# APPLICATION OF CHRONOMETRY METHOD TOWARDS CALCULATION OF REGULATION

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**Summary**

Work study is an area of construction production rationalization in which with scientific, logical, holistic and system analysis methods of the process we gain optimum in way of work and time of work. Chronometry method is one of the work study methods which is appropriate for recording shorter cyclic processes and is based on statistical sampling theory. Study shows applied chronometry method in work of standard cyclic construction machine. Technological process of loading material with hydraulic excavator into transport vehicle is shown. All the processes were recorded with snapback chronometry method in order to gain higher precision of labor time of each work operation in production technological process. This study's goal is accomplishing regulation due measured time cycle and compare measured effects with effects obtained with standard regulation of hydraulic excavator practical achievement. According to research results gained using snapback chronometry method on two construction sites show that the practical achievements average is around thirty percent higher when recorded on the site than it can be calculated by standard methodology.

**Keywords**: work study, snapback chronometry method, cyclic time, standard cyclic construction machine regulation

## Introduction

Many engineering and construction projects are based upon repetitive or cyclical processes, such as earthmoving. Fast development of production in today's world is based on project management regards on time, costs and quality which are key factors of every successful company on the market. Rationalization of production is a goal of every company. That goal can be achieved by minimization of time which has an effect on cost minimization (Pinter, Lončarić, 2006). Also it effects quicker reimbursement of invested assets. By production organization we comprehend performing as direct result of quality planning. With planning we set capacities, costs and the dates in advance, by managing we take into account realization and monitoring of achieved results. Planning of cyclic construction processes is often difficult due to their stochastic nature. In order to reduce this difficulty, many planning engineers maintain a large databank of productivity rates recorded from past projects. For a new construction operation, these productivity rates are adjusted**,** taking into account specific site factors and conditions that may influence productivity. Quality project management and achieving the minimization of time depends on various factors whose characteristics and impacts are engaged by work study. Work study is the systematic examination of the methods of carrying out activities so as to improve the effective use of resources and to set up standards of performance for the activities being carried out. Work study is divided in two groups in order to gain higher productivity. First group is a group of method studies which are used to simplify the job and develop more ergonomic methods of doing it. Second group is a group of work measurements which are used to find the time required to carry out the operation at a defined level of activity (Russell, Taylor, 2005a). One of the methods of performing work measurement is stopwatch time study which application in comparison to calculation of standard cyclic construction machine regulation will be presented in this paper.

## Stopwatch Time Study

Stopwatch time study measures how long it takes an average worker to complete a task at a normal pace. A "normal" operator is defined as a qualified, thoroughly experienced operator who is working under conditions as they customarily prevail at the work station, at a pace that is neither fast nor slow, but representative of an average. The actual time taken by the above-average operation must be increased, and the time taken by the below-average must be reduced to the value representative of normal performance. Performance rating is a technique for equitably determining the time required to perform a task by the normal operator after the observed values of the operation under study have been recorded (Nakayama, 2002).

Frederick W. Taylor started to develop time study at 1881 when he started measuring time at a machine shop at home with stopwatch and clipboard. That was the beginning of time study. Even Taylor used stopwatch, as basic tool for recording time, present tools hasn't changed much. Today besides standard tools of time study, stopwatch and clipboard, we use digital stopwatches, computers, barcodes and accustudy software (Izetbegović, 2007).

There are few directions which should be followed when we use stopwatch time study for recording durations of our operations. Therefore here are seven suggested basic steps for using stopwatch time study.

Stopwatch time study basic steps (Russell, Taylor, 2005b):

1) Establish the standard job method,
2) Divide the job into elementary operations,
3) Study the job,

4) Rate the workers performance,
5) Compute the observed average time,
6) Compute the normal time,
7) Compute the standard time.

Stopwatch time study knows two methods of recording short cyclic processes:

1) Continuous chronometry method,
2) Snapback chronometry method.

Continuous chronometry method is a timing technique in which the stopwatch is allowed to run for the entire job. Method results present a complete record for the entire observation period including all delays and foreign elements. Foreign elements are external things to the process that delay the work from moving forward such as supervisor interruptions, power losses, leaving workstation and tool breakage. When using continuous method clerical work is required.

Snapback chronometry method is another timing technique which is used to record duration of each work element process. Using this technique we must reset our stopwatch after each breakpoint. No clerical work is needed to substract from previous observations as in continuous method. We directly read and record observed time.

With both methods, if they are used correctly, we gain equivalent results. Despite possibilities of achieving equal results, the snapback chronometry method is recommended due to few advantages in relation to continuous chronometry method (Taboršak, 1987):

1) Time of each work operation can be directly read and recorded,
2) Observer error can be calculated,
3) It’s the same way of recording time not considering the order of performing operations,
4) Irregularities in work can be easily noticed,
5) Time of justified delays bounded to technological process can be calculated,
6) Easy recording of delay times during the work which are not connected to technological process,
7) If the recording was interrupted for any reason it can always be continued.

