Economic remuneration not in line with the responsibility of the work.
( ) ( ) ( ) 3. Adjustments in salary reasonably regular and certain.
( ) ( ) ( ) 4. Unfair discrimination in making salary adjustments.
( ) ( ) ( ) 5. Provision not made for salary differentials adjusted to cost of living for different areas of the department territory.
( ) ( ) ( ) 6. Salary progress too slow, either adjustments not given often enough or the amount of adjustment too small.
( ) ( ) ( ) 7. Salary levels satisfactory for starting and for the first few years of engineering work.
( ) ( ) ( ) 8. Salary levels adequate for higher level administrative positions.
( ) ( ) ( ) 9. Salary levels too low for older engineers in technical work not classified as supervisory or administrative in nature.
( ) ( ) ( ) 10. Engineering salary scale in general too low as compared with private industry and other opportunities.
( ) ( ) ( ) 11. No pay given for overtime work.
( ) ( ) ( ) 12. Regular pay increases given on a merit rating basis.
( ) ( ) ( ) 13. The chances of getting up to a reasonably comfortable living salary in later years are too slim to make a career with the highway department attractive.
( ) ( ) ( ) 14. Salaries are not sufficiently far out of line to make them a principal deciding factor regarding a career with the highway department.

E. Special reimbursements and benefits

( ) ( ) ( ) 1. Amount of paid vacation allowed per year satisfactory.
( ) ( ) ( ) 2. Not allowed expenses for trips to technical conferences and meetings.
( ) ( ) ( ) 3. Satisfactory sick leave and compensation policies in effect.
( ) ( ) ( ) 4. Allowances for travel and other expenses away from home not adequate.
( ) ( ) ( ) 5. Vacation time can be accumulated from year to year.
( ) ( ) ( ) 6. No group hospitalization or insurance plan.
( ) ( ) ( ) 7. Retirement plan including deductions and benefits satisfactory.
( ) ( ) ( ) 8. Car mileage allowance for private cars inadequate.
( ) ( ) ( ) 9. No consideration for length of service in vacation plan.
( ) ( ) ( ) 10. Adequate number of highway department-owned cars are provided for engineer use on difficult jobs or for lengthy travel.

F. Educational and development opportunities

( ) ( ) ( ) 1. Training program for newly employed engineers effective.
( ) ( ) ( ) 2. Not given opportunity to attend technical meetings and conferences.
( ) ( ) ( ) 3. Assignments rotated to give broad experience and over-all view of the department's work.
( ) ( ) ( ) 4. Not encouraged to study, improve, and develop.
( ) ( ) ( ) 5. Encouraged to work on technical society committees.
( ) ( ) ( ) 6. Co-workers from whom one can learn much.

( ) ( ) ( ) 7. Lack of opportunity for professional level training and experience.
( ) ( ) ( ) 8. Given opportunity to exchange technical information with engineers in other organizations.
( ) ( ) ( ) 9. Training program was not what I was lead to expect.
( ) ( ) ( ) 10. Good opportunity to learn and gain valuable experience in my field of interests.
( ) ( ) ( ) 11. Very little in the way of department educational programs provided.
( ) ( ) ( ) 12. No planned opportunity for advanced or additional study at educational institutions.
( ) ( ) ( ) 13. Encouraged to take extension courses.
( ) ( ) ( ) 14. No planned program of training and experience in preparation for the next higher positions for which I might be considered.

G. Opportunities and procedures for advancement

( ) ( ) ( ) 1. Only a relatively few administrative positions offer any desirable future.
( ) ( ) ( ) 2. Not enough opportunity and renumeration for technical engineering work.
( ) ( ) ( ) 3. Procedure for evaluating ability and making promotions is well planned and fair.
( ) ( ) ( ) 4. Rate of advancement very slow and discouraging after first few years of employment.
( ) ( ) ( ) 5. Too much consideration is given to years of service and not enough to qualifications and ability in making selections for promotion.
( ) ( ) ( ) 6. Promotions generally made from lower engineering grades and not from outside the highway department.
( ) ( ) ( ) 7. Expanded highway program and prospective retirements indicate good opportunities for advancement for some years to come.

