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AUTHORITY

AGO ltr 29 Apr 1980

UNANNOUNCED

RESEARCH MEMORANDUM

(14) A60-PRB-RM-57-23 (2) (11) Nov 57

NUMBER 57-23

(9) Research memo

(6) DETERMINING A WORKER'S NET WORTH: A COST-ACCOUNTING APPROACH-

A SYMPOSIUM

(American Psychological Association Convention Program--Aug - Sep 1957)

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DETERMINING A WORKER'S NET WORTH: A COST-ACCOUNTING APPROACH

J. E. Uhlaner

The papers this morning will deal with a discussion of a system for assessing the net worth of a worker developed in connection with the research program of the Personnel Research Branch, The Adjutant General's Office. Dr. Goldberg will concern himself with discussing the definitions of some of the basic concepts in this system, the approach used in arriving at a measure of net worth, and some elaboration of the meaning of a new unit, the Manpower Unit, devised for the purpose of this approach. He will be followed by Dr. Bornstein who will present an approach of measuring the performance of workers in order to arrive at a good estimate of a worker's assets or productivity. Since it was decided that performance measures would be critical for this portion of the evaluation and further that a measure obtained in as realistic a working setting as possible would be essential, the "concealed job sample" was devised as the best approach.

One of the practical problems of utilizing this approach to the evaluation of a worker's net worth concerns the collection of a huge amount of data. The feasibility of this approach, in part, depends on the ability of communicating the method of collecting the data for the job sample performance test. Mr. Robinson will discuss the communication procedures worked out by our group in carrying out the research in the selected few jobs.

Finally, Dr. Roy will discuss the use of performance measures of productivity and appraisal of associated costs to determine the worker's net worth. He will survey the situation with regard to the worker's evaluation and then summarize the system outlined by all the speakers and indicate how it can be applied to the industry and to the military.

I. A SYSTEM FOR STANDARD WORK UNITS IN CRITERION CONSTRUCTION: THE MANPOWER UNIT

Solomon C. Goldberg

In this presentation I will try to describe very broadly a method for applying cost accounting concepts to criterion measurement. In many ways this method will be similar to the "dollar criterion" proposed by Brogden and Taylor. We would agree with their definition that "The criterion should measure the contribution of the individual to the overall efficiency of the organization." This definition strongly implies that a man's net worth to his organization is the difference between his contribution to the organization and what it costs to keep him working. In other words, his assets minus his liabilities would be his net worth. This is the balance sheet concept of net worth we want to employ in our method (Chart 1).

Our major practical question is, "How do we get assets and liabilities into the same terms so that we can subtract one from the other?" For instance, if we are measuring the net worth of salad chefs, we can count the number of salads he makes in a given period of time as assets, and his materiel wastage and absenteeism as liabilities. But how can we subtract wastage and absenteeism from the number of salads he made to get net worth? Our problem is to find such a method. For example, if a chef is found to make 10 salads and 20 steaks in an hour, how can we add 10 salads and 20 steaks together to determine the worth of his assets?

At first glance the dollar criterion would be an appealing approach to these problems. All we would need do is find the dollar values of assets and liabilities and then make the appropriate additions and subtractions. However, conceptual difficulties are encountered in attempting to apply a dollar criterion to military jobs because the Military Establishment is not a profit making organization. A term more useful to the military would be manpower. In terms of manpower, what are a man's assets, his liabilities, his net worth? An approach of this sort was conceived by Uhlaner and elaborated by Brogden. Instead of the dollar, the appropriate unit of measurement for assets and liabilities is the Manpower Unit, which we will abbreviate as MPU.

A. DEVELOPMENT OF THE MPU

In order to illustrate how an MPU is obtained, let us choose a hypothetical job in which an individual has two separate duties--he packs apples into crates and he nails tops on to the crates. By means of a performance test, we can count the number of apples he packs within a given period of time, and we can count the number of box tops he nails within a like time period. However, before we can add the packing and nailing scores together we would have to be able to say that "so many" apples packed is equivalent to "so many" tops nailed. In other words a unit of measure common to packing and nailing is needed. To do this, we must have a reference point. You may recall how the unit of length called the yard was established.

CHART 1

THE BALANCE SHEET CONCEPT

ASSETS	LIABILITIES	
PERFORMANCE MEASURED IN STANDARD MANPOWER UNITS	JOB-RELATED COSTS	NON-JOB-RELATED COSTS
	COSTS, GREATER THAN NORMAL, CONVERTED TO MANPOWER UNITS	

NET WORTH TO ARMY	=	TOTAL PERFORMANCE M. P. U.'s	−	TOTAL JOB-RELATED LIABILITIES M. P. U.'s	+	TOTAL NON-JOB-RELATED LIABILITIES M. P. U.'s

An English king decreed that the length of his arm would be called a yard. The king's arm was an arbitrary reference, but the arbitrariness of the reference does not preclude it from being a standard unit henceforth.

With the MPU, our reference is the man of average intelligence, that is, one MPU is equivalent to that amount of work done in one hour by the man of average intelligence (Chart 2). Thus if it were found through performance testing that the man of average intelligence packed 500 apples per hour, this would be equivalent to one MPU; and if he nailed ten boxes per hour, this too would be equivalent to one MPU. If we tested a worker on the job and found he packed 250 apples per hour and nailed 20 boxes per hour, he would be given a score 0.5 MPU for packing half as many apples as standard and 2 MPU for nailing twice as many boxes as standard. His scores for the separate job elements of packing and nailing could be added to give him a total score of 2.5 MPU for the job.

