Solved problems about Direct time study problems

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Nomenclature

T_{ef}: Effective working time
T_n: Normal time
T_{obs}: Observed time
MP: Tasks while machine is off
MM: Tasks while machine is on
PD: Process delay
A_f: Fatigue allowance (% value)
FAT: Fatigue allowance time
A_p: Personal needs allowance (% value)
PAT: Personal needs allowance time
A_{pfd}: Allowance for fatigue, personal and delay (% value)
T_m: Machine cycle time
T_{std}: Standard Time (Work Standard)

Problem statement nº1. Direct Time Study

You want to calculate the standard time (T_{std}) at a workstation where a machine and an operator are located. As the current Time & Methods Engineer cannot devote much time to this, he will be in charge of doing only a partial direct timing using a stopwatch and the person in charge of the section will sample 2,400 observations.

Two cyclic work elements (to be measured) have been identified (Element A & Element B), one waiting element (C measured by work sampling) and one manual acyclic work element (D to be measured by sampling and by direct timing).

- **Element A** has been defined as a manual work element carried out while the machine is off. It consists of removing the finished part from the machine, placing a new one in the machine and turning the machine on again.
- **Element B** is a manual work element too. While the machine is processing the new part, the worker has to grease the part extracted during Element A in the previous cycle.
- **Element C** consists of waiting for the machine to finish its automatic cycle.
- **Element D** is a manual work element that is performed for every two parts manufactured. It consists of filling the container of grease that is used in Element B. During the observation, it has been observed that the operator does it after work element B. Nevertheless, in the approved work method, it is clearly stipulated that it must always be carried out after Element C.

Below are the results of a brief direct time study that has been considered sufficient for the level of accuracy that is sought. Measured times are expressed in thousandths of a minute:

	Element A		Element B	
Cycle	Performance Rating	T_{obs}	Performance Rating	T_{obs}
1	90	140	120	380*
2	105	120	80	140
3	95	132	90	125
4	95	490*	100	113

* The acyclic work element D was carried out during a cyclic work element.

In the sampling, it was observed that the performance rate of element D was 90.

During this study, 90 parts were produced, and the following observations of elements C and D were obtained:

	Element C	Element D
Number of observations of the element	1,100	500

Calculate:

a) Normal times of elements A and B ($T_n[A]$, $T_n[B]$)
b) Normal time of element D ($T_n[D]$)
c) Normal time of element C ($T_n[C]$)
d) Time granted as a Fatigue Allowance (FAT)
e) Time granted as Personal needs Allowance (PAT)
f) Standard time (T_{std})

Consider a fatigue allowance of 7% and a personal needs allowance of 5%.

Solution Problem nº1

To calculate the normal times of the cyclic elements, the valid cycles of the study of times are used. We assume that:

- min^{-3} = thousands of minutes
- during one cycle, just one part is produced.

Question a) Normal times of elements A and B

Element A

Rating	T_{obs}	Tn
90	140	126
105	120	126
95	132	125.4
	Average	125.8

$T_n[A]$ = 125,8 min^{-3}

Element B

Rating	T_{obs}	Tn
80	140	112
90	125	112,5
100	113	113
	Average	112,5

$T_n[B]$ = 112,5 min^{-3}

Question b) Normal time of element D

To calculate the normal time of element D, we use the time values when they happened:

$$T_n[D] \text{ each 2 cycles} = \left(\frac{(PR_{A,cycle4} \cdot T_{obs}[A_{cycle4}] - \text{Tn}[A]) + (PR_{B,cycle1} \cdot T_{obs}[B_{cycle1}] - \text{Tn}[B])}{2}\right) =$$

$$\left(\frac{\left(\frac{95}{100} \cdot -125.8\right) + \left(\frac{120}{100} \cdot 380 - 112{,}5\right)}{2}\right) = \left(\frac{339.7 + 343.5}{2}\right) = 341.6 \text{ min}^{-3}$$

Since the frequency is 1 every 2 cycles, the normal time of element D to consider per cycle is:
$T_n[D]$ = 341.6 / 2 = 170.8 min^{-3}

Question c) Normal time of element C

To calculate the waiting time C, it is necessary to use the work sampling study. However, we do not have all the data as you can see below:
The percentage (%) of appearance of element C is: %C = 1,100/2,400 = 0.46=46%
The time would be: T[C] = 0.46*T/90
Where T is the duration of the study in which the 90 parts were produced.
As T is a waiting time from the operator perspective, it is considered as a Process Delay.
T cannot be rated. T is not a normal time since it is considered a special supplement/allowance due to process delay.
In order to calculate T, the result of the work sampling study of the already calculated element D will be used.
We know that its % of occurrence is: %D = 500/2,400 = 0.21 = 21%
The normal time would be $T_n[D]$ =90/100*0.21*T/90= 170.8 min^{-3}
and clearing T = 81,333.3 min^{-3} = 1.35 hours
$T_n[C]$ = 0.46*81,333.3/90= 415.7 min^{-3}

