TIME STUDY AS A METHOD FOR MEASURING MACHINERY PERFORMANCE

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Abstract

Time study is examined as a method of work measurement to set machinery performance standards and provide machinery management information. A model developed from time study results can be used to predict actual field time to within 20%.

Introduction

Time study is a method of measuring work done by man and machine. Time study can be used to establish machinery performance standards and to measure actual productivity for comparison with pre-determined standards.

Method

"Time study is the basic technique of work measurement since it is concerned with the direct observation of work while it is being performed" (Curry[1]). An object of work measurement is to set target times with which to compare subsequent results, and thereby exercise control. Direct time study is only of use for repetitive work. Operations on farms are repetitive in nature but the terrain on which they are carried out is not always the same. Work must therefore be defined in sufficient detail to account as far as possible for the effect of the lack of uniformity of fields.

The techniques used at La Mercy to study the various elements of field operation is called Cumulative Timing. Times are recorded at the start of the study and at the end of each element without ever returning the stopwatch to zero. Individual times are afterwards obtained by subtraction of successive readings. Results from a time study are processed on an HP41C programmable calculator. Programmes convert the time study information into the following data :

- Total time for each element of work.
- Time for each element of work as a percentage of the total time.
- Total number of times that an element of work was performed.
- Average duration of one execution of each element of work.

The speed of travel can also be calculated, given the length of any selected row. A sample of time study results is given in Table 1.

TABLE 1

Example of results from a time study of fertilization

Element description	Total time per element (min.)	Time as %age of total time	No. of times element observed	Av. time per element (min.)
Travelling to load	3,3	10,9	1	3,3
Loading ..	1,5	4,9	1	1,5
Travelling after loading..	2,4	8,0	1	2,4
Downtime ..	4,3	14,6	4	1,1
Spreading ..	17,0	57,4	7	2,4
Turning.. ..	1,2	4,2	3	0,4

Speed (km/h) = 6,4

Measurements made on one field will probably not apply to many other fields. It is thus necessary to divide operations into constituent elements and to measure those field parameters that affect each element of operation independently. The following are examples of the most common elements of fertilization :

- Turning at the end of a row.
- Spreading fertilizer.
- Filling hoppers.
- Travelling to and from filling points.
- Downtime for adjustment or cleaning.
- Rest time.

Any one of these elements can be divided into sub elements if greater definition is needed.

Interpretation

The following points must be taken into consideration when interpreting the data from a time study programme.

Operator rating

Operators must be completely familiar with the equipment and procedures to avoid problems that should not occur in normal practice. The psychological effect on the operator of being watched and timed is difficult to assess. Consequently, the person doing the time study should be absolutely familiar with all aspects of the operation in order to assess the efforts of the operator accurately.

Factors quoted by Curry[1] that affect an operator's ratings are :

Factors outside the worker's control

- Variation in quality or specification of materials used.
- Changes in the operating efficiency of tools or equipment.
- Variations in the mental attention necessary for certain elements of the work.

Factors dependent on the worker

- Variation in the quality of work.
- The degree to which the worker is suited and accustomed to his work. This is determined not only by his physical and mental faculties, but also by training, skill and knowledge.
- The attitude of the worker to his task, the opinion he holds of supervisors, and other psychological factors.

Relaxation and contingency allowances

It is unrealistic to expect people to work at 100% of their capacity for any prolonged period of time. Table 2 is a list of some of the suggested relaxation times that should be allowed if maximum productivity is to be attained.

TABLE 2
Suggested relaxation time as a percentage of total working time

Factors	Typical example	Allowance %
A Energy output (Time needed for muscular recovery)		
1 Light	Light shovelling (10 kg)	7,5 - 12
2 Medium	Hacksaw or filing	12 - 19
3 Heavy	Swing heavy hammer 2–10kg	19 - 30
4 Very heavy ..	Loading weights	30 - 50
5 Exceptional ..	Loading heavy sacks	50
B Posture		
1 Sit	Normal sedentary work	0
2 Stand (both feet)	Whenever body is erect	1 - 2
3 Stand (one foot)	Using a foot control	2 - 4
4 Crouching ..	Lifting object from ground level	4 - 10
C Thermal conditions		
1 Normal	17 - 24°C	0
2 High	24 - 35°C	0 - 40
3 Excessive	35°C	40

These factors are additive and should be taken into account in time studies. They provide a measure against which to assess observed relaxation time.

The effect of field shape

A time study done on a particular field is not necessarily applicable to other fields unless the other fields require the same proportion of time for each operation. Consequently one cannot express results on a whole field basis. Times measured in field A are not likely to apply in field B.