H. Characteristics of direct supervision

( ) ( ) ( ) 1. Good bosses or supervisors, well-trained, know their job and how to handle people.
( ) ( ) ( ) 2. Supervisor expected too much of me beyond my education and experience.
( ) ( ) ( ) 3. My progress reviewed regularly and guidance and help given.
( ) ( ) ( ) 4. Supervisory personnel lacked training and ability in supervision.
( ) ( ) ( ) 5. No particular interest in my welfare and success.
( ) ( ) ( ) 6. Didn't know generally where I stood with the boss.
( ) ( ) ( ) 7. Given too much close supervision.
( ) ( ) ( ) 8. Supervisor didn't try to teach me the job or give me an opportunity to learn.
( ) ( ) ( ) 9. Supervisor tolerant of errors or mistakes, considerate and helpful.
( ) ( ) ( ) 10. Given opportunity to make important decisions.
( ) ( ) ( ) 11. Not informed of personal progress and deficiencies.
( ) ( ) ( ) 12. Given recognition by my supervisor for the work that I did.
( ) ( ) ( ) 13. Supervisor had poor personal attitude and made life unpleasant.
( ) ( ) ( ) 14. Given opportunity of working independently and on my own initiative.
( ) ( ) ( ) 15. Given guidance and counsel along personal as well as professional lines.

I. Professional status and recognition

( ) ( ) ( ) 1. Treated as part of the management team.
( ) ( ) ( ) 2. Inadequate recognition of achievements for the department.
( ) ( ) ( ) 3. Not given time to participate in outside professional activities.
( ) ( ) ( ) 4. Registration as a professional engineer not required except for a few top level positions.
( ) ( ) ( ) 5. Treated, respected, and recognized as professional men.
( ) ( ) ( ) 6. Apparent lack of appreciation by top management of the value of the engineering work.

( ) ( ) ( ) 7. Prospects for professional development good.
( ) ( ) ( ) 8. Engineers and non-professional employees treated the same.
( ) ( ) ( ) 9. Recognition and citations given for engineers doing outstanding professional work.

J. Political influences

( ) ( ) ( ) 1. No political endorsement or sponsor required to get an engineering job.
( ) ( ) ( ) 2. Too much political interference in general with the work and operations of the highway department.
( ) ( ) ( ) 3. The technical and engineering staff below a few top level positions are free from transfer or removal for political considerations.
( ) ( ) ( ) 4. All higher level positions filled on a political basis and subject to change with changes in administration.
( ) ( ) ( ) 5. All highway department employees, technical and non-technical, are employed on a career basis, are trained to do their jobs well, and are removed only for inefficiency or misconduct.
( ) ( ) ( ) 6. Political appointments of incompetent or unnecessary persons are made in the highway department.
( ) ( ) ( ) 7. No political contributions are required from the technical and engineering staff.
( ) ( ) ( ) 8. Undesirable and unnecessary changes in highway department policies occur with changes in administration.
( ) ( ) ( ) 9. All technical and engineering staff employed and removed on a merit basis only, free of political patronage procedures and implications.
( ) ( ) ( ) 10. Too much political influence brought to bear on engineering decisions.
( ) ( ) ( ) 11. No pressure on engineers to actively work in political campaigns.
( ) ( ) ( ) 12. Chief engineer removed and replaced with changes in administration.

K. Security of employment

( ) ( ) ( ) 1. Wide choice of employment and employers in the highway field.
( ) ( ) ( ) 2. Reasonable assurance of continued employment even in depression.
( ) ( ) ( ) 3. Lack of stability of employment, not continuous work.
( ) ( ) ( ) 4. Capricious removal from the job, demotion, or transfer, occurs too often.
( ) ( ) ( ) 5. Steady future highway development and the corresponding demand for engineering services offer a high degree of security of employment in the highway engineering field.

L. Human relations

( ) ( ) ( ) 1. Didn't like the way my boss treated me.
( ) ( ) ( ) 2. Associates friendly and helpful.
( ) ( ) ( ) 3. Irritated by some of the administrative staff who reviewed my work.
( ) ( ) ( ) 4. Enjoyed the people with whom I worked.
( ) ( ) ( ) 5. Didn't care for the official contacts that I had to make with the public.
( ) ( ) ( ) 6. Got along well and liked working with the contractor's organization on the job.
( ) ( ) ( ) 7. Didn't get cooperation from the persons who worked under me.