1. Support of Production

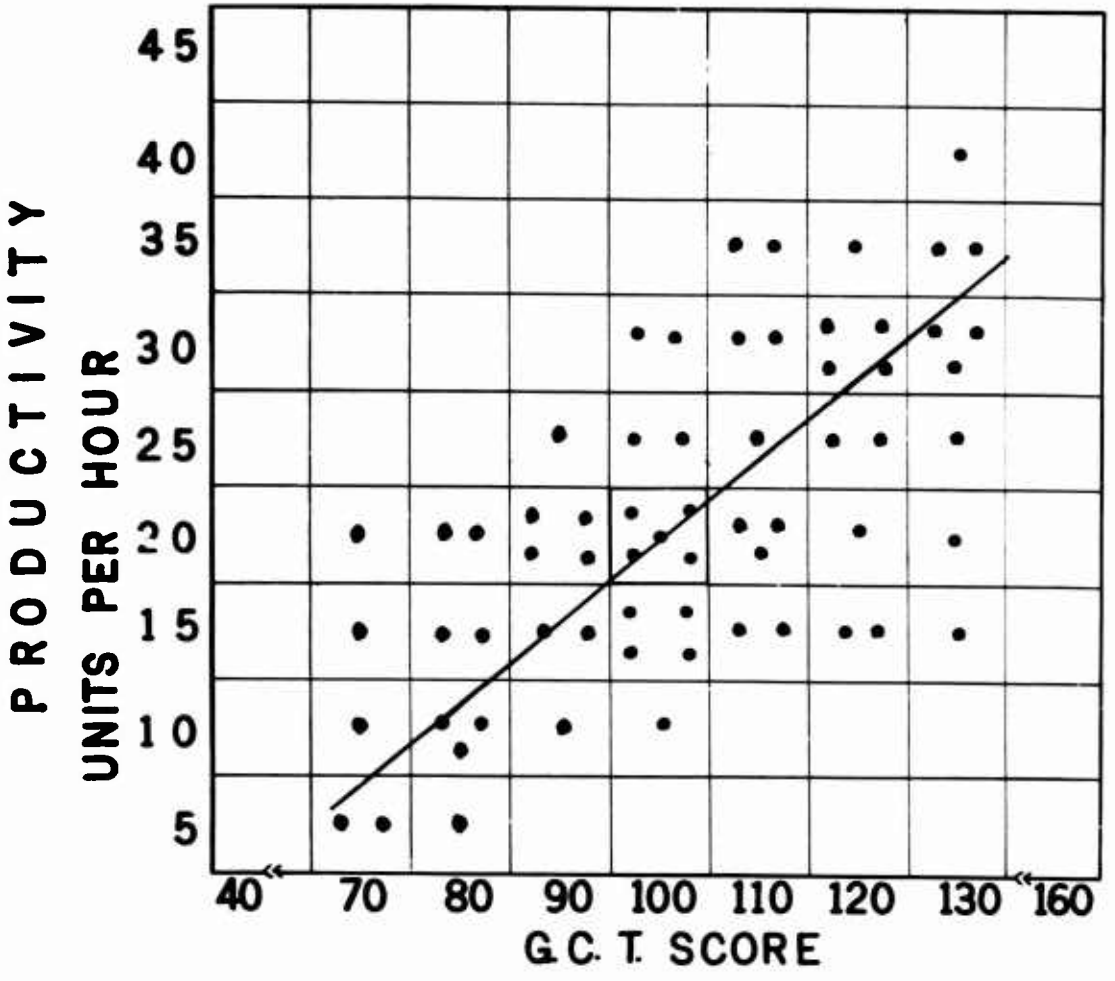
The derivation for the MPU just presented would be sufficient only for jobs that did not require support from other jobs. The realities are, however, that most jobs are supported by other jobs and would not be able to function properly without this support. For example, any job on an assembly line is supported by the jobs in which the parts to be assembled are made. The point to remember about support is that the finished product should not be credited exclusively to the man who finishes it. The finished product should also be credited to the people in support jobs. In the case of our apple packer, let us say that he is supported by four apple sorters who sort apples according to size prior to packing. Then if our apple packer packs 500 apples per hour, this must be credited to all five men. Assuming that all five men are of average intelligence, we could then state that 500 apples were yielded by five average man hours. One average man-hour of work or one MPU would then be equivalent to 100 apples. In other words, 500 apples must have gone through our apple packer's hands for him to earn one MPU, but he is only credited with his share of them, i.e., 100 apples. What difference does all this make? The amount of support on a job must be taken into account when we attempt to assess the productivity, especially of a member of a work team.

Let us follow the computational example, appearing at the end of this paper, which compares a person's MPU value when support is and is not considered. Let us say that the apple packer we are concerned with packs only 300 apples per hour instead of the standard 500. If support were not considered, our man would be credited with 3/5 MPU, i.e., 300 apples divided by 500 apples. On the other hand if we considered that our man is supported by four other men, then we must say that 300 apples were yielded by four MPU's of support plus an unknown number of MPU's expended by the man in question. In the example, this is equation (1) which reads 300 apples = 4 MPU (of support) + X MPU (of apple packing) (1). What this means is that we are trying to determine a man's MPU value to this aggregate if he packs only 300 apples per hour. Our first step is to convert the 300 apples to MPU's. This is done by dividing the 300 apples by the number of apples equivalent to one MPU, i.e., 100 apples.