Field characteristics that affect operating times for fertilization are :

- The number of tractor turns per hectare.
- The distance travelled to fill hoppers.
- The effect of conditions in the field on speed of operation and quality of result. This includes the slope of the field.

Results

The elements required to describe the operations have been timed in such a way that the results of these studies can be used to predict the performance to be expected from equipment operating in other situations. Elements which take place at an unpredictable frequency, such as downtime, are expressed as a percentage of total time. For example, if time measured, excluding downtime, is 150 minutes and downtime represents 20% of total time, then total time is :

$$\frac{100}{100 - 20} \text{ x } 150 = 187{,}5 \text{ minutes.}$$

The procedures followed to provide the information given for fertilization as an example, were used to study a wide range of other field operations, and these are listed in Table 3.

Table 3 is a list of elements of work and the time required to complete each element.

TABLE 3
Time required to execute elements of various operations

Operation \ Element	Speed (km/hour)	Time spent turning (min)	Time spent refilling (min)	Travel to and from refilling (%)	Hitching and unhitching trailers (min)	Travel between trailers (min)	Downtime (%)	Comments
Plough mouldboard (shallow)	4,8	0,4	—	—	—	—	5	0,85m width of cut (150 mm deep)
Plough conveniently	5,0	0,4	—	—	—	—	5	1,00 m width of cut (260 mm deep)
Disc harrow (1st or 2nd pass)	6,7	0,4	—	—	—	—	6	
Disc harrow (Final pass)	7,2	0,4	—	—	—	—	4	
Spray herbicides (pre-emergence) ..	4,7	0,3	8,0	8,0	—	—	12	Boom sprayer
Spray herbicides (post-emergence) ..	4,2	0,4	8,0	8,0	—	—	12	Boom sprayer fitted with six hand held lances
Fertilizer spreader (mounted)	5,6	0,4	3,0	23	—	—	10	Filled by 0,5 ton bags
Fertilizer spreader (semi-mounted ..	6,3	0,4	2,2	23	—	—	10	Filled by 0,5 tons bags
Fertilizer spreader (semi-mounted) ..	6,3	0,4	9,0	23	—	—	10	Filled by hand
Midway cane cutter	3,3	0,4	—	—	—	—	4	
Tractor and two trailers hauling cane	19	—	1,5*	—	1,3	1,0	19†	† Includes time waiting for next trailer to be completely loaded * Unloading
Planting	2,6 2,6	0,6 0,6	3,3 42%‡	— —	— —	— —	4 4	‡ The planter does not fill when empty but when most convenient

Table 4 is a list of the percentage of total time spent on executing each element of the operation.

Interpretation of data such as those in Table 4 must be done carefully. For example, during planting the planter only plants 48% of the time and travels at a speed of 2,6 km/h (from Table 3). If the machine were modified to travel 5 km/h, the time spent actually planting would be halved. If it took 20 hours to plant an area of cane, 9,6 (0,48 x 20) hours would be spent with the planter placing seed in the furrow, if it travelled at 2,6 km/h. At 5 km/h the actual planting time would have been only 5 hours and the figures in Table 4 would be as shown in Table 5.

These data appear to be worse than those in Table 4 but in fact indicate greater efficiency. This type of consideration illustrates why time study data should be interpreted with caution.

Prediction

A combination of time study results and field measurements has been used to develop a model to predict the time required to complete an operation. In order to check predictions at the La Mercy farm all tractors have been fitted with electronic hour meters to record the total time the tractor engine runs. A log book system to measure the time spent travelling from field to homestead or from field to field has been developed. Consequently the total time required to complete an operation in a field can be measured.

The following measurements are needed to predict field time :

- The number of times the tractor will have to turn to complete the field, the field area and the row spacing. For example, if a field is 5 ha in extent and consists of 165 lines (33 lines/ha, an average of 201 m long) and the implement applying fertilizer covers three lines on every pass, then $\frac{165}{3} = 55$ implement passes

would be required with 55 tractor turns.

- The hopper capacity and the application rates must be known.

The number of times the hopper will need to be filled (N) is given by :

$$N = \frac{\text{application rate x area}}{\text{hopper capacity}}$$

$$\text{eg} \quad \frac{450 \text{ kg/ha x 5 ha}}{1\,000 \text{ kg}} = 2{,}25.$$

or three fillings.

