Work Sampling Applications to Highway Personnel Management

K. L. BERGSTRALH, Senior Associate, Roy Jorgensen and Associates

•HIGHWAY agencies need reliable answers to the following questions with regard to staffing of highway and bridge design units: How many technicians should be employed per engineer? How many beginning level and intermediate technicians should be employed per advanced technician? Can staffing patterns be developed, in terms of personnel classifications, based on measured needs for engineers and technicians?

The objective of this research undertaking was to develop a technique to provide answers to the foregoing questions.

Research projects based on the technique described in this paper were completed by the Indiana State Highway Commission, the Virginia State Highway Department and the State Road Commission of West Virginia. The specific results of these projects are not reported in this paper. Composite and simulated data are used for illustrative purposes.

TECHNIQUE

The technique developed in this research is based on work sampling. Any single observation of a person at work gives the observer a limited impression of the work normally performed by that person. Several observations made over a period of time give a more reliable impression of the work performed. The making of a statistically valid number of observations provides a statistically reliable indication of the work performed.

The term "work sampling" is used to mean the making of observations of work performed by the persons employed in a given organizational unit. These observations, when properly classified and tabulated, can be used to analyze the characteristics of the workload and the proportions of the workload attributable to each person or personnel classification.

The principal steps involved in work sampling are (a) identifying and coding the work and auxiliary activities; (b) determining the number of work samples and the total sampling period required for statistical validity (the sampling plan); and (c) conducting the sampling program.

Work Activities

The workload of any given design function requires the performance of a wide variety of tasks. Because the performance of these tasks contributes directly to the accomplishment of the workload, they are called "direct production tasks."

Direct Production Tasks. —The conduct of a work sampling study requires identification of each significant task performed. The way in which these tasks are identified is shown in Table 1. Any element of work that can be performed by one person, or by two or more persons working together, is shown as a direct production task.

Auxiliary Activities. —Employees have need to perform certain personal tasks during working hours, such as making personal telephone calls, visiting with one another, and taking rests.

Paper sponored by Committee on Highway Organization and Administration and presented at the 45th Annual Meeting.

TABLE 1

DIRECT PRODUCTION TASKS LISTED IN RELATIVE ORDER OF DIFFICULTY
(Typical Bridge Design Division)

Task Code	Task	Task Code	Task
107	Computing costs by simple formulae	402	Drawing, structural, intermediate
109	Handling files, supplies, equipment	403	Tracing, complex
110	Maintaining time-activity records	404	Designing, geometric, intermediate
111	Maintaining bid sheet file	409	Answering informational requests
202	Drawing simple sketches, layouts, plots	410	Attending technical meetings
203	Tracing, simple	412	Studying project correspondence
208	Calculating watershed areas	413	Making field visits to assist field personnel
209	Searching plan files for data	454	Making preliminary layouts
210	Issuing prints	464	Drawing graphs, charts, maps
211	Recording bridge data	501	Designing, intermediate structures
214	Reviewing consultants' fee vouchers	502	Drawing, structural, complex
302	Drawing simple structures	504	Designing, geometric, complex
303	Tracing, intermediate, compositional	505	Checking and applying computer output
304	Designing, geometric, simple	507	Making cost estimate studies
306	Calculating quantities from plans	508	Making hydraulics studies
307	Making cost estimates, preliminary	509	Instructing and training personnel
308	Collecting hydrologic data	512	Investigating characteristics of materials
309	Studying new specifications	514	Preparing reports, procedures, instructions
312	Photo-compositioning of details from previous designs	515	Establishing and maintaining automatic data processing systems
313	Reviewing situation plans	516	Handling technical correspondence
315	Obtaining data for special studies	601	Designing, structural, complex
316	Checking and following-up status of plans	610	Reviewing consultants' plans
317	Processing new material for technical file	612	Analyzing and writing specifications
401	Designing simple structures	613	Supervising design work

Organization and direction of a large and complex workload necessarily involves other periods of time-loss, such as waiting for assignments, waiting for data, and waiting for decisions.

These activities, because they do not contribute to the accomplishment of the workload but are unavoidable in the employment of manpower, are called "auxiliary activities."