M. Personnel management

( ) ( ) ( ) 1. Proper methods of rating and evaluating performance used.
( ) ( ) ( ) 2. No provision for handling grievances or complaints.
( ) ( ) ( ) 3. Non-discrimination in personnel actions; fair treatment given all around.
( ) ( ) ( ) 4. Little or no apparent concern about or attention to personnel problems.
( ) ( ) ( ) 5. Position classification system well developed and adequate for technical and engineering jobs of the different levels of responsibility.
( ) ( ) ( ) 6. No training for supervision and administration.
( ) ( ) ( ) 7. Not enough delegation of authority to heads of major subdivisions to act on personnel matters.

( ) ( ) ( ) 8. Personnel actions handled promptly and fairly.
( ) ( ) ( ) 9. Performance rating system used is unfair and produces considerable dissatisfaction.
( ) ( ) ( ) 10. Effective methods of evaluating jobs and establishing salaries for different positions provided.
( ) ( ) ( ) 11. Inadequate personnel organization provided.
( ) ( ) ( ) 12. Employee associations and activities encouraged.
( ) ( ) ( ) 13. Personnel policies and actions too standardized and restricted.
( ) ( ) ( ) 14. A personnel advisory committee appointed and active in study and recommendations for personnel improvements.
( ) ( ) ( ) 15. Sufficient staff provided at all levels to handle personnel problems.
( ) ( ) ( ) 16. No merit rating system in effect.
( ) ( ) ( ) 17. Adequate personnel management plans and policies provided.

N. General morale

( ) ( ) ( ) 1. Work of the highway department essential to national economy; feel that total accomplishment is important.
( ) ( ) ( ) 2. Other employees dissatisfied and disgruntled with the highway department; continued talk of all the things that are wrong.
( ) ( ) ( ) 3. Good public relations section that keeps the public properly informed on the work of the department and the engineering methods used to provide good highways.
( ) ( ) ( ) 4. No interest taken in my personal problems.
( ) ( ) ( ) 5. Given a feeling of fair treatment in relation to others.
( ) ( ) ( ) 6. Highway department not respected by the general public.
( ) ( ) ( ) 7. Made to feel that I am important to the highway department.
( ) ( ) ( ) 8. Older supervisory employees have attitude of indifference and dissatisfaction with the department.
( ) ( ) ( ) 9. Given a feeling that the job is important and worth doing.
( ) ( ) ( ) 10. General feeling among employees and outsiders that the highway department is a poor organization for which to work.
( ) ( ) ( ) 11. Made to feel a real pride in the department and the things that it does.
( ) ( ) ( ) 12. Appreciation shown for extra effort and good work.
( ) ( ) ( ) 13. Highway department organized and managed efficiently to stimulate pride.
( ) ( ) ( ) 14. Satisfied with present work with highway department and am not interested in other employment.
( ) ( ) ( ) 15. Am not satisfied with present employment with highway department, but haven't yet had sufficient urge to cause me to go elsewhere.
( ) ( ) ( ) 16. Am not satisfied with present employment with highway department and intend to take another job when I find something to my liking.
( ) ( ) ( ) 17. Members of the legislative group responsible for laws and regulation of the highway department show little respect or consideration for the technical and engineering staff.

O. Communications

( ) ( ) ( ) 1. Established plans and procedures in effect for keeping employees informed on what is going on and planned for the highway department.
( ) ( ) ( ) 2. Not kept informed on objectives of the department.
( ) ( ) ( ) 3. Given free opportunity to make suggestions to improve employment conditions.
( ) ( ) ( ) 4. Hear too many things indirectly about the highway department that I would much prefer to hear directly from my boss.
( ) ( ) ( ) 5. Am encouraged to submit suggestions that will make a better engineering job.
( ) ( ) ( ) 6. Very seldom am I informed about personnel actions affecting me until they have become effective.
( ) ( ) ( ) 7. Communications from top level administrations are inadequate to develop close engineering-administration relations and a sense of teamwork.

P. Organization and general administration of the highway department

( ) ( ) ( ) 1. Organization of the highway department adequate for efficient operation.

( ) ( ) ( ) 2. Need a public relations section in the department.

( ) ( ) ( ) 3. Need to hire or train many more engineering technicians as supporting help for the engineering staff.

