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IMPROVED WORK SAMPLING USING CORRELATION ANALYSIS OF ACTIVITIES' RECORDS

Borut Buchmeister, Marjan Leber, Iztok Palcic, Natasa Vujica Herzog
University of Maribor, Faculty of Mechanical Engineering,
Production Engineering Institute, Lab. for Production & Operations Management
Smetanova 17, SI – 2000 Maribor
Slovenia

ABSTRACT
Work sampling is the process of making sufficient random observations of operators' activities over a period of time to determine the proportion of the workday spent on certain types of work or non-work. When jobs do not have short cycle times or high repetition rates the use of such statistical technique is required, because work sampling data can provide information that can be used to establish standards. The work sampling procedure is well standardized by the recommended steps, but some contributions are possible in the evaluation of the observations.
In the paper we present our contribution in the improvement of the decision process based on the work sampling data. We introduce the correlation comparison of the measured hourly proportions of all pairs of activities to check, if there are some interrelationships. The results enable easier decision making about the influence of the selected activities to trigger the others.
Keywords: work sampling, activities, correlation analysis

1. INTRODUCTION
There are many jobs where time study, standard data, and predetermined time standards just are not useful, productive ways to set standards. When jobs do not have short cycle times or high repetition rates, such as those in maintenance, material handling, clerical and the like, these methods are not effective. Jobs with long cycle times and low frequency of repetition require the use of work sampling [1, 2, 3].
Work sampling is the process of making sufficient random observations of an operator's activities to determine the relative amount of time the operator spends on the various activities associated with the job. Although it is not the express purpose of work sampling to determine how long specific tasks should take, work sampling data, when coupled with historical production data for key volume indicators and performance levelling, can provide information that can be used to establish standards. The major goal of work sampling, however, is to determine the proportion of the workday spent on certain types of work. To set the amount of time required to perform a task is not a goal of work sampling [4, 5].
Rather than observing the worker constantly for many days, the data collector may observe the workers at 15 to 30 instances during each day for two weeks or more. These observations are simply snapshots of what the workers are doing at that moment [6]. If enough observations are made over a sufficiently long and representative period of time, the fraction of time workers spend on various activities can be estimated statistically.

2. METHODOLOGY
The method to conduct a work sampling study is as follows [1]:
- Establish the purpose of the study. Is the intent to set a standard to drive staffing levels or is it to identify the proportion of time spent on each major category of work?
- Identify the subjects. Who is doing the work within the organization?

- Identify the measures of output. This is essential if the objective of the study is to develop standards.
- Establish a time period for the study. The period of the study should be long enough to be representative of normal operations.
- Define the activities. This includes a definition of the major tasks performed. An example of some work definitions is included in a case study in section 4.
- Determine the number of observations needed. After the work elements are defined, the number of observations for the desired accuracy and confidence level must be determined.
- Schedule the observations. If an analyst will record the data, use a random number table or random number generator.
- Inform the personnel involved. As in any productivity measurement study this part of the procedure is important. Workers and their supervisors might think that they personally are being measured rather than the work they are doing.
- Record the raw data.
- Summarize the data. Determine the proportion of time spent on each activity.

Work sampling studies are easy and inexpensive to perform. One observer can monitor and sample the behaviour of several workers during the same period. To carry out data collection, each observer selects a number of workers performing the same operation. A work sampling study usually requires a substantial period of time to complete. The minimum number of observations (N_{obs}) necessary to achieve the desired level of accuracy and confidence can be computed by:

$$N_{obs} = (z^2 \cdot \dot{p} \cdot (1 - \dot{p})) / e^2 \qquad \ldots (1)$$

where $\dot{p}$ is the proportion of observations during which the target activity is performed, z-value is a factor for the confidence level (typically $z = 1.96$ for 95 % confidence level), e is the maximum absolute error desired (between 0.01 and 0.05).

As mentioned before the most important issue is what fraction of time is spent doing each type of activity, or what fraction of time is spent on productive work versus idle time or unproductive work [7]. Reports include: activities' proportion (for whole study), activities' proportion during a work day (for hours 1 to 8), activities' proportion related to days of a week (Monday to Friday), and activities' proportion related to work shifts (1 to 3).

3. INCLUSION OF THE CORRELATION ANALYSIS

Within the results we have also the proportions of all observed activities during workday hours (1 to 8). We can presume that sometimes specific activities trigger the occurrence of another activity (or more activities). If such activities are unproductive, then we are able to prevent the appearance of selected activities (mainly in the field of idle time) with the goal to reduce losses, caused by such interrelationships.

So we compare the hourly proportions (8 data) of all pairs of activities using the equation for the correlation coefficient:

$$r = \frac{8 \cdot \Sigma xy - (\Sigma x) \cdot (\Sigma y)}{\sqrt{(8 \cdot \Sigma x^2 - (\Sigma x)^2) \cdot (8 \cdot \Sigma y^2 - (\Sigma y)^2)}} \qquad \ldots (2)$$

where x is the proportion of the first compared activity and y the same for the second activity (both for 8 hours). The result is between -1 and 1, where: 1 indicates a strong positive relationship, -1 indicates a strong negative relationship, and a result of zero indicates no relationship at all. We suggest that all results lower than -0.6 and higher than 0.6 should be considered. This additional calculation is the main contribution of our paper.

4. CASE STUDY

In a textile company we have made the necessary observations in the frame of work sampling project. For the purpose of this paper the assembly workplaces' data (1600 observations) for 17 activities were used for the analysis. The activities and their proportions during the 8-hours workday (with a 30 minutes break in the 4th hour) are collected in Table 1.

