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# Determination of Productive Potential of Bottleneck Machines through Work Sampling

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**ABSTRACT**:Work study is divided into two parts: a) Method Study b) Work Measurement and work sampling is one of the work measurement techniques. It is a technique of industrial engineering used to measure the productivity potential of men, machines orworkplaces through random observations and alsoused to calculate the standard time. In this study we have taken the observation at random interval of time to determining the frequency of occurrence of job events with respect to one or more machines. Job events considered in this case study are: Machine working, parts loading, parts unloading, machine idle due to operator, machine idle due to breakdown, machine idle due to inspection. This study let us know how the application of work sampling is used to identify the productive potential of bottleneck machines.

**KEYWORDS**:Work Sampling, Productivity, Bottleneck Machines, Job Events, Accuracy.

## I. INTRODUCTION

Productivity concept operationalized as the ratio of output to input, the productivity measures aims at identifying how efficiently theresources in a system are used in producing thedesired output[9].Understanding how craftsmen use their work hours to carry out activities isthe primary step in a productivity improvement program[6].Work Sampling was pioneered by L.H.C. Tippet in a British Textile Mill. Work Sampling has been defined in a B. S. Glossary as a technique in which a statistically competent number of instantaneous observations are taken, over a period of time, of a group of machines, process or workers [2].Work sampling measures time utilization, and therefore, it is only an indirect measurement of actual productivity [4].Work sampling is very useful for the study of non-repetitive activities or when the work method is nonspecific, and the cycle times are long [1]. To make a productive measurements, only activities directly result in measurable physical progress could be considered as work [8].To get the clear picture of machine idle time and working time, machine has to be observed continuously. But to observe the machine continuously is not possible because it will require large number of resources. Therefore, other method is to observe the machine at random interval and note machine is working or not, this method has the high probability to reflect the true situation with some margin of error. This is the basis of work sampling. Work Sampling is not beneficial to study a single operator or a machine or machines spread over a large area because time is wasted in movement.

Work Sampling can be applied to any field like education (college, schools), Hospitals, banks, etc. In industries itcan be applied in any department like purchase, production, finance, etc. Work sampling gives actual data whereas any continuous study can give a manipulated data because all are aware when continuous study is taken but while taking the work sampling study only management is aware about the study. Work sampling is taken over a period of days. Therefore it gives more accurate results. Any interruptions in study do not affect the results. It is bit difficult to understand by everyone. Work Sampling and related methods use probability theory to reduce the amount of time necessary to observe events or activities that do not occur in systematic manner without loss of information [7].

## II. RELATED WORK

Work Sampling is a valuable predictor in the productivity projection model [3].Work sampling is a technique that measures the time craftsmen spend in various categories of activities, such as direct work, transporting materials or waiting [5].In J. de la Riva, A. I. Garcia, R. M. Reyes and A. Woocay (2015) study, heart rate measuring equipment was used on workers performing their activities duringthe work period while in parallel a traditional wok sampling

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study was performed. The methodology proposed in J. de la Riva, A. I. Garcia, R. M. Reyes and A. Woocay (2015) study allows the determination of the allowance percentage for any activity.Because it includes: the person's physical effort, physiologic and work environment that is reflected in the heart ratedurin the accomplishment of the task.Work sampling is a subjective measure and is prone to manysources of error in addition to statistical sampling error (Thomas 1982). H. Randolph Thomas (1991) paper examined the hypothesis that direct-work percentages from work sampling studies can be used to predict labor productivity measured as the work hours per unit of output.Abraham Assefa TSEHAYAEand Aminah Robinson FAYEK (2012)paperpresented a research framework to develop a crew-based work sampling study, with an illustration of how work sampling and productivity data can be used to establish comparative proportions of direct and support activities for different trades.Established proportions can be then used as baselines for construction labourproductivity improvement efforts.The results of H. Randolph Thomas, Jose M. Guevara, and Carl T. Gustenhoven (1984) study indicate that work sampling can be used as a reliable estimator of construction productivity provided the definition of direct work is narrowly defined.Sanjay S.Patil and Nanadkumar K. Hukeri (2010) in their text book, given the work sampling procedure as: 1) Decide the objectives of the study. 2) Explain objectives to related persons. 3) Fix up work and delay elements. 4) Decide duration of study. 5) Determining the desired accuracy and confidence level of final result. 6) Make a preliminary estimate of percentage activity or delay to be measured. 7) Design actual study (Determination of number of observations, Determination of number of rounds, Fixation of time required to make a round, Comparison of average time to make a round, Preparation of schedule for the rounds, Design of observation data sheet.) 8) Record the Observations 9) Summarize the result 10) Check the accuracy of the data. 11) Prepare the report.