( ) ( ) ( ) 4. Decisions made at too high a level; not enough delegation of authority for efficient operation.

( ) ( ) ( ) 5. Engineering manpower is effectively utilized.

( ) ( ) ( ) 6. Too much delay in getting important decisions made.

( ) ( ) ( ) 7. Strong and effective leadership provided at the several administrative levels.

( ) ( ) ( ) 8. Much time and effort wasted by changes in decisions and assignments of work.

Q. Outside or other influences

( ) ( ) ( ) 1. Offered a big salary outside that I could not refuse.

( ) ( ) ( ) 2. Wife dissatisfied with moving, housing, my absence from home, type of work I did, associates and their families, living conditions.

( ) ( ) ( ) 3. Offered position elsewhere with opportunity greater than anything possible in the highway department.

( ) ( ) ( ) 4. Preferred to work nearer home.

( ) ( ) ( ) 5. Received other important benefits in new job not available to me in the highway department.

( ) ( ) ( ) 6. Preferred to work at a particular location.

R. Additional comments (Add here any other remarks about employment with the highway department not covered by previous statements that will be helpful in the evaluation.)

S. Over-all rating of highway department

In considering your lifetime engineering career, how would you rate the highway department as a prospective organization in which to develop that career? Please mark your rating with an X in the appropriate brackets below, marking (10) if you consider the highway department an excellent and desirable prospect, (1) if you consider it a very poor and undesirable prospect, or the appropriate number in between according to your judgment of the career prospects.

( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
1	2	3	4	5	6	7	8	9	10
Very Poor									Excellent

T. If you have marked any number other than (10) in S above, please answer yes or no to the following:

From your experience do you think that is practical and possible to make the necessary changes in the highway department required to make it an excellent prospect for career employment?

____

Increasing Productivity of Engineers Through the Use of Electronic Computers

L. R. SCHUREMAN, Highway Engineer
Bureau of Public Roads

● IN A symposium at the 35th (1956) Annual Meeting of the Highway Research Board, the potentialities of the electronic computer as a means of increasing engineering productivity were stressed.[1]

At that time, exploratory work in the Arizona Highway Department, the California Division of Highways, and the Bureau of Public Roads had just begun to produce tangible results. In Arizona, a method had been developed and adopted for the computation of centerline grades on a Univac 120 punched-card electronic computer as the initial step in the mechanization of earthwork computation. In California, methods had been developed and adopted for performing survey computations and earthwork computations on an IBM 604 electronic calculating punch. (Subsequently an IBM 650 electronic computer was installed and these methods were adapted to it.) The Bureau of Public Roads, in collaboration with the Computer Division, Bendix Aviation Corp., had developed a method for computing earthwork quantities on a Bendix G-15 electronic computer. This method was demonstrated at the ARBA convention at Miami Beach in January 1956.

From these initial applications, highway engineers have been quick to recognize the possibilities in electronic computers and during the past year interest has grown tremendously. Regional conferences of officials and engineers of the state highway departments, the Bureau of Public Roads, computer manufacturers, consulting firms, and contractors' organizations were held in Chicago, Albany, and Atlanta. At these conferences, electronic computers and their application to highway engineering operations were explained, demonstrated, and discussed.

Engineers in the state highway departments and in the Bureau of Public Roads have been and are devoting much time and effort to further exploration and a number of additional applications have been developed or are in process of development. This paper is essentially a report on these applications and other aspects of computer use.

THE ELECTRONIC COMPUTER

The type of electronic computer best suited to highway engineering work, and the one which has been used in all of the applications developed thus far, is the general-purpose digital computer. As its name implies, the digital computer works with digits or numbers. The other type of electronic computer is the analogue computer, in which quantities or physical conditions such as pressure, temperature, or flow are represented by analogous electrical quantities.

The electronic digital computer is simply a computing machine which can add, subtract, multiply, and divide. However, in addition, it can follow a predetermined continuous sequence of operations without human intervention; it can compare two numbers and follow either of two courses of action, depending on which number is the larger; and it can store numbers in its "memory" for use as needed in the computation. These characteristics, together with its fantastic speed of operation, make the electronic digital computer an extremely valuable device for the solution of problems involving large masses of data or large numbers of mathematical operations. The desk calculator can complete, as an average, about four or five arithmetic operations per minute, but a medium-sized electronic computer can complete many thousands of such operations in a minute. It can do this 24 hours a day, month after month, with an average down-time of only about 10 percent.