Table 1. Time usage within a workday (hours' report).

Activity	**Proportion of time** in the hour of a workday [%]							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Complete all parts	14.00	15.00	17.00	18.00	12.50	18.00	12.00	13.50
2. Assembly the parts	58.50	56.00	53.50	41.50	42.50	53.50	49.00	45.50
3. Depositing the parts	14.00	17.50	14.50	5.50	15.50	17.50	14.00	13.00
4. Annotation of work results	1.50	0.50	0.00	0.50	1.00	0.50	1.00	5.00
5. Cleaning the machine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50
6. Keeping workplace in order	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.50
7. Conversation about tasks	0.00	0.00	0.50	1.50	0.00	0.00	0.00	2.50
8. Idle time (waiting for duties)	2.50	2.00	1.00	1.00	1.00	0.00	0.50	0.50
9. Waiting time – bad quality	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
10. Waiting time – missing device	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11. Machine failure	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00
12. Repair of defects	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00
13. Business meeting	0.00	0.00	0.00	1.50	2.50	0.00	0.00	0.00
14. Work on other workplace	0.00	0.00	0.50	1.50	0.00	0.00	0.00	0.00
15. Absence from company	4.00	4.00	6.00	6.00	6.00	5.00	4.50	6.00
16. Private conversation	2.00	0.50	0.50	0.50	0.00	1.00	3.50	2.00
17. Private absence from workplace	3.50	4.50	5.00	22.50	19.00	4.00	15.00	2.00
Total: **Productive work**	86.50	88.50	85.00	65.00	70.50	89.00	75.00	72.00
Total: **Losses**	13.50	11.50	15.00	35.00	29.50	11.00	25.00	28.00

The results of the pairwise correlation calculation using eq. (2) are summarized in the Table 2. All values are multiplied by 10 and rounded (so, values between -9 and +9 appear).

Table 2. Coefficients of correlation between the activities (for the presented case).

Act.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	/	1	-2	-4	-2	-2	1	-1	3	0	-5	6	-1	6	2	-5	0
2		/	5	-2	-2	-2	-5	4	2	0	0	3	-7	-4	-7	1	-7
3			/	0	-1	-1	-5	0	0	0	0	3	-3	-8	-4	0	-5
4				/	9	9	7	-1	-3	0	0	-3	-1	-2	2	3	-3
5					/	9	8	-2	-1	0	-1	-2	-2	-1	3	2	-3
6						/	8	-2	-1	0	-1	-2	-2	-1	3	2	-3
7							/	-2	0	0	-2	-2	0	3	6	0	0
8								/	0	0	-2	-4	0	0	-5	-1	-1
9									/	0	-1	6	-2	1	3	-2	-2
10										/	0	0	0	0	0	0	0
11											/	-2	-2	-1	-3	7	2
12												/	-3	0	2	-2	-3
13													/	3	5	-5	7
14														/	4	-3	5
15															/	-4	3
16																/	-1

4.1. Discussion

When checking, if there are some interrelationships between the activities, we have to discuss these combinations, based on the results in Table 2 (for values lower than -6 or higher than 6):

- Assembly the parts : Absence from company – of course: more productive work, less absence and loses (and vice versa).
- Assembly the parts : Private absence from workplace – the same comment as above.
- Depositing the parts : Work on other workplace – the same comment as above.
- Annotation of work results : Cleaning the machine – normal sequence after the job's completion.
- Annotation of work results : Keeping workplace in order – after the job's completion some maintenance is normally needed.

- Annotation of work results : Conversation about tasks – it is evident that before starting new task some instructions from foreman are usually needed; maybe some improvements in working documentation are required (useful comment no. 1).
- Cleaning the machine : Keeping workplace in order – this activities are connected; no changes.
- Cleaning the machine : Conversation about tasks – maybe the information about the machine maintenance is insufficient or working documentation is incomplete (useful comment no. 2).
- Keeping workplace in order : Conversation about tasks – the same comment as above.
- Machine failure : Private conversation – during the machine downtime the worker spends time in private chatting; time to repair should be as short as possible; maybe we should hire more maintenance staff or improve knowledge of the existent service technicians to be faster (useful comment no. 3).
- Business meeting : Private absence from workplace – obviously the workers take the opportunity of absence; when they are outside the workshop hall it is possible to return later than adequately; maybe we should change the room for business meetings, selecting closer places or some corner in the workshop directly (useful comment no. 4).

It is evident that with the correlation test we are getting an additional tool for work sampling results evaluation. Even in simpler cases some hints for critical reflection are present. Sometimes they are correct (activities' interrelationship exists) and require some changes in the production process, but it may also happen that they will be useless.

5. CONCLUSION

Work sampling is the statistical technique for determining the proportion of time spent by workers in various defined categories of activity. Workers are observed at random times throughout the work period, recording what they are doing each time. Work sampling permits quick analysis, recognition, and enhancement of job responsibilities, tasks, performance competencies, and organizational work flows. Its primary advantage is in studying nonrepetitive activities, but it can also be used to develop time standards for repetitive jobs. In such cases a lot of observations (1000 and more) are required to achieve acceptable accuracy.

In the paper we introduce the pairwise correlation comparison of the measured hourly proportions of all activities to check, if there are some interrelationships. The results of the work sampling method are given in tables (hard to read, pure statistics), now some additional calculations are made to enable the discussion between the members of the work design team about the necessary process improvements. With the correlation analysis we are getting the first signal that some activities trigger the occurrence of another (maybe non-value-adding) activity. This is the essential contribution in the decision making process.

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