The extent to which these auxiliary activities must be identified separately is dependent on the objectives of each work sampling study. If one of the objectives, for example, is measuring the time spent by the employee force in making personal telephone calls, this particular activity must be listed and coded. If the objective is limited to analysis of the workload characteristics, these activities not attributable to the workload can be grouped under one code, auxiliary activities. There is need to make record of these observation, if only to account for the observations made.

Sampling Plan

The sampling plan is based on: (a) the calendar period over which work sampling should take place, (b) the number of work samples required for satisfactory statistical validity, and (c) randomness in the taking of samples.

Calendar Period. —Work sampling should take place over a period of weeks or months considered to be representative of the annual workload. Periods used in the studies on which this paper is based spanned 24, 30 and 35 working days.

Sample Number. —Any person familiar with the science of statistics can calculate the number of samples (observations) that should be taken. The total number is based on: (a) the level of statistical validity desired, and (b) the frequency with which each variable is expected to occur.

Random Sampling. —Given the total number of days available for sampling and the total number of samples to be taken, tables of random numbers can be used to select the days and the times of day during which observations should be made. These days and times of day should be made known only to the observers.

Sampling Program

The conduct of a work sampling program consists of: (a) having observers make observations on the random days and at the random times of day selected, and (b) recording those observations.

Observers. —Persons selected as observers should be able to glance at an employee at any given time and identify the task then being performed. In bridge and road design organizations, advanced technicians are usually qualified to perform this function, subject to a trial run during which they can learn to identify unfamiliar tasks.

One observer can make the rounds and take the samples for a 30- to 40-employee force, usually within a 10- to 12-min period. Another observer should be trained and prepared to make the observations on occasions when the first observer is absent or otherwise unavailable for this work.

TABLE 2

RECORDING OF WORK SAMPLING OBSERVATIONS

Employee	Personnel Class.	Observation Number and Code						
		1	2	3	4	5	6	7
1	3	101	102	102	101	703	101	103
2	6	403	507	509	302	606	403	403
3	2	307	308	103	103	401	209	211

Recording. —Each observation should be recorded in code. Typical recordings are given in Table 2, where four items of data are recorded: (a) name of employee, (b) personnel classification of employee, (c) number of each observation, and (d) task or activity being performed by employee at time of observation.

Each of these items of data is coded for machine sorting and tabulating.

WORK SAMPLING PURPOSES

The information obtained from work sampling can be applied to the solution of personnel classification problems as well as problems of staffing patterns.

Personnel Classifications

The tasks performed in a bridge or road design division range in difficulty from collating and stapling plan sheets to analyzing design data and developing design standards and policies. The knowledge, skills and abilities required to perform each of these tasks increase in proportion to the increased difficulty and importance of each successive task.

Theory. —If the design tasks can, with satisfactory accuracy, be ranked in order of difficulty from the simplest to the most complex, and if the proportion of the total workload represented by each task can be determined, two possibilities exist: (a) the total workload can be divided into groups of tasks and a personnel classification can be created to represent each task group, and (b) the recruiting, training and management of manpower can be guided by these divisions of the workload.

Data Analysis.—The design tasks indicated in Table 1 were arranged in order of the relative difficulty of performance of each task, by a committee of design engineers and technicians.