CHART 2

DETERMINING ONE MAN POWER UNIT

(1 M.P.U. = AVERAGE PRODUCTIVITY, IN 1 HOUR, OF MEN HAVING G.C.T. SCORE OF 100)



LEGEND

. = 10 MEN

. = 10 MEN HAVING G.C.T. SCORES OF 100

= AVERAGE PRODUCIVITY OF MEN WITH G.C.T. OF 100

1 M.P.U. = 20 UNITS PER HOUR

This yields equation (2) in the example which reads 3 MPU = 4 MPU (of support) + X MPU (of apple packing). Solving equation (2) for X we find that our apple packer has a value of minus one MPU. This says that when our apple packer packs 200 apples less than standard and when at the same time he is supported by four standard workers, his value to this aggregate is negative. An additional interpretation is that the organization would be more efficient without this man, even though he packed a positive number of apples. How can this be so? It can be shown that if one of the standard support men replaced the deficient apple packer, this smaller aggregate of only four men would produce 400 apples per hour. This means that adding the deficient man to the short crew would result in 100 less apples produced. This is why his MPU value is negative.

2. Lost Time

Thus far we have considered a man's value on an hourly base. More often we will want to know his value over an extended time period,--perhaps a year or even longer. In this event we would have to take into account the time during the year the individual was absent from duty. During that time he is obviously not producing anything. Thus to obtain a man's yearly production, we would merely multiply his hourly production by the number of hours in the year he was present for duty.

3. Off-the-job Costs

Other man-hour costs are those incurred by the worker when he is absent from the job. This is particularly applicable to those organizations which provide fringe benefits such as resident nurses or doctors to attend workers who are temporarily ill. The Army, of course, does this on a full time basis. These costs, too, would be translated into man hours and charged to the worker.

4. Conversion of MPUs to Dollars

If the psychologist in industry or in the military has more use for a dollar measure than for an MPU measure, the conversion from MPUs to dollars may be accomplished by equating one MPU with the dollar cost of an average man for one hour. In the Army this was found from comptroller figures to be $2.61 per hour (Chart 3). Thus an individual's MPU score may easily be converted to dollars.

Moreover, there are many jobs in industry for which an individual worker's dollar value would be desired but might be more difficult to obtain than would a MPU value. If average dollar costs per man are available as in the Army, MPU values for individual men can then be translated into their corresponding dollar terms.

In other jobs where dollar criterion scores are obtainable, it may be of additional interest to management to know the corresponding MPU scores. These can be obtained by dividing each individual's dollar score by the dollar score of the average man.

CHART 3

ILLUSTRATIVE BALANCE SHEET FOR ONE SOLDIER

(A HYPOTHETICAL CASE)

ASSETS (M.P.U.'s PER YEAR)	LIABILITIES (M.P.U.'s PER YEAR; BASE, $2.61=1 M.P.U.)	
PRODUCTIVITY 1,000 M.P.U.	EXTRA TRAINING ($522.00) 200 M.P.U.	HEALTH SERVICES ($208.80) 80 M.P.U.
	EXTRA SUPERVISION ($261.00) 100 M.P.U.	DISCIPLINARY INFRACTIONS ($313.20) 120 M.P.U.
TOTAL PRODUCTIVITY 1,000 M.P.U.	TOTAL JOB-RELATED COSTS ($783.00) 300 M.P.U.	TOTAL NON-JOB RELATED COSTS ($522.00) 200 M.P.U.

NET WORTH = ASSETS − LIABILITIES

= 1,000 M.P.U.'s − (300 M.P.U.'s + 200 M.P.U.'s)

= 500 M.P.U.'s

B. SUMMARY

I have attempted to describe a system of criterion measurement which, by means of a common unit of measure, makes it possible to combine scores on different tasks in a job. This unit of measure is the MPU. The reference for the MPU is the man of average intelligence. I have tried to show that an MPU is equivalent to this average man's prorated share of the things he produces in one hour with the aid of the men who support him on the job, and the men who take care of him when he is off the job.

In this short presentation only a broad outline of the MPU system could be presented. For those who are interested in more details, the development of the MPU in symbolic notation is given below, following the apple packing example.

300 apples = 4 MPU (support) + X MPU (apple packing) (1)

3 MPU = 4 MPU (support) + X MPU (apple packing) (2)

X MPU = 1 MPU (3)

Development of Manpower Unit in Symbolic Form:

$$U_{av,m} = X_{av,m} + S_{av,m} + C_{av,m} \quad (4)$$

where:

$U_{av,m}$ = the observed number of units of production for any given task m of a job produced by the average man in a year.

$X_{av,m}$ = the number of average man hours apportioned to task m in a calender year for an average man; i.e., the number of hours in the year he is "being paid for."

$S_{av,m}$ = the number of average man hours in a calender year in support of the average men on task m.

$C_{av,m}$ = off the job costs, in average man hours, apportioned to task m for the year.