[1] "Increasing Productivity in Engineering" L. R. Schureman, Highway Research Board Bulletin 134, p. 62, (1956).

To use the computer for the solution of a problem, it is necessary to feed into it a prepared detailed instruction series that governs its sequence of operations in solving the problem. This is called a program. Depending on the complexity of the problem, the preparation of the program may take weeks or months. However, once completed and checked, the program, expressed in coded form on tape or cards, or wired on control panels, can be placed in the computer in a very short time. It can be used over and over, year after year, whenever that particular kind of problem is to be solved. As many programs as desired may be developed for the same computer, so that it may be used at 9:00 a. m. for earthwork computation, at 9:30 a. m. to produce a payroll, at 11:00 a. m. for a structural design problem, and so on.

In the development of a computer program, the problem first must be carefully defined and analyzed. It is then broken down into its component parts and these parts are further broken down into elementary mathematical operations, all arranged in proper sequence for the solution of the problem. This sequence, expressed in the form of a flow chart or a precise step-by-step written procedure, is then translated into "machine language" so that the program can be used by the computer. It is then carefully checked on test problems and released for use.

In an engineering problem, the engineer's knowledge, accumulated through years of study and experience, is embodied in the program. Once the program is completed and released, this knowledge is thereafter applied automatically, thus relieving the engineer of repetitive analysis and routine computation. In this way, the engineer and the computer form a team in which the capabilities of each are used to best advantage.

The knowledge, imagination and judgment of the engineer used in devising a design proposal for a specific project must, of course, remain with the engineer—it cannot be mechanized. The value of the electronic computer lies in its use in the analysis and evaluation of the design proposal or of alternate design proposals. It cannot replace the engineer, but it can serve effectively in increasing his productivity.

APPLICATIONS OF THE ELECTRONIC COMPUTER IN HIGHWAY ENGINEERING

At present electronic computers are being used for survey computations; for the computation of centerline grades; for earthwork computations, both at the design stage and for final payment; for both geometric and structural design computations for bridges; for traffic studies, including the development of trip desire charts, and the assignment of traffic to a proposed new route or system of routes; and for a number of less complex operations.

More then 20 states are either using electronic computers on highway engineering work or are awaiting delivery of them. Others are considering installations. Some states, and the Bureau of Public Roads, are using computer facilities at service bureaus, universities or other agencies. In addition, a number of consultants either have computers or are using computer facilities commercially available.

The computers being used in the states or on order include the Bendix G-15, the IBM 604, the IBM 650, and the Univac 120. The Bendix computer uses punched tape, the others use punched cards. Other computers of comparable capabilities are available and may also enter the field.

Survey Computations

In the California Division of Highways, survey computations involving an average of more than 2, 000 courses per day are now being performed on the electronic computer, covering location, interchange and bridge design and layout, and right-of-way takings. The computations include the determination of unknown lengths and/or bearings, error of closure, traverse adjustments, coordinates, and areas for closed traverses, and are performed in a central computing unit which serves both the headquarters office and the eleven district offices. Survey data from district offices are processed and mailed back to the districts, usually on the same day as received. The time required for the computer method, including the preparation of input data, is about 20 percent of the time required using manual methods. The cost is about 40 percent of the cost by manual methods.

Similar programs have been developed and adopted by the Texas Highway Department and the Nebraska Department of Roads and Irrigation.

The Bureau of Public Roads is developing a program for location traverses which will compute bearings and coordinates starting from any point of known coordinates, using measured course lengths and deflection angles.

The Oregon Highway Department is using electro-mechanical punched-card equipment for survey computations, with plans for converting to an electronic computer in the near future.

Grade Computations

In the Arizona Highway Department, the program developed for the computation of centerline grades, previously mentioned, is being used in day-to-day operations. The grades are computed in a continuous process through vertical curves and station equations. The time required for the computer method, including the preparation of input data, is about 25 percent of the time required using manual methods.

The Louisiana Highway Department and the Ohio Highway Department have completed similar programs, and the Illinois Division of Highways has included grade computation in its program for the computation of earthwork quantities.