Question d) Time granted as a fatigue allowance (FAT)

Elements A, B and D are working elements. Therefore, a fatigue allowance (A_f) should be assigned for them.
FAT = A_f ($T_n[A]$+ $T_n[B]$+ $T_n[D]$) = 0.07 * (125.8 + 112.5 + 170.8) = 28.64 min^{-3}

Question e) Time granted as a personal need allowance (PAT)

The personal needs allowance (A_p) to take into account for both work elements and process delays is:
PAT = A_p ($T_n[A]$+ $T_n[B]$+ $T_n[D]$ + $T_n[C]$) = 0.05 * (125.8 + 112.5 + 170.8 + 415.7) = 41.24 min^{-3}

Question f) Standard time (T_{std})

As the waiting time of the operator is less than half a minute per cycle, the allowance cannot be reduced. FAT and PAT are added without reduction.

The standard time (T_{std}) would be:

$T_{std} = T_n[A] + T_n[B] + T_n[D] + T_n[C] + FAT + PAT = 125.8 + 112.5 + 170.8 + 415.7 + 28.64 + 41.24 = 894.68 = 0.894$ man-min / part

Problem nº2. Direct Time Study

In Workstation #04 of the manufacturing and assembly line of fans "Fan Deck Metallic", the gluing of the parts of the housing and other operations are carried out.
An operator is currently assigned to the tasks performed there. The operator works with an automatic ultrasonic gluing press. Two manual work elements have been identified:

- **Element AAA**: consists of extracting the elaborated part from the press, placing a new one in the press and turning the press on.
- **Element BBB**: consists of placing a wire in the part elaborated during the previous Element AAA. The work method indicates that it must be done while the press processes a new part.

A CCC element has also been identified. It consists of waiting for the press to end its automatic cycle.
Every 20 parts, the operator performs the DDD element. This consists of fetching a new bag of 20 wires. The method indicates that this acyclic element must be done within the machine cycle time. Nevertheless, in some cases, the operator does it when he wants.
In order to re-balance the line, it has been decided to perform a new direct time study of the operations that are carried out in the production system.
The results of the direct time study (using a stopwatch) are as follows:

	AAA Element		BBB Element		CCC Element	
Cycle	**PR**	**Time**	**PR**	**Time**	**PR**	**Time**
1	90	122	80	115	-	120
2	105	105	105	519*	-	**
3	95	116	100	85	-	150
4	100	110	100	87	-	148
5	100	560*	90	94	-	141

* The acyclic element DDD has been detected
** No waiting time for the operator has been detected since the machine had stopped before BBB element finished.

The measured times are in thousandths of a minute (min^{-3}) and PR = Performance Rating. Consider a basic fatigue allowance of 7% and a personal needs allowance of 5%.
You must calculate:

1. Normal time of the cyclic elements (T_n[AAA + BBB])
2. Normal time of the acyclic element (T_n[DDD])
3. Machine cycle time (T_m)
4. Fatigue allowance time (FAT)
5. Personal allowance time (PAT)
6. Standard time (T_{std})

Solution Problem nº2

Question 1) Normal time of the cyclic elements (T_n[AAA + BBB])

Manual Element AAA

Valid Cycle	Rating	Obs. Time	Norm Time (Tn)
1	90	122	109,8
2	105	105	110,25
3	95	116	110,2
4	100	110	110

Average T_n[BBB] = 110,06 min^{-3}

Manual Element BBB

Valid Cycle	Rating	Obs. Time	Norm Time (Tn)
1	80	115	92
3	100	85	85
4	100	87	87
5	90	94	84,6

Average T_n[BBB] = 87,15 min^{-3}

T_n[AAA+BBB] = 197,21 min^{-3}

Question 2) Normal time of the acyclic element (Tn[DDD])

Manual acyclic DDD element:

- 1st observed data (560-110) = 450 min^{-3}
- 2nd observed data (519·1.05-89) = 456 min^{-3}
- T_n[DDD] each 20 cycles = (450 + 456) / 2 = 453 min^{-3}

The frequency of this element, based on objective data, is 1 per 20 cycles. The normal time for Element DDD to be considered per cycle will be:

- T_n[DDD] = 453/20 = 22.65 min^{-3}

Question 3) Machine cycle time (Tm)

To determine the machine cycle time, the study should be limited to the cycles where a process delay has been detected (cycles 1, 3, 4 and 5).