In order to determine the value in production units of one average man hour (AMH) we divide equation (4) through by $(X_{av,m} + S_{av,m} + C_{av,m})$ which process yields:

$$1 \text{ AMH} = \frac{U_{av,m}}{X_{av,m} + S_{av,m} + C_{av,m}} \quad (5)$$

Thus, the number of production units equivalent to a manpower unit is the right side of equation (5), which, hereinafter, will be symbolized more simply as $U_{mpu,m}$. To determine the MPU contribution of any individual i who produces more or fewer units of production than average, the units produced in a year by i are divided by the number of units equivalent to an MPU, (Umpu). The resulting equation (6) is then solved for Xim:

$$\frac{Uim}{Umpu,m} = Xim + Sim + Cim \qquad (6)$$

where:

Uim = the observed number of units of production for any given task m of a job produced by individual i in a year.

Xim = the number of MPU's attributable to i in a year for task m.

Sim = the number of MPU's in support of i in a year for task m.

Cim = the number of MPU's in off-the-job costs incurred by i, apportioned to task m.

Umpu,m = the number of units produced in one clock hour by an average man for task m.

Solving equation 6 for Xim we get

$$Xim = \frac{Uim}{Umpu,m} - (Sim + Cim) \qquad (7)$$

Support can be logically separated into two types. First, the support a worker receives whether or not he is present for duty is termed overhead support. In this category are such things as administrative work, building maintenance, and the like. Each worker receives his share of overhead support, and the supporting personnel expend this effort whether or not the worker is present for duty. Second, the support a worker receives directly from supporting personnel and which can occur only when the worker is present for duty is termed direct support. In this category would be the support of KP's peeling potatoes for cooks. If the cooks are absent, the KP's would not perform their supporting duties. The point here is that a worker should not be charged with direct support on those occasions that he is absent from duty.

For this purpose Sim is broken up as follows:

$$Sim = Som + \frac{Ti}{Tav} Sdm \qquad (8)$$

where:

Som = the number of MPU's in support of i in a year for task m regardless of the presence or absence of i on the job (overhead support).

Sdm = the number of MPU's in support of i in a year for task m only when i is present for duty (direct support).

Ti = hours actually worked in a year by i

Tav = hours actually worked in a year by the average man.

Substituting equation (8) in equation (7) gives:

$$\frac{Uim}{Umpu,m} = Xi,m + So,m + \frac{Ti}{Tav} Sd,m + Cim \qquad (9)$$

Solving equation (5) for Xim gives:

$$Xim = \frac{Uim}{Umpu,m} - \left[So,m + \frac{Ti}{Tav} Sd,m + Cim\right] \qquad (10)$$

In order to obtain the total MPU's attributable to the efforts of i for k tasks in a job, Xim must be summed over k tasks as follows:

$$\text{Total MPU for Xi} = \sum_{m=1}^{\quad} Xim \qquad (11)$$

II. THE CONCEALED JOB SAMPLE

Harry Bernstein

After outlining the need for obtaining a statement of a worker's net worth, Dr. Goldberg presented several concepts which should be incorporated in such a statement. One of these was the manpower unit. I am going to talk about the mechanics of obtaining some of the data which go into the determination of the manpower unit. More specifically, I am going to deal with the problems of how to measure the actual productivity of a worker. I will be concerned with the "raw stuff" of productivity--the rate of adequate work.

We in the Personnel Research Branch believed that a trust-worthy index of rate of adequate work could be obtained only from measuring instruments which would substantially meet three major requirements: (1) unbiased samples of job performance, (2) measurements from which ratio scores could be derived, and (3) comprehensive job coverage. The measurement tool which seemed to offer the best possibilities was the concealed job sample. By concealed job sample, I mean a standardized sample of work performance which is objectively scored but yet which has been obtained under conditions as similar as possible to those found on the job. This paper describes the major characteristics of the concealed job samples used to measure the rate of adequate worth on three Army jobs: the field artillery cannoneer, the pole lineman, and the cook's helper.

The pole lineman and the cook's helper jobs have very close parallels in the civilian economy. And even several aspects of the cannoneer's job are quite similar to tasks found on many factory assembly lines. Therefore, the techniques I am about to discuss should be as applicable to industrial settings as they have been in the military situation.

A. UNBIASED SAMPLES OF JOB PERFORMANCE

The salient features of the measurement rational requirements will be found in Chart 4. Let us turn to the first measurement requirement--unbiased samples of job performance. Putting it as simply as possible, it was desired that the examinee work just as he might work on any ordinary day. This meant that he should not be aware that he was being tested. It also meant that there should be nothing unusual about the work setting or the tasks performed or the manner in which examinee interacts with his co-workers and supervisors. At the same time, the standardized conditions required for a test had to be operative. As mentioned earlier, a concealed job sample seemed to be the best bet to accomplish these purposes.

Three major problems had to be solved before adequate test concealment could be achieved. First, there was a requirement for a reasonable approximation of the actual physical work setting. Second, sufficient control over the behavior of worker and his co-workers had to be established so that each examinee performed exactly the same tasks. And, finally, the recorder-observer had to be introduced into the situation without revealing the fact that a test is going on.