## III. CASE STUDY

This case study was conducted in automobile parts manufacturer company, where they are used to produce the diesel injectors which are of two types: a) Conventional injectors b) Common rail injectors. There are several bottleneck machines in different value streams of plant, from which some are selected for the study. Methodology followed to apply work sampling technique in this study is given below in fig.1.

## IV. METHODOLOGY

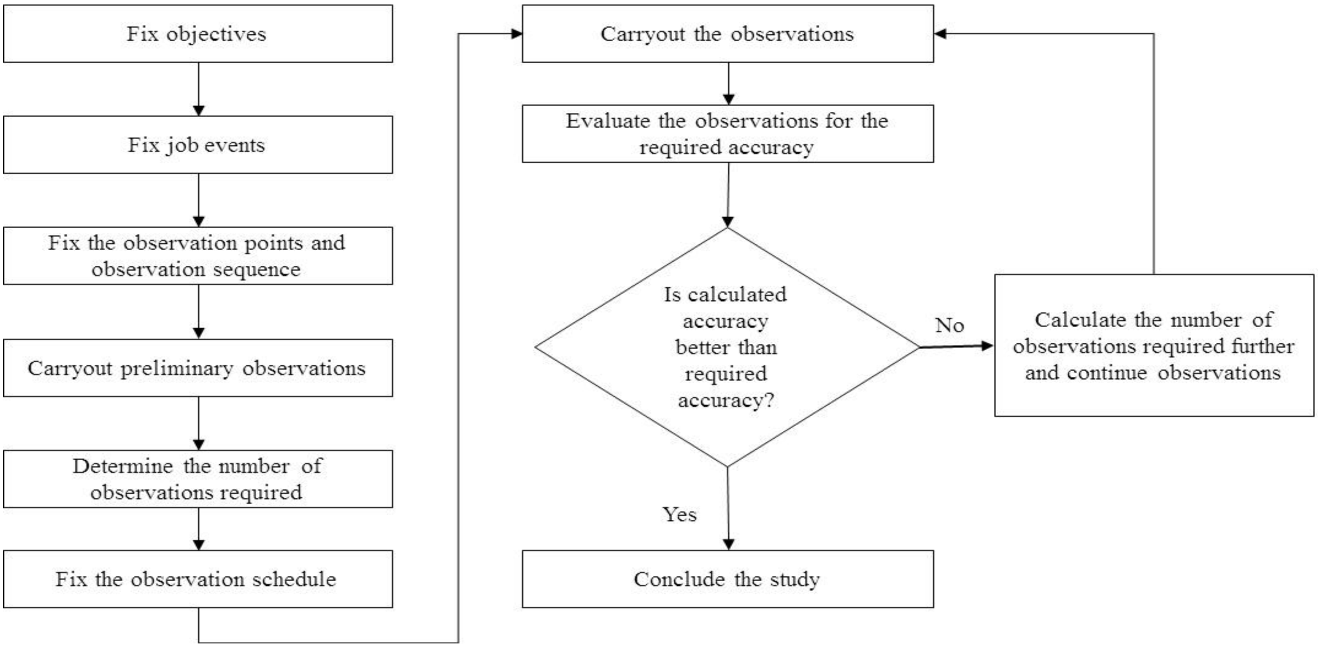


Fig.1: Methodology

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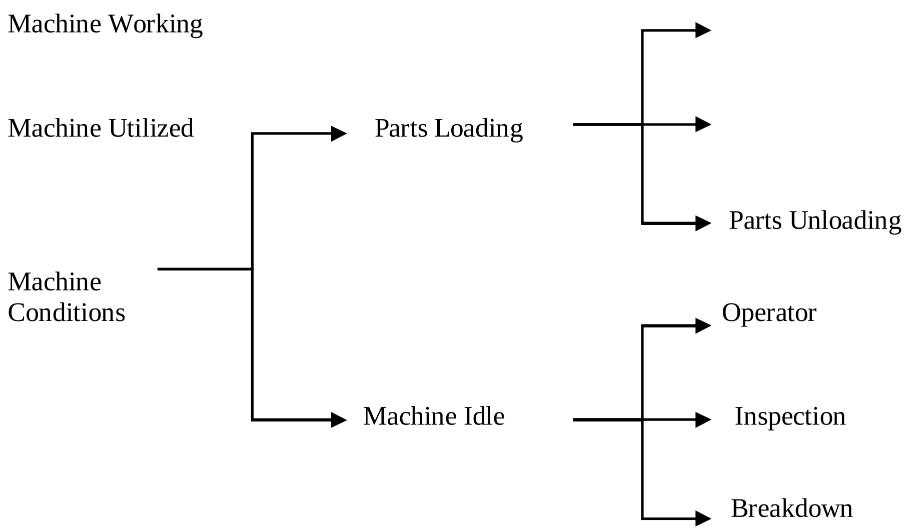
Objective of the study was to determine productivity potential of bottleneck machines through work samplingtechnique i.e. we need to find out how much productivity of bottleneck machines can be increasedby eliminating the machine idlenessdue to operator. After fixing the objective, next is to fix the job events, job events are as follows:

**Job Events:**




Observation points and observation sequence was fixed to carry out the observations.Preliminary observations were carried out as shown in table 1.

| Machines | Job Events | No. of Machines | Preliminary Readings | Percentage of Job Event |
|---|---|---|---|---|
| **M1** | Machine working | **4** | 124 | 74.7% |
| | Parts Loading | | N/A | N/A |
| | Parts Unloading | | N/A | N/A |
| | Idle due to Operator | | 40 | 24.1% |
| | Idle due to Inspection | | N/A | N/A |
| | Idle due to Breakdown | | 2 | 1.2% |
| | Total Observations | | **166** | |
| **M2** | Machine working | **4** | 147 | 54.0% |
| | Parts Loading | | N/A | N/A |
| | Parts Unloading | | N/A | N/A |
| | Idle due to Operator | | 84 | 30.9% |
| | Idle due to Inspection | | N/A | N/A |
| | Idle due to Breakdown | | 41 | 15.1% |