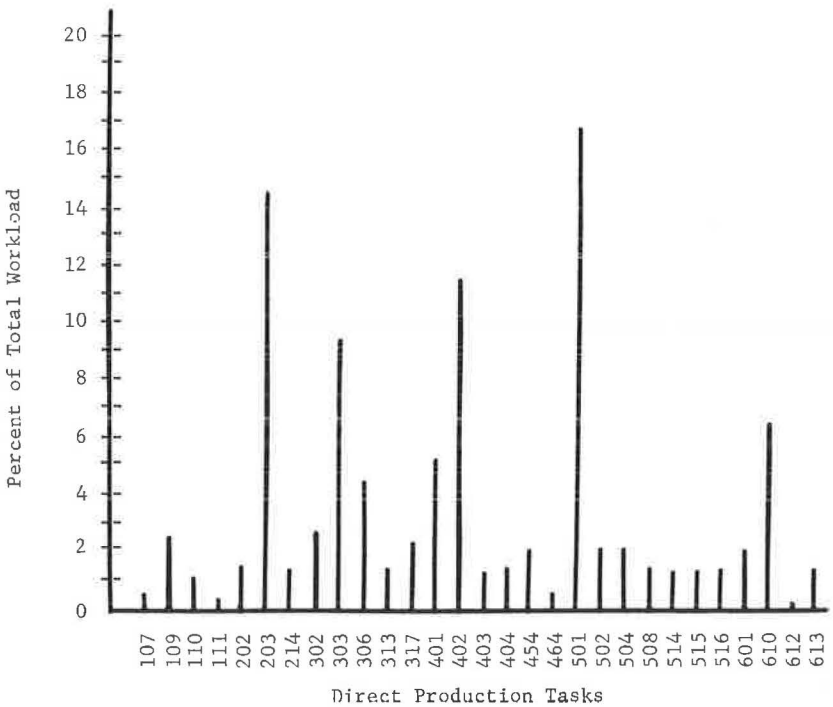

Figure 1. Distribution of direct production tasks; percentage of total workload represented by each task; typical bridge design division.

TABLE 3

DIRECT PRODUCTION TASK GROUPS BASED ON SIGNIFICANT DIVISIONS OF THE WORKLOAD
(Typical Only)

TASK GROUP 1

111 Maintaining bid sheet file
- 107 Computing costs by simple formulae
- 109 Handling files, supplies, equipment
- 110 Maintaining time-activity records

TASK GROUP 2

214 Reviewing consultants' fee vouchers
- 202 Drawing simple sketches, layouts, plots
- 203 Tracing, simple
- 208 Calculating watershed areas
- 209 Searching plan files for data
- 210 Issuing prints
- 211 Recording bridge data

TASK GROUP 3

317 Processing new material for technical file
- 302 Drawing simple structures
- 303 Tracing, intermediate, compositional
- 304 Designing, geometric, simple
- 306 Calculating quantities from plans
- 307 Making cost estimates, preliminary
- 308 Collecting hydrologic data
- 309 Studying new specifications
- 312 Photo-compositioning of details from previous designs
- 313 Reviewing situation plans
- 315 Obtaining data for special studies
- 316 Checking and following-up status of plans

TASK GROUP 4

464 Drawing graphs, charts, maps
- 401 Designing simple structures
- 402 Drawing, structural, intermediate
- 403 Tracing, complex
- 404 Designing, geometric, intermediate
- 409 Answering informational requests
- 410 Attending technical meetings
- 412 Studying project correspondence
- 413 Making field visits to assist field personnel
- 454 Making preliminary layouts

TASK GROUP 5

516 Handling technical correspondence
- 501 Designing, intermediate structures
- 502 Drawing, structural, complex
- 504 Designing, geometric, complex
- 505 Checking and applying computer output
- 507 Making cost estimate studies
- 508 Making hydraulics studies
- 509 Instructing and training personnel
- 512 Investigating characteristics of materials
- 514 Preparing reports, procedures, instructions
- 515 Establishing and maintaining automatic data processing systems

TASK GROUP 6

613 Supervising design work
- 601 Designing, structural, complex
- 610 Reviewing consultants' plans
- 612 Analyzing and writing specifications