CHART 4

THE CONCEALED JOB SAMPLE

		JOBS		
1	2	3	4	5
Requirements of Measurement Rationale	Concealed Job Sample Approach	Field Artillery Cannoneer	Pole Lineman	Cook's Helper
I. Unbiased Samples of Job Performance	a. Approximation of Physical Work setting	duplication of Fixed setting	duplication of Mobile Setting	Use of existing setting
	b. Control of Co-worker Behavior	Team Activity with "stereotyped" roles	Team Activity with fluid roles	Individual
	c. Introduction of Recorder-Observer	(1) Bogus Fire Direction Control Center (2) Safety Officer	Team Chief	Bogus First Cook Trainee
II. Ratio Scale Scores (interval scale with known zero point)	a. Fixed Length of time; varying amounts of work			
	b. Fixed amount of work; varying length of time	b. Fixed Amount of work varying length of time	b. Fixed Amount of work; varying length of time	
	c. Statistical Correction of varying amounts of work and lengths of time			c. Statistical Correction of varying amounts of work and lengths of time
III. Comprehensive job Coverage	Job Elements Selected by a. Amount of time spent on job b. Test Administration Feasibility	31% of work week sampled	53% of work week sampled	45% of work week sampled

1. The Field Artillery Cannoneer

The first job studied was the field artillery cannoneer. The cannoneer carries out stereotyped tasks in a highly routinized team activity. Basically, the team services a single large piece of equipment: the artillery piece. Instructions are relayed to the team by telephone, and each member of the team is supposed to respond to these instructions in a rigidly prescribed manner.

Concealment on this job was not too difficult to achieve. The fixed physical setting was approximated by having the firing officer locate the suitable equipment in the same relative position each time the artillery pieces were fired.

Control over the cannoneer's interactions with the other crew members was relatively simple. A smaller crew than was usual in garrison serviced the weapon. This type of crew was then given some dry runs so it could get used to the new crew operation. After that, the members of the crew performed substantially the same jobs usually performed. Crew members then rotated assignments as they normally do in training thus permitting independent measures on the work performance in each crew position.

Each cannoneer was scored by two people. Speed of work was scored by men sitting in a bogus fire-direction control center about fifty yards away from the artillery pieces--a usual training setup. The safety officer, who by Army regulation must be at the piece when it is fired, scored quality or accuracy of work. Since he is required to carry a safety card and check safety limits each time the piece fired, it was a small matter to change his function without the cannoneers' being aware of his new activity. The cannoneers were told that they were firing the piece in support of a fire direction training problem.

2. The Pole Lineman

The concealed job sample constructed for the pole lineman job was far and away the most difficult one to construct. The pole lineman operates as a part of the team which sets up or takes down telephone cable in a military communication network. The lineman's work role is flexible. It is dependent upon his own skill, the skill of the rest of the wire team, the team chief's supervisory habits and abilities, and the nature of the specific communication job to be performed.

The physical area in which the lineman works usually ranges over several miles of terrain. Approximation on this job consisted of selecting work areas which would contain the same number of major and minor roads, which covered roughly the same type of terrain, and which required the same amount of cable, equipment, and manpower. In some few instances small fake roads had to be bulldozed. The final results of these efforts were pretty much indistinguishable from the physical setting in which the examinee usually worked.

Control of the wire team was a difficult matter. An entire crew had to be thoroughly trained for the test performance. Each man was assigned a function which he carried out exactly each time the team performed. The entire operation of the team was designed to provide each man with a reasonable type and amount of work. The work pattern was arranged so that completion of the entire task was completely dependent upon the speed and skill of the examinee who, incidentally, was detailed to this crew on the testing day.

The work of the pole lineman was scored by the Team Chief. In the ordinary work situation the Team Chief has a fair amount of record keeping to do. One type of record keeping requires labelling the cables being laid or picked up. In the job sample, the scoring was done on a bogus tag card while the examinee worked. The entire crew was told that they were supporting a tactical problem. Of course this orientation was for the examinee's benefit rather than for the rest of the crew since they already knew that this was a test situation.

3. The Cook's Helper

Concealment on the cook's helper job was the easiest to work out. The cook's helper performs primarily as an individual worker in the midst of an aggregate of individual workers. Moreover, he works in a fixed, compact work area. Incidentally, our experience seems to indicate that concealed job samples might be relatively simple to construct for most jobs that are primarily individual in character.

On the cook's job the existing physical setting could be used. It was only necessary to insure that all of the kitchens used for testing were of the same general type.

Practically nothing had to be done to control the cook's helper's co-workers. The mess steward merely had to give the desired assignments to all of the workers in the kitchen.

The observer-recorder was introduced into this situation as trainee for a first cook's job--a job requiring rather ordinary on-the-job training. He spent most of his time with the first cook, ostensibly in order to learn about the job of the first cook. However, since he knew exactly what the examinee was to do, as well as being very familiar with the kitchen operation, he noted how long each pertinent activity took without being observed by the examinee. His scoring was done on a small card which was usually carried in a breast pocket. Recording was done out of sight of the examinee.

B. RATIO SCALE SCORES

Now to move on to the second requirement of the measurement rationale--that of obtaining measurements from which ratio scale scores could be derived. As Dr. Goldberg stated, ratio scores fall at equal intervals on a scale with a known zero point. The zero point on these job samples is no adequate work. The other major problem was how to obtain equal intervals.

In any work setting, there appear to be three alternate possible methods of obtaining a ratio scale of job performance. These are:

1. Set a fixed length of time and allow amount of work to vary;

2. Set a fixed amount of work and allow the length of time required to accomplish this work to vary;

3. Apply statistical corrections to varying amounts of work and/or varying lengths of time required to accomplish the given amount of work.