| | Total Observations | | **272** | |
| **M3** | Machine working | **1** | 70 | 87.5% |
| | Parts Loading | | N/A | N/A |
| | Parts Unloading | | N/A | N/A |
| | Idle due to Operator | | 10 | 12.5% |

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| | | | | |
|---|---|---|---|---|
| | Idle due to Inspection | | N/A | N/A |
| | Idle due to Breakdown | | N/A | N/A |
| | Total Observations | | **80** | |
| **M4** | Machine working | **5** | 120 | 44.4% |
| | Parts Loading | | 16 | 5.9% |
| | Parts Unloading | | 11 | 4.1% |
| | Idle due to Operator | | 120 | 44.4% |
| | Idle due to Inspection | | 1 | 0.4% |
| | Idle due to Breakdown | | 2 | 0.7% |
| | Total Observations | | **270** | |
| **M5** | Machine working | **5** | 131 | 65.5% |
| | Parts Loading | | N/A | N/A |
| | Parts Unloading | | N/A | N/A |
| | Idle due to Operator | | 29 | 14.5% |
| | Idle due to Inspection | | N/A | N/A |
| | Idle due to Breakdown | | 40 | 20.0% |
| | Total Observations | | **200** | |

Table 1:Preliminary Observations

Next step is to calculate the number of observationsrequired for the 95% of confidence level and 5% ofaccuracy because any manual element is timed, there will be an error. To reduce the error, sufficient amount of observations are taken.After knowing the number of observations required, schedule to carry out observations was prepared by using random number table. Table 2 shows the number of observations required, actual observations taken and the accuracy of the data.

**Calculations:**

Observations required for **5%** Accuracy:

$N= Z^2*(1-P)/ (S^2*P)$

$N= 1.96^2 *(1-P)/ (0.05^2*P)$

$N= 1536.64*(1-P)/P$

Accuracy can be calculated as:

$S = 1.96*\sqrt{(1-P)/N*P}$

N= Number of Observations required.