The Texas Highway Department is investigating the feasibility of developing a program for determining the most economical grade line for a given profile and given basic design criteria.

Earthwork Computations

Earthwork quantities are presently being computed on electronic computers in Arizona, California, Texas, Washington, and the Bureau of Public Roads, both for use in the design stage and for final payment. The time required for the computer methods, including the preparation of input data, ranges from 5 to 10 percent of the time required using manual methods. Data on relative costs are being developed; however, rough estimates indicate that the cost by computer methods is from 20 to 25 percent of the cost by manual methods.

For earthwork quantities at the design stage, the input includes the cross-section data, centerline grades, and design template data, with provision for superelevation, curve widening, and varying side slopes. The computer produces a tabulation of the cut and fill volumes at each station and the difference between them adjusted for shrinkage or swell, the cumulative volumes of cut and of fill, mass diagram ordinates, and slope stake coordinates.

For the computation of earthwork quantities from staked cross-sections, the procedure is similar except that slope stake data are not included in the computer output. When final sections are used, the computer input consists of the original and the final cross-section data.

A number of other states, including Illinois, Louisiana, Massachusetts, Michigan, Missouri, Nebraska, New Mexico, New York, and Ohio, are in the process of developing computer programs for earthwork computation.

In Oregon and Montana, electro-mechanical punched-card equipment is being used for the computation of final payment earthwork quantities. Conversion to electronic computers is expected to be made in the near future.

Structural Design

Outstanding in the area of structural design is the work being done by the American Bridge Division, United States Steel Corporation, which is using an electronic computer as standard procedure in computing dimensions, stresses and deflections for various types of structures. The structures involved include continuous girder bridges with up to five spans; arches; rigid frames; cantilever and suspension bridges; and various types of trusses up to 80 panels in length. It is reported that the use of the electronic computer saves about 75 percent of the cost of equivalent calculations performed manually, with an even greater saving in designers' time. In one instance, a set of 20 equations with 20 unknowns, involving wind stresses in a suspension bridge, was solved on the electronic computer in about 10 minutes.

The Georgia Highway Department has completed and tested a computer program for geometric computations for multispan skewed bridges on curves alignment, on either a grade or a vertical curve, and with bents either parallel or not parallel. The beams are placed on chords of concentric arcs. The computer produces chord distances between intersections of the concentric arcs with bent cap centerlines, distances between the concentric arcs measured along the centerline of each bent cap, centerline grade elevations, rate of slope for each beam, and middle ordinates of the concentric arcs at the midpoint of each span. Programs are in process of development for the structural analysis of rigid-frame bents subjected to varying dead, live and wind loads, and of continuous reinforced concrete spans with variable moment of inertia. Georgia is also developing a program for the design of composite simple spans.

In the Arizona Highway Department, a program for the computation of dead load deflections for continuous beam bridges has been completed and a program for the design of retaining walls and bridge abutments is being developed.

In the California Division of Highways, a program for curved, multispan bridges similar to the one developed in Georgia has been completed. Programs have also been completed for the design of composite beams, and for the computation and tabulation of bridge reinforcement steel quantities. In addition, California is in the process of developing a program for the analysis of rectangular columns subjected to biaxial bending.

In the Washington Department of Highways, a program is being developed for the analysis of five-span continuous reinforced concrete beam bridges, which can also be used for lesser numbers of spans.

The Bureau of Public Roads has nearly completed a program for the analysis of continuous steel beam bridges of three to five equal or unequal spans.

Photogrammetry

In the area of photogrammetry, the California Division of Highways is in the process of developing a program for checking aerial contour maps using Church's four-point analytical method. When completed and tested, if found satisfactory, this program should eliminate a great deal of field checking.

In the Ohio Highway Department, a method and a program are being developed for the computation of earthwork quantities using cross-section data taken directly from aerial photographs in a Kelsh plotter. Preliminary estimates for evaluating alternate alignments, as well as more precise estimates for plan quantities, are covered. An auxiliary device is used with the plotter to measure horizontal distances with the same degree of precision possible in the measurement of vertical distances.