TABLE 4

Percentage of total time spent on each element of various operations

Operation \ Element	Operating	Turning	Refilling	Travel to and from refilling	Hitch and unhitch trailers	Travel between trailers	Downtime	Comments
Ploughing	83	15	—	—	—	—	2	
Disc harrowing	78	16	—	—	—	—	6	
Spraying Pre-emergence	52	8	16	10	—	—	14	
Spraying Post-emergence	51	14	16	8	—	—	11	
Spreading fertilizer	39	23	1	31	—	—	6	Filled by 0,5 ton bags
Spreading fertilizer	49	16	21	6	—	—	8	Filled by hand using 50 kg bags
Planting	48	8	40	—	—	—	4	
Midway cutter	85	9	—	—	—	—	6	
One tractor and two trailers hauling	51	—	10*	—	9	7	23†	* Unload † Includes handling chains
One tractor and one trailer hauling	30	—	28*	—	12**	23‡	7	Meyer & Worlock[2] * Loading ** Unloading ‡ Chain handling

TABLE 5

Percentage distribution of time when planting with a machine travelling at 5 km/hour

Operation \ Element (%age of time)	Operating	Turning	Refilling	Downtime	Comments
Planting	32	10	52	6	Speed increased to 5 km/hour

The vehicle travels at 6,3 km/h with a total distance of 55 x 201 m = 11,0 km.

$$\text{The total time spent spreading} = \frac{11,0}{6,3} = 1,75 \text{ hours.}$$

$$\text{Total time spent turning} = \frac{55 \times 0,4}{60} = 0,37 \text{ hours}$$ (0,4 min. per turn from Table 3).

$$\text{Total time spent filling} = \frac{3 \times 9,0}{60} = 0,45 \text{ hours}$$ (9,0 min. filling time from Table 3).

Total time excluding downtime and time to travel to and from refilling base 2,57 hours.

Downtime	10%
Travel to and from refilling	23%
Total additional time	33%

$$\text{Therefore total time required is } \frac{2,57}{100 - 33} \times 100 = 3.84 \text{ hours}$$

This type of prediction has been made for a number of fields and operations and the comparisons of measured and predicted times are shown in Table 6.

Although some predictions in Table 6 differ from the measured results by as much as 38%, the mean deviation is only −3,3% and the standard error is 20%, implying that most predictions were within 20% of the truth.

Conclusion

The results of time studies have been used to predict the time required per field per operation. The predictions are within 20% of the measured time and this difference probably arises from inconsistent operator performance and associated problems. Time study has been shown to be a reliable method for measuring the performance of equipment for budgeting and setting performance standards.

REFERENCES

1. Curry, R. M. (1963). Work study. London: Pitman.
2. Meyer, E. and Worlock, B. (1979). Experiences with mechanized cane production systems at La Mercy. *SASTA Proc.* **53**: 143-146.

TABLE 6

Comparison of measured with predicted performance

Operation	Field No.	No. of rows	Area (ha)	Turn time (min)	Refill time (min)	Operating time (min)	Total predicted time (min)	Measured total time (min)	Deviation of predicted from measured, %
Ploughing 1st pass	301	611	8,0	351	—	1 164	1 515	1 585	— 4
	409	100	3,0	57	—	436	516	626	—18
	412	67	2,2	38	—	319	375	341	+ 10
Discing (1st or 2nd pass)	301	611	8,0	192	—	324	540	576	— 6
	412	67	2,2	21	—	89	115	150	—23
	501	101	2,6	32	—	106	137	156	—12
Discing (final pass)	301	611	8,0	171	—	349	542	624	—13
	501	101	2,6	28	—	113	147	125	+ 18
	503	122	5,5	34	—	240	285	462	—38
Planting	602	201	1,6	159	149*	246	630	990	—36
					340†		745		—25
Spray application (boom sprayer)	406	49	3,7	3	24	63	114	104	+ 10
Spray application (sprayer fitted with hand held lances	605	194	5,7	10	23	77	151	194	—22
	506	125	2,8	7	16	38	82	69	+ 20
Fertilizer application with a semi-mounted implement loaded by hand	506	125	2,8	10	9	27	63	55	+ 15
	508	126	2,0	10	9	19	52	45	+ 16
Fertilizer application with a semi-mounted implement loaded by ½ ton bags	606	145	2,7	12	1	26	53	46	+ 16
	601	202	5,0	16	2	48	90	78	+ 15
Fertilizer application with a mounted implement loaded by ½ ton bags	301	534	7,0	48	14	125	225	196	+ 15

* estimated on the basis that 8 t/ha of seed was used, the machine having a capacity of 300 kg and each loading took 5,5 mins.
† estimates from observations that 42% of total time is spent loading the planter.