## Application of snapback chronometry method

In this research we used snapback chronometry method to record duration of work processes of standard cyclic construction machine. Technological process of loading material with hydraulic excavator into transport vehicle is shown.

Measurements were taken on the part of local road number 233, Jurjenići – Šporova jama section, which is a northern connection of two cities, Kastav and Rijeka. Great significance of this regional road for the city of Rijeka and surroundings is gaining the alternative traffic route which will be used during whole year in order to reduce traffic load especially during summer time.

Data was recorded during the work of Komatsu PC340NLC standard hydraulic excavator. This is a modern hydraulic excavator built for very complex and demanding job in engineering especially earth digging, loading and demolishing. This machine weights 35 tons. Excavations were taken with the bucket capacity of 2,2 $m^3$.

Measurements were taken during winter conditions in November and December of 2007. Average day temperature was 8.7°C and the average humidity was 48%. Almost three quarters of all time N-NE wind blew.

At the beginning we divided our supervised job into elementary work operations as shown in Table 1. Each work operation is numerated.

Table 1: Work operations

| No. | Work operations |
|---|---|
| 1. | Clutching material |
| 2. | Rotation of excavators boom with the bucket full of material |
| 3. | Loading into transport vehicle |
| 4. | Return into start position |

Table 2 show measured time of each operation during fifteen cycles. Table shows fifteen representative measured cycles of overall 375 measured cycles.

Table 2: Recorded cycles by each work operation

| Number of Cycles | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. |
| 5,87 | 6,48 | 5,73 | 7,24 | 8,33 | 6,60 | 5,97 | 6,79 | 6,98 | 4,73 | 6,58 | 5,55 | 7,07 | 5,70 | 4,25 |
| 9,18 | 8,60 | 8,17 | 8,51 | 7,23 | 6,44 | 6,78 | 8,28 | 9,06 | 8,25 | 11,08 | 7,11 | 7,49 | 8,63 | 7,01 |
| 4,28 | 4,42 | 4,04 | 4,37 | 4,81 | 3,66 | 3,38 | 8,41 | 4,35 | 3,12 | 3,25 | 3,45 | 4,39 | 4,87 | 7,52 |
| 7,39 | 8,31 | 8,61 | 7,97 | 7,34 | 5,84 | 8,89 | 6,52 | 7,15 | 6,84 | 7,28 | 7,66 | 5,61 | 6,72 | 7,84 |

Table 3 shows summary time of recorded cycles presented in Table 2 by each work operation. Beside summary time, rating factor and normal time of each operation is shown. Normal time is product of average time of each operation and related rating factor. Normal cycle time is a sum of normal times of each operation.

Table 3: Overview of normal cycle time calculating process

| Summary time | | | | | Rating factor | Normal time $N_{vs}=\Sigma N_t$ |
|---|---|---|---|---|---|---|
| $x_{max}$ | $x_{min}$ | $\Sigma x$ (sec) | $\Sigma x$ (%) | $x_{sr}$ | | |
| 8,33 | 4,25 | 93,87 | 23,83 | 6,26 | 1,10 | 6,88 |
| 11,08 | 6,44 | 121,82 | 30,92 | 8,12 | 0,95 | 7,72 |
| 8,41 | 3,12 | 68,32 | 17,34 | 4,55 | 1,00 | 4,55 |
| 8,89 | 5,61 | 109,97 | 27,91 | 7,33 | 1,05 | 7,70 |
| | | | | | | $N_{vs}$=26,85 |

Normal cycle time:

$$N_{vs}=\Sigma N_t$$

$$N_{vs}=26,85 \text{ s/cycle} \rightarrow 0,00746 \text{ h/cycle}$$

Standard time ($N_v$) is a product of normal cycle time ($N_{vs}$) and additional time coefficient ($K_D$):

$$N_v=N_{vs}*K_D,$$

$$K_D=1+k_a*k_n+k_d.$$

Table 4: $K_D$ – Additional time coefficient

| | | |
|---|---|---|
| ka | *From Taboršak* | 1 |
| kn | *From Taboršak* | 1 |
| kd | $(t_P+t_N+t_E)/100$ | 0,035 |
| $K_D$ | $K_D=1+k_a*k_n+k_d$ | 2,035 |

$N_v=N_{vs}*K_D=0,00746*2,035=0,01518$

$N_v=0,01518$ h/cycle

$U_p^v=1/N_v$

$U_p^v=65,88$ cycle/h

We calculated our regulation with measured time that resulted in having to spend 0,01518 hours per cycle. Our cyclic construction machine is Komatsu PC340NLC hydraulic excavator with the bucket capacity of 2,2 $m^3$. In order to load material into transport vehicle, boom of the excavator turns around for 180°. In order to compare these results with results that we gained with calculation of regulation due standard methodology we must determine how many cubic meters is included in one cycle.