The three coordinates of each point on the cross-section are automatically punched into cards for use as electronic computer input. A second device is being investigated by which these punched cards, together with design data cards, are used to direct the movement of a point of light on an oscilloscope, thus delineating the cross-section and the design template at each station. By using an open shutter microfilm camera, the cross-section with the template superimposed on it is recorded on microfilm for use by the designer. Based on the designer's analysis, the design data cards are revised and used with the cross-section cards as computer input data for the earthwork computation. New microfilm recordings are made and occasional sections are enlarged, reproduced, and made a part of the contract plans. In addition, the tabulation of earthwork quantities produced by the computer, and an automatic plotting of the mass diagram, are reproduced photographically and included in the contract plans.

Traffic Studies

For a number of years punched-card processing and tabulating equipment has been used in the analysis of the large masses of data involved in highway planning studies. The electronic computer provides a means of further facilitating and greatly expediting the handling of these data and of increasing the quality of route planning through more thorough analyses than are feasible with conventional punched-card equipment. In a number of states, procedures and programs are being developed for converting parts of these studies to analysis on electronic computers.

Electronic computers are already being used in urban studies in the analysis of origin and destination survey data, including the development of trip desire charts, the prediction of future traffic distribution, the assignment of traffic to a proposed new route or system of routes, and the computation of benefit-cost ratios.

In the Detroit Metropolitan Area Transportation Study, using an IBM 604 electronic calculating punch, a total of 23, 500 zone-to-zone movements were assigned to a network of expressways and connecting arterials totaling 370 miles in length in less than three weeks, including all coding, card punching, processing, and tabulating of assigned volumes.

In the Washington (D. C.) Metropolitan Study, a Univac is being used to project 1948 origin and destination survey data to 1955, to compare the results with data obtained in a second origin and destination survey made in 1955-6, to prepare projections of urban travel for the years 1965 and 1980, and to apply the projected traffic distribution to the planning of an adequate highway and mass transportation system.

In the Chicago Area Transportation Study, a Datatron electronic computer is being used. Considerable experimental work is being done there in developing new and improved methods using the computer. In one method being developed, trips are traced in succession on a cathode ray tube and recorded on photographic film, thus automatically producing trip desire densities. The dathode ray tube-computer combination is also being used in fitting regression curves to plotted points. In the assignment of traffic on the computer, a "feedback" device is being used to provide automatically for the effects of overloads.

Basic experimental work is being done on the use of electronic computers in simulating traffic flow, principally at the Institute of Transportation and Traffic of the University of California, at the University of Michigan, and at Brown University.

In the Bureau of Public Roads an IBM 705 electronic computer is being used to compare various methods of predicting future traffic distribution to determine which method is the most satisfactory and also the number of iterations required for reasonable accuracy. Origin and destination surveys made in 1948 and in 1955 are being used in developing the comparisons. With a total of about 30, 000 zone-to-zone movements using six modes of travel, this study could not be attempted by manual methods.

In a nationwide traffic study being undertaken in the Bureau of Public Roads, origin and destination surveys from a number of metropolitan areas are being used to obtain trip desire data for county-to-county movement somewhat comparable to zone-to-zone movement in a metropolitan area study. This is a multiple correlation problem involving population, distance between areas, automobile registrations, income, recreational facilities, and other factors, which could not possibly be undertaken without the help of an electronic computer.

Hydrology and Hydraulics

The use of electronic computers in the solution of hydrologic and hydraulic problems involved in highway engineering is being explored in the Bureau of Public Roads. One type of problem being investigated involves multiple correlation of hydrologic data in estimating peak rates of runoff for selected frequencies from watersheds in the same physiographic area for use in the hydraulic design of highway structures.

A second type of problem adaptable to solution on electronic computers involves the determination of backwater produced by a given bridge, taking into account stream contraction, type of abutment, effect of piers, eccentricity of the bridge with respect to the flood plain, and skew. This problem occurs in determining the waterway opening required for floods of various frequencies within a given limiting amount of backwater. It can also be applied to the determination of the most economical hydraulic design for a given site, taking into consideration first cost, costs arising from flood damage (including scour), flooding of adjacent lands and effects on approaches, and disruption of traffic.

Other Applications

In the Texas Highway Department, a program has been developed and adopted for extending, analyzing and tabulating bid data at contract lettings. A similar procedure in the Washington Department of Highways is being converted from electro-mechanical equipment to the electronic computer.