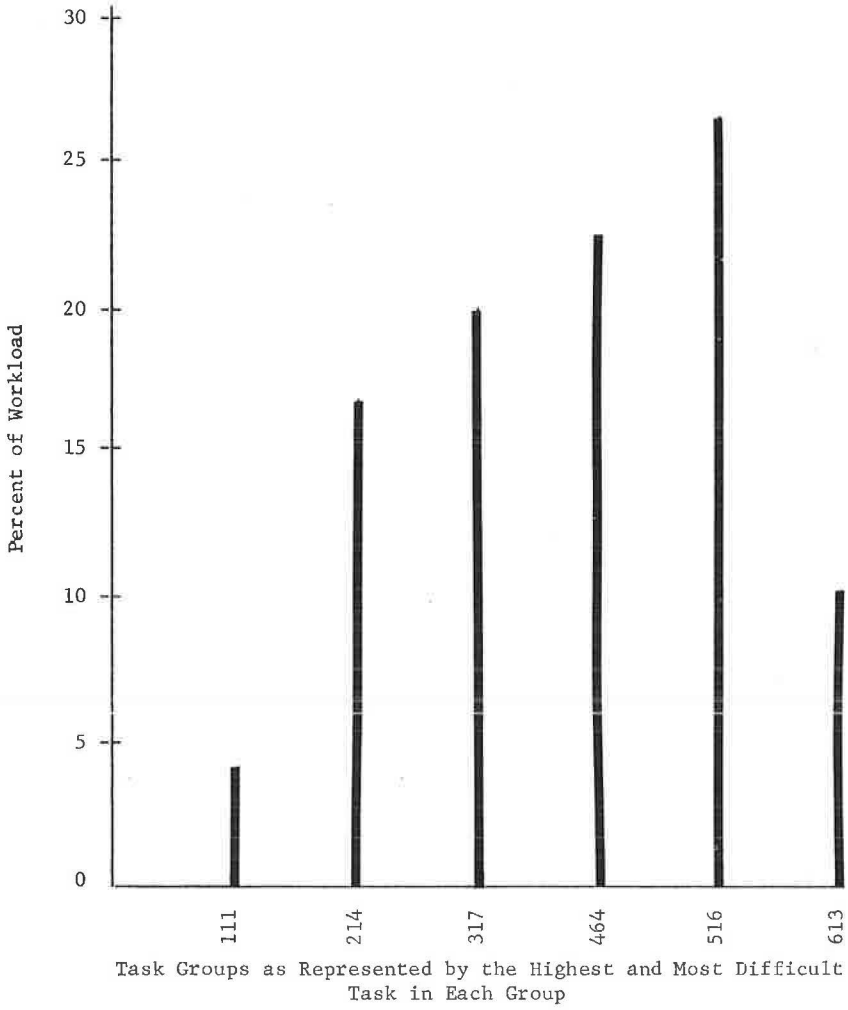

Figure 2. Distribution of the total workload by direct production task groups; typical bridge design division.

Figure 1 shows the percentage of a total bridge division workload represented by the direct production tasks given in Table 1. Tasks that individually represent less than 0. 2 percent of the total workload are included with the next higher task until 1. 5 percent of the workload is represented. Task number 107 represents approximately 0. 3 percent of the total workload. Task numbers 109, 203 and 303, respectively, represent 2. 1, 14. 3, and 9. 6 percent of the workload.

Task Groups. —Using the task distribution shown in Figure 1, minor segments of the workload can be combined with major segments to form task groups. Such task groups, represented by the highest and most difficult task in each group, are given in Table 3. (Tasks representing 0. 2 percent of the workload, or less, have been omitted from Fig. 1.)

Figure 2 shows the distribution of the total bridge division workload by task groups. The proportion of the workload attributed to each task group is equal to the sum of the proportions attributed to each task within the group as shown in Figure 1. The task groups represented by the code numbers are those given in Table 3.

Personnel Classification. —Each task group can be used as the basis for developing a personnel classification. In developing a classification series, allowance must be

made for a reasonable overlap between one classification and the next, but the work around which a classification is formed should be represented by the highest and most difficult task within each task group and by the significant direct-production tasks in each group.

Division of the workload into task group segments, and utilization of the task group segments, with guidance concerning the significance of tasks from the work sampling results, permit the position classifier to reflect the workload characteristics in the classification plan. This reflection is based on reliable data.

Staffing Patterns and Ratios

In theory, the work performed in a large and complex organizational unit comparable to a design division in a state highway department can be so organized and assigned that: (a) engineers can consistently apply themselves to the solution of engineering problems, (b) advanced technicians can consistently apply themselves to advanced technician tasks, and (c) intermediate and beginning-level technicians can consistently apply themselves to intermediate and beginning-level technician work. In practice, there is need for flexibility in the assignment of work.

This section of the paper is devoted to the use of work sampling data in the development of staffing patterns.

Data. —The distribution shown in Figure 2 indicates the following with regard to workload characteristics:

1. Four percent of the workload is attributable to Task Group 1, and 17 percent to Task Group 2.
2. Task Groups 3, 4, 5 and 6 account for 20, 22, 27 and 10 percent of the workload, respectively.

Staffing. —An analysis of the manpower staffing needs on the basis of work sampling results is given in Table 4. The percentages of the workload performed by each task group have been converted to manpower ratios for each task group. The work attributable to Task Group 6 (10 % of the total workload) has been used as the base.

In Staffing Pattern One, for every person employed to perform work assigned to Task Group 6, three persons should be employed to perform work assigned to Task Group 5, and two persons, preferably one beginning-level engineer and one advanced technician, should be employed to perform work assigned to Task Group 4.