The first approach could not be used because stopping a man in the middle of his work would destroy test concealment. The second approach--the presentation of a fixed amount of work coupled with an obtained measure of how long it took to do--was used on two of the jobs. Therefore, each cannoneer was required to unload the same amount of ammunition, fuze a standard number of rounds, and load and fire the same number of rounds. On the lineman job, work situations were set up requiring the lineman to climb a predetermined number of telephone poles, make a specified number of ties, dig a standard number of ditches, and pound just the same number of stakes. Two measurements were made of each of these activities: First, a judgment of whether the task was adequately or inadequately completed, and second, the time required to complete the task.

The third method, that of statistically correcting for varying lengths of time to complete a varying amount of work, was applied in the cook's helper work situation. This method was necessary in this situation because men were tested in existing kitchens, each of which fed varying numbers of men. This meant that different cook's helpers prepared different amounts of food. If concealment were to be maintained, cook's helpers could not be given a standard amount of food-stuffs to handle. Taking into account the relationship between speed of work and amount of foodstuffs handled, we were able to give each examinee a score which reflected how long it would have taken him to prepare the same quantity of foodstuffs.

C. COMPREHENSIVE JOB COVERAGE

Of the three major requirements of the measurement rationale, comprehensive coverage of job performance was the most difficult to satisfy.

1. Section of Job Elements or Tasks

The measurement rationale suggests two major criteria for the selection or inclusion of job elements in the overall criterion. These are (a) the amount of time spent each week by a job incumbent on the job element and (b) the amount of support given the job element. As Dr. Goldberg indicated earlier, relatively little variation in the job performance of the worker on job elements high on either of these criteria could make a great difference in job output.

The initial step, therefore, in selecting tasks or elements for inclusion in the job sample, was the obtaining of estimates of time spent on an element from 100 or more supervisors. Such estimates were obtained for each job element. However, support estimates could only be obtained for the job as a whole.

2. Picking the Job Sample

As in all performance testing, considerations of time, equipment and money entered heavily in the choice of job elements which were measured. Job elements were included in the job sample in what we believed was the optimum combination of feasibility and importance. The result was expensive and time-consuming. The cook's helper work sample covered an entire day. The other two job samples were approximately of a morning or an afternoon's duration. These procedures yielded samples of activities which made up 31% of the cannoneer's work week, 53% of the pole lineman's work week, and 45% of the cook's helper's work week.

3. Measurement of Excluded Job Elements

However much was included in the job sample, all the job elements could not be measured. And that is the major limitation of the concealed job sample technique. If some of the more intangible products of job performance could be scaled in terms comparable to those already presented, the technique might give a still more complete description of job performance.

III. THE COMMUNICATION OF JOB-SAMPLE PERFORMANCE TEST PROCEDURES TO OTHER PERSONS WHO WILL UTILIZE THEM

John E. Robinson, Jr.*

It has been evident from the preceding papers that the productivity measures developed for this research were very complex tests. The amount of difficulty to be expected in any attempt to describe the nature of these beasts for our colleagues or other legitimate users is easily appreciated. With reference to this communication problem, the following paragraphs will outline our experience in four areas:

First, what were some of the specific commmunication problems caused by the nature of the tests?

Second, what methods were employed in attempting to solve these problems?

Third, How expensive were these methods?

Fourth, how well did these methods work?

A. COMMUNICATION PROBLEMS

The specific communication problems arose generally from the inherent complexity of the tests and from the fact that the standard testing situation had to be the normal duty situation. These specific problems are listed below:

1. Measurable tasks had to be defined in detail. Specific statements had to be made concerning what was done by the examinee to or with the materials appropriate to each task.

2. Independent performance had to be identified. We could not permit the measurement of an individual to be contaminated by a helper or helpers. In some cases the test utilized only a portion of a standard performance because only such a portion could be attributed to the examinee himself.

3. Scoring points (which usually were timing points) had to be specified exactly. Observers had to be given one particular behavior-event as a starting point for their observation and another for a stopping point. The performance occurring between these two points had to be objectively measurable for adequacy.

4. The overall evaluative scheme had to be described. All persons having a role in administering the tests had to be told the nature of the sub-scores to be derived and the total "grade" to be given as a result of the detailed observations. This helped give meaning to each observing task.

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*Now with Applied Psychology Corporation, Arlington, Va.

5. The probable variations in work performance (on measurable tasks) had to be anticipated and described. The observers had to know in advance what liberties might be taken with the SOP, and how these deviations were to be scored.

6. Beyond these "expected" deviations, job information had to be presented in depth so that observers could handle unforseen variations in a manner consistent with the productivity evaluation desired. The information desired here was general, functional, or background type information about the job being measured.

B. DEALING WITH THE PROBLEMS

Essentially four methods or devices were used to deal with these communication problems.

1. A conventional test administrator's manual was prepared, aimed at the professional test research person or personnel testing supervisor. Specific sections described in careful detail the procedures and material necessary to operate the test.

2. A printed supplement to the manual was used. This supplement was slanted toward the observers or scorers who would serve on the testing team. It paralleled the basic manual in organization, but stressed the scoring procedures to be used for all expected varieties of performance.

3. A photographic supplement was prepared for each test. This supplement was made up of still photographs illustrating salient points in the test (timing points, etc.), and a verbal commentary integrating the photographs. The pictures and narrative passages were aimed at giving rapid training to test team members who were already familiar with the duties being measured. It was also expected that this publication would provide a good introduction to the job duties for those persons who might not be familiar with them.