In the Arizona Highway Department, a program for sieve analysis of soils has been developed.

In the Bureau of Public Roads, programs have been developed and adopted for computing the acreage of clearing and grubbing, and for the computation of borrow pit excavation.

A program for computing borrow pit excavation has also been developed at the Massachusetts Institute of Technology for the Massachusetts Department of Public Works.

Electronic computers are to be used on the new AASHO Road Test to process and analyze the tremendous mass of data developed during the course of the test. With the millions of pieces of data involved, it is estimated that it would take 10 to 15 years after completion of the test to analyze the data and prepare the final report if the electronic data processing equipment were not used. In this application, data from electronic detecting devices will be recorded in a form which can be used as direct computer input, or in some cases in a form which can be electronically converted to an acceptable input form to further expedite the processing of the test data.

These applications of the electronic computer to highway engineering are either in use or in process of development. Some of the other areas which suggest themselves as possibilities for electronic computation include sufficiency ratings, accident analyses, parking studies, and various problems susceptible to analysis by statistical methods.

From the applications cites, it is evident that rapid progress is being made. The highway profession can justly feel proud of these accomplishments. It also is evident that the electronic computer is a valuable device for research and exploration, as well as for day-to-day operations.

ORGANIZATION AND PERSONNEL

The field is too new and is developing too rapidly for well-defined patterns in organization and personnel to have become established.

With respect to organization, however, the present tendency is to use a single integrated data processing and computing unit located in the highway department headquarters office. This kind of organizational arrangement is most flexible and provides a centralized processing, computing, and tabulating service for all types of engineering problems, and for accounting and related operations as well.

With respect to personnel, minimum requirements include an operator for the computer and operators for auxiliary equipment, together with directing personnel. A maintenance technician is not essential, as service can be obtained for a monthly charge. If the machine is installed on a rental basis, which is the usual arrangement, service is furnished by the manufacturer.

Responsibility for over-all operation, including the development of applications to engineering problems, should be assigned to an experienced engineer, trained in the use of the computer, including programming. This is the usual practice. In addition, it is usual practice to train a selected group of engineers, who are specialists in location, design, structures, planning, and other technical areas, in computer programming to enable them to assist in the development of programs in their specialized fields as part of their assigned duties. A number of states have found it advantageous to employ a mathematician, or to assign a statistician already on the staff, to assist the computer development engineer. A person trained in either of these disciplines can be of considerable help in analyzing problems, in formulating solutions, and in developing both the procedural and coded programs in the most efficient form.

CORRELATION OF PROGRAM DEVELOPMENT

With a number of states working on the development of computer applications to highway engineering operations, there is need for correlation to minimize duplication and otherwise to gain maximum advantage from the efforts expended. The Bureau of Public Roads is developing a plan for the collection and distribution of information on program development and allied subjects on a continuing basis. Plans are also under way for the development of a library of programs so that those developed in one state can be made available to all the other states.

THE FUTURE

Although the general tendency has been to follow established conventional procedures the work in Ohio and the work in Chicago are impressive examples of what can be done with the computer in developing entirely new methods. As further progress is made, it seems logical to expect further departures from existing methods, leading to more exhaustive analyses and more refined design. In Canada, a program has been developed for the structural design of a beam bridge deck which takes into account the interaction of forces on longitudinal and transverse members through the use of matrices derived from correlated deflection equations for all members of the deck acting as a grid. Although this kind of analysis would be prohibitive in cost and time if done manually, it is reported to be entirely practicable using an electronic computer. A similar method of analysis is being used in England in the structural analysis of rigid building frames on electronic computers.

With respect to computer capabilities, it seems obvious that there will be continued improvement. Memory capacity is being enlarged, storage access time is being reduced, input and output speeds are being increased, character reading devices are being perfected, and other improvements are in the making. In addition, there is a definite trend toward transistorization, which will result in reduced space, weight and power requirements. With respect to programming, more and more library routines will of course be developed, and it is quite possible that coding ultimately will become entirely a computer function.

The progress made thus far in applying electronic computers to highway engineering work is indicative of possible future progress. Each successful development leads to another, and computer possibilities would seem to be limited only by vision and ingenuity in adapting them to the needs.

HRB:OR-95

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, 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.