1 cycle=$q*x_r$

Using observation method (Lopez, 2005) we estimated that with each bucket loading only 75% of bucket capacity is filled ($x_r=0,75$).

1 cycle=2,2*0,75=1,65 $m^3$

$U_{px}^v= U_p^v*1,65=108,70\ m^3/h$
$U_{px}^v=108,70\ m^3/h$

$N_{vx}=1/U_{px}^v$
$N_{vx}=0,00920\ h/m^3$

## Calculation of regulation based on standard methodology

For the calculation of regulation based on standard methodology approximately the same data is used as in snapback chronometry method. Bucket capacity is 2,2 $m^3$ and the angle of boom rotation is 180°. Excavation was semi hard one and the cycle time ($t_c$) is taken from tables in total of 28 seconds i.e. 0,0078 hours (Linarić etc., 2007).

The practical achievement is calculated by following expressions:

$$U_p = \frac{q * T}{t_c} * k_A * k_B * k_C ,$$

$k_a = k_p * k_r * k_{vm}$, $k_b = k_{rp} * k_o * k_{ut}$, $k_c = k_{og} * k_{rv} * k_{ds}$.

Table 5: Selected reduction coefficients

| Coefficients of: | Material coefficient $k_A$ | Working condition coefficient $k_B$ | Organization coefficient $k_C$ |
|---|---|---|---|
| Loading bucket capacity ($k_p$) | 0,90 | - | - |
| Meuble material ($k_r$) | 0,90 | - | - |
| Humidity of material ($k_{vm}$) | 0,95 | - | - |
| Working area ($k_{rp}$) | - | 0,95 | - |
| Rotating of boom ($k_o$) | - | 0,70 | - |
| Loading ($k_{ut}$) | - | 0,90 | |
| Mechanic work condition ($k_{og}$) | - | - | 0,83 |
| Utilization working time ($k_{rv}$) | - | - | 0,92 |
| Machine wear and tear ($k_{ds}$) | - | - | 0,91 |
| Σ | 0,670 | 0,5985 | 0,695 |

Up=(2,2*1/0,0078)*0,670*0,5985*0,695=78,69 $m^3$/h

Up=78,69 $m^3$/h

N=1/Up

N=0,01323 h/$m^3$

## Conclusion

Work measurement determinates time required to carry out the operation at a defined level of activity in order to achieve higher productivity. Work measurement is the careful analysis of a task, its size, the method used in its performance and its efficiency. The objective is to determine the workload in an operation, the time that is required, and the number of workers needed to perform the work efficiently. Work measurement can be extremely effective at informing supervisors of the working times and delays inherent in different ways of carrying out work.

The purpose of a measurement method is to achieve full coverage of the work to be measured. A good work measurement system has many benefits. It helps to reduce labor costs, increase productivity and improve supervision, planning, scheduling, performance appraisal and decision making.

This paper shows the application of snapback chronometry method which is the one of time study methods. The snapback approach requires a stopwatch with a reset button that allows the observer to read and record the time at the end of each work operation than reset the watch to zero.

Job times are vital inputs for manpower planning, estimating labor costs, scheduling, budgeting and designing incentive systems. In addition, from the worker’s standpoint, time standards provide an indication of expected output. Time standards used under Standard Cost Systems reflect the amount of time it should take for an average worker to do a job under typical operating conditions. The standards include expected activity time plus allowances for probable delays.

Snapback chronometry method is used to determine standard time of a standard cyclic construction machine in one standard earth moving technological process. Technological process of loading material with hydraulic excavator into transport vehicle is shown.

In our research we determine that the standard time apropos regulation is 0,00920 $h/m^3$ for our specific cyclic construction machine and specific but realistic conditions where the measurements were taken. Results gathered by snapback chronometry method were compared with calculation of regulation based on standard methodology. In that calculation with reduction coefficients we gave the best possible approximation of working conditions which occurred on our measured construction site. Regulation which calculation is based on standard methodology is 0,01323 $h/m^3$. That is 30% higher than the regulation results gained by snapback method.

Although popular, the time study method is subjective and relies heavily on the experience of the time study analyst. A computerized data collector provides more accurate timing than a stopwatch. However, converting actual time to the expected or normal time remains a problem.

Most of work measurement methods are designed for measuring the work in industrial (ideal) surroundings while construction sites are far from ideal. Thus there is a large gap in application and calibration of work measurement methods on construction sites.

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