4. A motion picture record of the test in operation was made. One obvious reason for such a life-like record was to facilitate the training of observers: in projection rooms the test could be portrayed many times --in part or in its entirety. A second, and equally obvious reason was to provide an orientation instrument for use in briefing higher headquarters, field command personnel, or psychologists interested in this kind of test.

C. COST OF METHODS

The cost of these communication methods was well within reason. Reproduction costs of mimeographed or multilithed material were standard. The cost of the photographic supplements was gratifyingly low. Signal Corps personnel and equipment were available in some cases. (For industrial or educational institutions, the average Audio-Visual Aids

group should prove very satisfactory.) In other cases where Signal Corps help was unavailable, good still photographs were obtained with a 35-mm camera in the hands of an amateur of average skill. The most important consideration in this matter is to plan carefully the scenes and behaviors that are to be photographed. Wasted footage and exposures are a powerful cost-increasing factor in this type of test communication.

D. TRYOUT

We have reason to believe that these communication methods work very well. The Cannoneer test was scheduled for administration at Fort Benning, Georgia and Fort Carson, Colorado, in the early summer of 1956. Two psychologists of the Personnel Research Branch were presented with these materials three weeks before testing was to begin. They were told to prepare to administer the test in the field, even though they had had no previous contact with the test. An experienced person accompanied them to correct errors and answer questions, but these two men successfully trained the necessary teams of observer-scorers, and tested approximately 250 men. Any points of uncertainty were carefully noted, and the appropriate corrections were made in the communication materials. It is our belief that these materials are suitable for the communication of these tests to new users, and that the expense involved is relatively low in view of the complexity and utility of the measures.

IV. THE USE OF PERFORMANCE MEASURES OF PRODUCTIVITY AND APPRAISALS OF ASSOCIATED COSTS TO DETERMINE A WORKERS NET WORTH

Howard L. Roy

In the discussion so far, you have heard the outline of a system for assessing the net worth of a worker. You have also heard a description of concealed job sample tests which were developed to measure productivity in three Army jobs. In the next few minutes, I would like to survey the situation with regard to worker evaluation, then to summarize the system outlined and indicate how it can meet some of our present needs--how it can be applied to industry and the military.

The great bulk of the task of evaluating workers in industry and in the Army is accomplished by means of some form of merit rating. A vast variety of forms are administered with varying degrees of care by all sorts of people. They all depend on someone's judgment of how well the worker is doing his job. In a few isolated instances, production records provide a more objective basis for worker evaluation. Still less frequently, one finds performance tests being used as measures of job proficiency. All of these methods have one thing in common. They all result in a rank ordering of personnel. That is, each man is given a relative standing in relation to the members of a particular group. Such measures provide useful information but for many employers not enough information. In addition to knowing whether one man is a better worker than another, the employer may want to know whether either one of them is making a positive contribution to his business and he may want to know how much better one worker is than another.

What is needed is a measure that will express a man's net contribution to his organization. Not only do we need to know how much a man has produced, we also need to know how much it costs to get that production. It is quite conceivable that two workers, whose measured gross output is equal, are not at all equal in terms of their net value to the company.

A. REQUIREMENTS OF A NET WORTH MEASURE

What are the requirements of a measure that will yield a net worth or net contribution of the worker?

1. Objectivity

Ideally, observers should be required to record only such objective things as how long it took to accomplish a task, how many units were completed in a time period, whether the individual did or did not perform a particular action. This is an ideal, and one toward which to strive, not a requirement to be held too rigidly, because to hold to absolute objectivity would preclude measurement in a great many areas of human endeavor.

2. Common Metric

A second requirement is that the criterion measures have a common metric. Most jobs contain many elements. In order to obtain the complete measure of a worker's production it is necessary to combine the separate measures of output on each of these elements. For example, a worker's job may include such diverse elements as driving a truck, painting, repairing door locks, and storing supplies. To make an accurate appraisal of his worth to the organization there must be a measure of the worker's output on each of the job elements and it must be possible to sum these measures for statement in a single expression.

3. Zero Point and Equal Intervals of Increment

It is necessary, not only to rank order men but to indicate how far each worker is above another. And there must be a point on the scale which represents no production or no contribution to the effort of the organization.

4. Measure of Individual Output

The system must be capable of providing a measure of the individual's output when he is performing as part of a group. In very few cases does a man produce anything independently. Nevertheless, the system which will yield a measure of net worth must assess what is attributable to Individual X, when Individual X and four or five others produce something jointly.

5. Reflect Prevailing Conditions

The criterion measures themselves, should not be allowed to affect performance. Ideally the measure should reflect what a man produces under the prevailing conditions of the job--not what he could produce under special motivation such as a test might provide.

6. Feasibility

In addition to these psychometric requirements, there is the very practical requirement that the measures be feasible for operational use and acceptable to management.

B. MEETING THE REQUIREMENTS

In the system which has been outlined here, we endeavored to meet these requirements. Objectively scored performance tests provided measures of productivity. The observer-scorers recorded time and quantity of production. Since quality of performance is a necessary consideration, we accepted an operational definition of quality. If the work or the product passed the inspection which management normally imposed on it, it was considered to be acceptable work. For example, if a lineman spliced a wire and the first line supervisor, whose responsibility it was to check that splice, said "OK", then it was considered acceptable for the test and was counted as a unit of work completed.