In these cycles, the observed machine cycle time is then the sum of the manual work element times when the machine was processing a part and the measured process delay.

By observing the man-machine diagram of the operation below, we can calculate the Time Machine (T_m) as follows:

- T_m = 115 + 120 = 85 + 150 = 87 + 148 = 94 + 141
- T_m = 235 min^{-3}

Question 4) Fatigue allowance time (FAT)

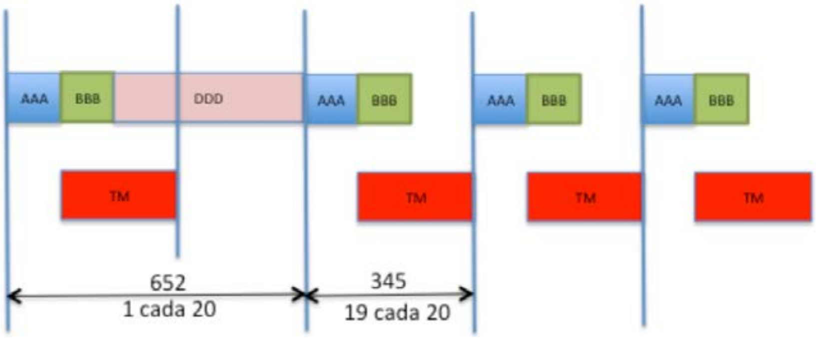


Fig. 1 Man-machine diagram of 20 work cycles

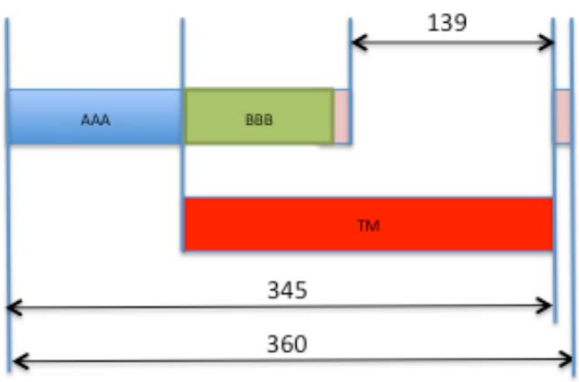
According to the standard work method, the acyclic element DDD must be carried out during the process delay.
As can be seen in Fig. 1, the total normal time is greater than the difference between T_M and Element BBB (work element performed while machine is running). We know that when the worker performs the acyclic element DDD, there will be no process delay and the machine will wait for the operator to return.

- T_m-T_n[BBB] = 235-87 = 148 <453

That is to say that

- Once every 20 cycles, the real duration of the cycle is:
  - T_n[AAA] + T_n[BBB] + T_n[DDD] = 197 + 453 = 650 min^{-3}
- For the remaining 19 cycles, the real duration of the cycle is:
  - T_n[AAA] + T_m = 110 + 235 = 345 min^{-3}

In short, as the time of work element DDD is greater than 148, part of the acyclic element DDD is carried out during the machine cycle and part is carried out after the end of the machine cycle.



To determine the "average cycle", we should average the activity while the machine is on as well as while the machine is off.

Part of the acyclic work element DDD must be included while the machine is running and should be calculated as follows:

- Element DDD during T_m : 148/20 = 7.4 min^{-3}

Let's assume that **Machine Preparation (MP) tasks are performed with the machine off.** In this case, part of the acyclic work element DDD must be included while the machine is off and should be calculated as follows:

- Element DDD during MP = (453-148) / 20 = 305/20 = 15.25 min^{-3}

Consequently, the normal cycle time is

- T_n[AAA]+ T_m + Element DDD during MP = 110 + 235 + 15.25 = 360.25 ≅ 360 min^{-3}

Assuming that **DP is the Delay of the automated Process (Time in which the worker is idle waiting for the machine to finish its automated process)**. The process delay (DP) can be calculated as follows:

- DP = T_m - T_n[BBB]- Element DDD during T_m =235-89-7,4 = 138.6 ≅ 139 min^{-3}

The fatigue allowance is calculated considering all manual work elements (in this case: AAA, BBB and DDD).
Since the process delay PD = 0,139 min is less than 0,5 min, the entire fatigue allowance (FAT) must be added to the normal cycle time.