P= Working Percentage

Z= Confidence Level (95%)

S= Accuracy or Acceptable Error (5%)

As the accuracy of machine M3 was coming greater than 5% i.e. 6.2% after the observations of phase 1 readings. The required number of observations was calculated again and observations were carried out again (Phase 2). And where the accuracy is less or equal to 5%, phase 2 is not required in such situation as shown in table 2.

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| Machines | Job Events | No. of machines | No. of Observations required (Phase 1) (N) | Observations Taken (Phase 1) | Percentage of Job Event | Accuracy (S) | No. of Observations required (Phase 2) (N) | Observations Taken (Phase 2) | Percentage of Job Event | Accuracy (S) |
|---|---|---|---|---|---|---|---|---|---|---|
| M1 | Machine working | 4 | 512.2 | 428 | 82.3% | 4.0% | Not Required | Not Required | Not Required | Not Required |
| | Parts Loading | | | N/A | N/A | | | | | |
| | Parts Unloading | | | N/A | N/A | | | | | |
| | Idle due to Operator | | | 51 | 9.8% | | | | | |
| | Idle due to Inspection | | | N/A | N/A | | | | | |
| | Idle due to Breakdown | | | 41 | 7.9% | | | | | |
| | Total Observations | | | **520** | | | | | | |
| | | | | | | | | | | |
| M2 | Machine working | 4 | 1309.0 | 898 | 68.6% | 3.3% | Not Required | Not Required | Not Required | Not Required |
| | Parts Loading | | | N/A | N/A | | | | | |
| | Parts Unloading | | | N/A | N/A | | | | | |
| | Idle due to Operator | | | 240 | 18.3% | | | | | |
| | Idle due to Inspection | | | N/A | N/A | | | | | |
| | Idle due to Breakdown | | | 171 | 13.1% | | | | | |
| | Total Observations | | | **1309** | | | | | | |
| | | | | | | | | | | |
| M3 | Machine working | 1 | 209.5 | 179 | 81.7% | 6.2% | 337.311 | 281 | 82.2% | 4.97% |
| | Parts Loading | | | N/A | N/A | | | N/A | N/A | |
| | Parts Unloading | | | N/A | N/A | | | N/A | N/A | |
| | Idle due to Operator | | | 36 | 16.4% | | | 45 | 13.2% | |
| | Idle due to Inspection | | | 2 | 0.9% | | | 10 | 2.9% | |
| | Idle due to Breakdown | | | 2 | 0.9% | | | 6 | 1.8% | |
| | Total Observations | | | **219** | | | | **342** | | |
| | | | | | | | | | | |
| M4 | Machine working | 5 | 1309.0 | 703 | 53.7% | 3.4% | Not Required | Not Required | Not Required | Not Required |
| | Parts Loading | | | 91 | 7.0% | | | | | |
| | Parts Unloading | | | 64 | 4.9% | | | | | |
| | Idle due to Operator | | | 347 | 26.5% | | | | | |
| | Idle due to Inspection | | | 7 | 0.5% | | | | | |
| | Idle due to Breakdown | | | 38 | 2.9% | | | | | |
| | Total Observations | | | **1309** | | | | | | |
| | | | | | | | | | | |
| M5 | Machine working | 5 | 791.6 | 653 | 81.6% | 3.2% | Not Required | Not Required | Not Required | Not Required |
| | Parts Loading | | | N/A | N/A | | | | | |
| | Parts Unloading | | | N/A | N/A | | | | | |
| | Idle due to Operator | | | 52 | 6.5% | | | | | |
| | Idle due to Inspection | | | N/A | N/A | | | | | |
| | Idle due to Breakdown | | | 95 | 11.9% | | | | | |
| | Total Observations | | | **800** | | | | | | |

Table 2: Observations and Accuracy

## V. RESULTS

The following (Ref. Table 3) are the percentage of productive potential of respective machine. The productivity of the machine can be increased by the following percentage if the machine idleness due to operator is eliminated.

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| Machines | No. of machines | Productivity potential |
|---|---|---|
| | | Process wise |
| M1 | 4 | 9.8% |
| M2 | 4 | 18% |
| M3 | 1 | 13.2% |
| M4 | 5 | 27% |
| M5 | 5 | 7% |

Table 3: Result

To eliminate the machine idleness due to operator and to increase the productivity, discussion with the union is a way forward to be made.

## VI. CONCLUSION

Therefore from the study it is proved that work sampling technique can be used successfully to identify the productive potential of men/machines/workplaces.

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