In the expression, "Net Worth = Production Minus Costs," the term costs includes both on-the-job and off-the-job costs. By on-the-job costs we mean such items as wages, training, supervision, wastage. By off-the-job costs are meant such things as disciplinary infractions, care of dependents, health services. The military is very much concerned with off-the-job costs since it is responsible for its workers 24 hours a day. The same is true in many civilian jobs. Management is concerned with costs incurred off-the-job by many hotel and hospital workers and in nearly all cases of overseas jobs responsibility for the worker extends beyond his working hours. Most of the costs of production were available from existing bookkeeping systems. To compute them was simply a matter of extracting from these records such information as number of days worked, sick time and costs of medical care, chargeable breakage, disciplinary infractions etc. In some cases it was necessary to set up special record keeping systems to be operated for the duration of the study. The same would probably be true for some industries.

The common metric requirement was met by the man-power-unit. Remember that a man-power-unit was defined as the amount of production on a given job, in one hour's time by an average man. In this case the measure of averageness was mental ability; the average man was the man with a mean general intelligence test score. The average man's production is the standard against which other men's production can be compared by simply determining the ratio between them. And, since this ratio is a pure number, it can be used to compare productivity in different elements of the job or even in different jobs. If 20 beds made per hour is the average man's production as a hospital orderly and 40 hams boned per hour is an average man's production in the packing plant then, in terms of work output, these two amounts are equal. And a man who produces 10 beds per hour or 20 hams per hour has a rate of 1/2 MPU.

The man-power-unit also meets the problem of zero point and equal intervals of increment. If the measure of a man's production divided by the measure of an average man's production = 0 it is clear that he has produced nothing. And, when his costs of production are high, it is possible for this ratio to be a negative number and thus indicate how much of a loss this worker is to the company. Or, conversely in the case of the high producing, low cost worker, how much greater is his contribution to the organization than that of the average man.

C. THE MARGINAL WORKER

Perhaps the most important attribute of the system outlined by Dr. Goldberg is its ability to measure the individual's contribution when the individual is working as a member of a group. Because of this capacity of the system, it is possible to show how much the group is retarded or facilitated by an individual. One might suppose that a worker who produced some positive amount would yield a positive gain to his organization. However, to the extent that his performance slows down production of the group, his net worth to the organization is reduced. We are all aware that

one good worker can often do a job faster by himself than he could if he had a poor worker helping him. Although it is not always apparent, the same is true of groups of workers. The poor producer is quickly recognized as a negative contributor when his measure of output is weighted by the number of people whose work is retarded by him. Incidentally, this makes it possible to evaluate jobs as well as men. On some jobs, a mediocre performer will not slow the group appreciably; on others the work of the entire group will be retarded. In other words, in such situations adding the poor producer results in a loss of manpower rather than a gain.

In a tight labor market, management is faced with the choice of hiring men who are marginal producers or of reassigning from within the organization. A system of this kind can demonstrate clearly that adding marginal workers to some jobs can actually result in lower output rate than would have resulted if they had not been hired. On the other hand, reassignment of average men from within the organization are not likely to reduce output further, and have several potential advantages that normally derive from promoting within the organization.

D. CONCEALED JOB SAMPLES

The concealed job-samples described by Dr. Bornstein seem to us the best way to assess typical job performance. If testing is carried out on the job under the same kind of conditions which normally prevail, and if the worker can be kept from knowing that he is being observed, then there is no reason to believe that the process of evaluation has affected his performance either favorably or unfavorably. Of course, adequate concealment is not always easy, and it is sometimes expensive, but if we are agreed that performance under typical conditions is what we want to measure then I think we must also agree that the expense and the efforts expended are justified.

E. JOB COVERAGE

One of the problems which will always cause concern is that of job coverage. How much of the job is measurable according to the standards I described for you? Jobs will differ widely in this respect, of course, but in nearly all jobs there will be elements which do not lend themselves to measurement by objective performance tests. Suppose we have a job composed of 10 elements, on each of which the worker spends equal amounts of time, and of these elements five are measurable. Shall we extrapolate from the measurement of 50% of his job to the whole job? Suppose we could measure only 10% of the job? Should we assume this 10% is typical of performance in the whole job? In our work we did just that. We made the judgment that performance in the measurable portions of the job gave us the best estimate of performance in the job as a whole. We checked this out in two ways: we obtained subjective rating of performance on the separate elements of the jobs--both measurable and unmeasurable and we obtained expert opinion as to the representativeness of the measurable job elements.

E. FEASIBILITY AND ACCEPTABILITY

I mentioned that a non-psychometric requirement of a system of job evaluation is its feasibility for operation and its acceptability by management. On the basis of its face validity, the type of system we have described is acceptable to management. We asked the opinions of a large number of management people and found this to be so. Feasibility for operational use is another matter. These systems are time consuming, expensive and difficult to set up and administer, but they have one redeeming feature. They yield the information we want, viz., the measure of a worker's net worth. Perhaps we are forced to conlcude that systems of this kind serve best as evaluative criteria. Such measures can be tied back through correlation with predictors which are economical and feasible to administer. By this means the psychological traits and background patterns of individuals who make positive contributions can be determined and such individuals selected at the hiring line.

F. SUMMARY

In summary then, we have outlined an evaluation system designed to measure the net worth of a worker to his organization. We have introduced a unit of work measurement, the MPU, which makes it possible to compare production on different parts of jobs and across jobs. We have described job samples capable of measuring work output under typical working conditions. We believe that application of this kind of system will result in the most efficient utilization of available personnel.