- FAT = 0,07 (197 + 22.65) = 15,37 ≅ 15
- FAT = 15 min^{-3}

Question 5) Personal allowance time (PAT)

The personal needs allowance (PAT) is calculated considering all work elements that make up the entire normal cycle time. In this case, the following elements should be considered: Element AAA+ T_m + Element DDD during MP.
Since the process delay PD = 0,139 min is less than 10 min, the personal needs allowance time (PAT) must be added to the normal cycle time.

- PAT = 0.05 x 360 = 18
- PAT = 18 min^{-3}

Question 6) Standard time (T_{std})

Consequently, the Standard Time (also called Work Standard) will be as follows:

- T_{std} = T_n + FAT + PAT = 360 + 15 + 18 = 393 man-min^{-3}/part = 0.393 man-min^{-3}/part

Problem nº3. Direct Time Study

In a company that manufactures metal parts, there are two workstations in series. Workstation 1 (WS1) is a numerical control machine. Workstation 2 (WS2) is a manual finishing station.

WS1: Workstation of the Numerical Control Machine

At WS1, the operator loads and unloads the machine that carries out a forming process. While the machine is on, the operator should fetch parts located in a container which holds around 100 parts. The time it takes the operator to fetch the parts is unknown. Usually, this is considered a process delay (PD).

The working day is 8 hours long. Traditionally, a break of half an hour is given to eat and rest.

To estimate this process delay, you have carried out a work sampling during 4 work periods of 3 hours each. During the observations, the operator was performing 3 main types of activity: (1) feeding the machine while the machine is off, (2) fetching parts and (3) waiting for the machine to finish its automatic cycle (process delay).
Of the 240 observations made, you observed:

- in 47 observations, the operator was feeding the machine with the machine was off,
- in 94 observations, the operator was fetching parts,
- in 94 observations, the operator was waiting for the machine to finish its automatic cycle and
- in another 5 observations, the operator was performing personal needs.

During the duration of the working sampling study, 879 parts had been produced.
The top management considers that an additional allowance factor for personal time and fatigue of 2.3% must be applied to the entire duration of the worker's time spent at the workplace.

WS2: Manual Finishing Station

After WS1, each metal part arrives at WS2. There, an operator performs a series of manual work activities. As an example, the operator adds two components to the metal part.
To estimate the standard time at WS2, a direct time study was performed using a stopwatch.
The work cycle of the operator has been divided into 2 work elements (element 1 and element 2).
The results of the study are shown in the table (times are expressed in thousandths of a minute).
Note that, during the study, 2 acyclic work elements were noted and must be considered when determining the standard time.

	Element 1		Element 2	
Cycle	PR	T_{obs}	PR	T_{obs}
1	90	460	100	1,762**
2	100	1,910**	90	345
3	110	1,680*	90	355
4	120	350	90	1,690*
5	100	410	120	255

* Element that consists of fetching a container which contains 100 parts.
** Element that consists of checking the previous parts produced. This is carried out once every 30 produced parts.

You must:

- At WS1:
  1. Determine the normal time of the activity of the operator while the machine is off
  1. Determine the normal time of replenishment work.
  2. Define the Standard time (T_{std}) at this workstation.
  3. If, on a given workday, 900 parts have been produced, calculate the average work performance rate (base 100) of the operator.

- At WS2:
  1. Calculate the standard time at this workstation, applying a fatigue allowance of 10%.
  2. If, on a given workday, 525 parts have been produced, calculate the average work performance rate of the operator.

Solution problem nº3

WS1: Numerical control machine Workstation

Question 1) Normal time of the activity of the operator while the machine is off (PD)

Effective minutes of the operator's work:

- T_{ef} = (8.00-0.50) × 60 = 450 man-min / day

If during 450 man-min, 879 parts have been produced, the standard time (T_{std}) is then:

- T_{std} = 450/879 = 0.512 man-min / part

The personal needs and fatigue allowance (2.3%) should be applied as follows:

- T_{std} = MP + MM + FAT + PAT = (MP + MM + PD) × (1+ A_{pfd})

= (MP + MM + PD) × 1.023 = 0.512 man-min / part

- MP + MM + PD = 0.500 min

In this case, we will assume that

2. MP is while the operator works while the machine is off
3. MM is when the operator is performing replenishment activities
4. PD is when the operator is waiting for the end of the machine automatic cycle
5. PN is personal needs

Using the work sampling study, we can then calculate the percentage of time of each activity type:

- % MP = 47/240 = 19.6%
- % PD = 94/240 = 39.2%
- % MM = 94/240 = 39.2%
- % PN = 5/240 = 2.1%

%PN is useful to be sure that personal needs allowance granted is sufficient.
The duration of the study is:

- 4 periods × 3 hours × 60 min / h = 720 min

As T_{std} has been calculated considering a normal performance rate, the production level should have been:

- 720 / 0.512 = 1,406 parts

Consequently:

- MP = 720 × 0.196 / 1,406 = 0.100 min
- PD = 720 × 0.392 / 1,406 = 0.201 min

Question 2) Normal time of the replenishment work

The normal time of the replenishment work element is the time it takes for the operator to fetch 100 parts placed in a specific container. This acyclic work element is performed while the machine is on, and therefore will be:

- T_n[MM] each 100 cycles = 0.201x100 = 20.1 min
- T_n[MM] = 720 × 0.392 / 1,406 = 0.201 min

Question 3) Standard time at WS1

So, we can estimate T_m:

- T_m = $MM + PD$ = 0.402
- T_{std} = 0.512 man-min / part

T_m cannot be changed at the operator's will, so it remains constant whatever the worker performance rate is.

Question 4) Average work performance rate of the operator

If 900 parts are produced on a given day, the time to produce 1 part is:

- 7.5 × 60/900 = 0.5 man-min / part

This time includes two main activities:

- The time of MP performed by the operator (adjusted to its work performance rate) plus the time of T_m with its corresponding allowances. This occurs 99 cycles out of every 100.

  1.023 × (MP+ T_m) × 99/100
- The time of MP performed by the operator (adjusted to its work performance rate) plus the time of MM with its corresponding allowances. This occurs once every 100 cycles.

  1.023 × (MP + MM) × 1/100

1.023 × [99/100× (MP+ T_m) + 1/100× (MP + MM)] = 0.5 [Exact case]

1.023 × (MP + T_m) = 1.023 × (MP + 0.402) = 0.5 [Approximation]

Using the approximation, MP = 0.087

As T_{obs}×PR_{Obs} = Tn×100

The observed performance rate (PR_{obs}) can be calculated as follows:

- 0.087×PR_{Obs} = 0.1×100
- PR_{obs} = 114.94 = 115

WS2: Manual finishing workstation

Cycle	PR	T_n[Element 1]	PR	T_n[Element 2]
1	90	414	100	1,762**
2	100	1,910**	90	311
3	110	1,848*	90	319
4	120	420	90	1,521*
5	100	410	120	306

The average normal time of the two elements should be calculated not taking into account the elements marked with * and **. The results are as follow:

- T_n[1] ≈ 0.415

	Element 1		
Cycle	Rating	T_{obs}	Tn
1	90	460	414
4	120	350	420
5	100	410	410
		Average T_n	414,67

- T_n[2] = 0.312

	Element 2		
Cycle	Rating	T_{obs}	Tn
2	90	311	279,9
3	90	319	287,1
5	120	306	367,2
		Average T_n	311,40

The normal time of the acyclic element A ($T_n[A]$) should consider the capacity of the box and the number of metallic parts consumed per cycle. As a box holds 100 parts and 2 parts are consumed per cycle, $T_n[A]$ is calculated as follows:

$$T_n[A] = \frac{1}{frequency}\left(\frac{\left(PR_{1,cyle3} \times T_{obs,cycle3}[1] - T_n[1]\right) + \left(PR_{2,cyle4} \times T_{obs,cycle4}[2] - T_n[2]\right)}{2}\right)$$

$$T_n[A] = \frac{2}{100}\left(\frac{\left(\frac{110}{100} \times 1{,}848 - 0.415\right) + \left(\frac{90}{100} \times 1{,}521 - 0.312\right)}{2}\right) = 0.027$$

The normal time of the acyclic element B ($T_n[B]$) can be calculated following the same logic (once every 30 produced parts):

$$T_n[B] = \frac{1}{30}\left(\frac{\left(\frac{100}{100} \times 1{,}910 - 0.415\right) + \left(\frac{90}{100} \times 1{,}752 - 0.312\right)}{2}\right) = 0.049$$

The total normal time is then

- $T_n = T_n[1] + T_n[2] + T_n[A] + T_n[B]$

= 0.415 + 0.312 + 0.026 + 0.049
= 0.802 min / part
And the standard time will be

- T_{std} = 1.1 × 0.802 = 0.882 man-min / part

As in 7.5 hours, 525 parts have been produced, the standard time is

- T_{std} [obs] = 7.5 × 60/525 = 0.85 man-min / part

Therefore, since it is a manual work activity in this workstation,

- PR_{obs} = 0.88/0.85×100=103.5∼104