On the basis of these ratios, five engineers and six technicians should be employed in a bridge design manpower unit, provided the workload is uniform from day to day with regard to proportion of work attributable to each task group. (The number of units required is dependent on the size of the total workload and the amount of work that can be produced by a manpower unit.)

According to Staffing Pattern Two, nine engineers and eleven technicians can be employed in a manpower unit in a bridge design division.

Of the engineers, two should be employed in the highest classification, five should be employed in the intermediate classification, and two should be employed in the lowest classification.

The technician distribution provides for three in the highest classification, and four, three and one in each of the successively lower classifications.

The 20-man staffing pattern more accurately reflects the workload distribution than does the 11-man staffing pattern, as shown by the 2 percent deviation and the 7 percent deviation, respectively.

Peak Engineering Time. —The analysis in Table 4 assumes that the workload is consistent from day to day with regard to the percentage of work attributable to the engineering level of employment. Should this not be the case, the number of engineers employed would have to be proportionate to the peak demand or delays which would occur in the performance of the engineering phases of the work.

One study included an analysis of the peaks and valleys of demand for engineering time. This single study showed less than a 2-percent range in the time devoted by engineers to engineering tasks as against technician tasks.

TABLE 4

ANALYSIS OF MANPOWER STAFFING NEEDS FOR A DESIGN DIVISION IN TERMS OF WORK SAMPLING RESULTS

Task Group	Workload Distribution per Work Sampling[a] (%)	Staffing Pattern One			Staffing Pattern Two		
		No. of Persons	Percent of Force	Cumulative Deviation from Optimum[b] (%)	No. of Persons	Percent of Force	Cumulative Deviation from Optimum[b] (%)
Task Group 6	10						
Engineer III		1	9	-1]	2	10	0
Task Group 5	27						
Engineer II		3	27	-1]	5	25	-2
Task Group 4	22						
Engineer I		1	18	-5	2	25	+1
Technician D		1			3		
Task Group 3	20						
Technician C		2	18	-7	4	20	+1
Task Group 2	17						
Technician B		2	18	-6	3	15	-1
Task Group 1	4						
Technician A		1	9	-1	1	5	0
Total engineers		5			9		
Total technicians		6			11		
Total personnel		11			20		

[a]The workload distribution to individual task groups can be modified by reforming task groups.

[b]The assumption is made that the deviation will be cumulative. In actual situations, persons in the higher classifications usually perform work in each of the lower task groups, causing the deviations to increase over those indicated. Also, any deviation from these averages toward temporary increases in the engineering workloads increases the need for engineers in proportion to technicians.

This one study notwithstanding, the number of engineers indicated as required in Table 4 must be considered minimum. Any deviation from the average distribution of the workload into task groups must be considered a basis for employment of additional engineers, there being a need to staff the organization to provide for a near-peak demand for engineering knowledge and skill.

SUMMARY

The objective of this paper was to set forth techniques, based on work sampling, that can be used to find answers to manpower management questions. Specific problems discussed concerned engineer-technician ratios, advanced technician-subordinate technician ratios, and personnel classification and staffing pattern development.

The following can be accomplished through work sampling and analysis techniques:

1. The tasks that must be performed in the accomplishment of a given workload can be defined (the tasks and their relative level of difficulty can be determined readily and quite accurately by a small committee of engineers and technicians).
2. The proportion of the total workload represented by each task can be determined by work sampling.
3. Given the proportions of the total workload represented by each task, and a workable method of task analysis, task groups can be formed to represent significant segments of the total workload; each successive task group should require a higher level of knowledge, skills and abilities for performance than the next lower task group.
4. The tasks within each task group, and the knowledge, skills and abilities required for their performance, can be used to create personnel classifications; these classifications will reflect the characteristics of the workload itself and the needs of the manpower force for the accomplishment of that workload.
5. The proportions of the workload attributable to each task group can be used to guide decision-making concerning the manpower force needed in each personnel classification, although staffing to meet above-average demands for knowledge and skill may be necessary.

The taking of work samples and the analysis of work sampling results are a relatively simple undertaking. The time required for a work sampling program is no greater than that required for a job audit program or a time-sheet analysis program; it is usually much less, and significantly more accurate.