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A STATISTICAL ANALYSIS OF SOME OF THE CAUSES OF TIMED VARIANCE IN STOP WATCH TIME STUDY

12T

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ABSTRACT

One of the causes of random variation in observed element times in stop watch time study is timed variation. Timed variation is due to a host of chance happenings in observed performance. Each of these chance happenings is so minor by itself that it is accepted as normal and is often not even detected. These may arise from fortuitous variations in the methods, materials, operator performance, etc. The objective of this thesis was to evaluate the effect, if any, on the timed variance of the length of an element and its complexity.

From data obtained in a factory, the variance in the observed times and the average length of each element were calculated. Tables of secondary adjustment values were used in evaluating the complexity of each element.

The single, multiple and partial correlation coefficients between the three variables were calculated and tested for significance. There was no evidence of a relationship existing between the timed variance and the length of the element, but the correlation between the timed variance and the element complexity was, statistically, highly significant. However, this significant relationship between the timed variance and element complexity would have to be investigated further before any definite statement about it could be made, since the range of values of element complexity applicable to the elements used in this study, was limited.

CHAPTER I

INTRODUCTION

Time study has been defined as a procedure for determining the amount of time required, under certain standard conditions of measurement, for tasks involving some human activity (1). However, even in the most carefully controlled situations, completely standardized conditions of measurement cannot be obtained. One approach to reducing the amount of human judgment, and as a consequence the human error, in work measurement has been the development of synthesized time standards. These synthesized time standards may remove the error involved in the practice of rating, but their final accuracy is still a function of the accuracy of the time studies used to compile them, and within every time study there is random variation in the element times due to departures from the standard conditions.

This variation may be due to chance variability or assignable variability, the assignable variability being caused by some circumstances which are noticeable, like fumbles, change in operator's method, etc. The effects of the assignable variability can be eliminated from the study before using the data for setting standards. The chance variability may be considered to be due to either timing variation or timed variation: the timing variation is a characteristic of the timing device used (2), while the timed variation has been defined in the following words (3):

> Timed variation is due to a host of chance happenings in observed performance. Each of these chance happenings is so minor by itself that it is accepted as normal and is often not even detected. These may arise from fortuitous variations in the methods, materials, equipment, performance, tools, workplace layout, operator actions, etc.

This paper is an attempt to examine and evaluate statistically some of the factors causing this timed variation in time studies. More specifically, the causes of timed variation which were studied were: the random variations in the element lengths and the random variations in the element complexities.

CHAPTER II

LITERATURE SURVEY

In time study practice, it is usual to get a number of different observed times for the same element or group of elements. Even after eliminating those times which were affected by some noticeable occurrence such as change in operator pace or method, missed time, fumble, etc., there are still variations in the times considered valid in the study.

There are different opinions amongst various authors as to the procedure which should be followed to determine the 'best' time for an element from data of this nature. Lowry, Maynard and Stegemerten (4) advocated discarding abnormal readings, that is, "ones which are extremely high or low and hence easy to pick out". Another author, attempting to be more specific, suggests that all readings that vary by more than twenty-five per cent from the average reading must be discarded (5).

However, this viewpoint that unusually high or low readings should be eliminated from the study is not adhered to by all who write on the topic. Presgrave (6) says that, "any recording that is beyond the normal range cannot be ignored with safety, in spite of the common practice of discarding extremes". He continues by saying that unusually low timings are especially open to conjecture, since they may provide the key to the whole study. Abruzzi (7) also suggests that it is bad practice to eliminate unusual element times arbitrarily. He states:

> No empirical justification exists for discarding readings merely because of their magnitude, especially in the indiscriminate manner recommended in so many texts. In fact, this is likely to degenerate into a completely arbitrary procedure, whose sole apparent function is to reduce the variability of the readings arbitrarily. The only safe procedure, then, is to discard a reading only when it is known to be biased because of some specific occurrence during the time study.

Mundel (8) does not regard element times which seem too high or low as abnormal. Instead, it is his opinion that we must invariably expect some variation from reading to reading for any element, even if the worker is not attempting to vary his pace. He suggests that this variation will be caused by, among other causes, the following:

Random variations in operator movement and pace.

Random variations in the positions of the parts worked with.

Random variations in the positions of the tools used.

Random variations in the slight errors in watch reading.

The variation in the errors in watch reading has been studied by Lazarus (9). He found that the timing variation using the decimal-minute stop watch, had a standard deviation of approximately 0·008 minutes for either the snap-back or continuous method of timing. As an estimate of the timed variation caused by a host of chance happenings in observed performance, Lehrer and Moder (10) assumed, as a first approach, that the timed variation is of approximately the same magnitude as the timing variation. This assumption was qualified in the following way:

> The assumption of timed variation being equal to timed variation may not be absolutely correct. There is strong evidence to indicate that timed variation may be a function of the characteristics of the work being performed, the operator being observed, and the organization where the work and observation take place.

In summarizing the writings on the subject of variability in element times, it appears that the proper way to consider and allow for this variability has not yet been conclusively determined. To the writer's knowledge, no experimental work has been done as yet, with the object of determining and evaluating some of the causes of the timed variation in elemental stop watch study.

CHAPTER III

PROCEDURE

Stop watch data actually being used in the setting of standards for wage payment were obtained from a factory. This procedure had the advantage that the data was obtained under actual operating conditions and may be considered as a representative sample of the type of data which we could normally expect to find in practice. Neither the time study observer who compiled the data used, nor the operator whose performance was observed, knew that the results of the time studies were to be subject to a statistical analysis. The element times used in this study were acceptable to the company concerned as a basis for their standards. The writer could not determine what level of requirements the time studies had to meet to be considered acceptable by the company.

Selection of Data.--Some restrictions were placed on the selection of the data to be used. All operations considered were completely manual and an attempt was made to collect data which had all been compiled by the same time study man while the operations were being performed by the one operator. All the data used was collected from one factory, at similar job locations and under similar working conditions. These restrictions were placed in order to minimize the effects on the observed elemental times which may be due to variations resulting from different observers, operators and working conditions.

The recorded element times were checked, and any which had been affected by an observed assignable cause such as a fumble, or change in method, were eliminated: the remaining times which had no assigned cause of variability were used in the statistical analysis. For each element, the observed times were separated according to the rating factor which the time study man had assigned to each time; that is, all times for an element which had a rating of, say, 110, were grouped together and considered as a sample of observations. The length of each element was taken to be the average of the time values remaining.

In order to evaluate the complexity of the elements it was decided to use Mundel's tables of secondary adjustments (11) as a measure of element complexity. A brief extract of Mundel's explanation of this concept of element complexity is given below:

> Some jobs are more difficult than others, and these job differences will place different limits on the pace possible on each job with a fixed rate of exertion relative to the maximum possible on the job, but they may be objectively evaluated. The method consists of determining the various factors that would make for difficulty in the job, evaluating their effect, and expressing this effect as a secondary adjustment or allowance. The factors affecting job pace are:
>
> 1. Total amount of body involved in the element.
> 2. Foot pedals used during the element.
> 3. Bimanualness of the element.
> 4. Eye-hand co-ordination required to perform the element.
> 5. Handling or sensory requirement of the element.
> 6. Resistance that must be overcome on the element, that is, thrust on levers or weight lifted.

Tables of per cent adjustments for different degrees of each of these factors have been prepared by Mundel, and a copy of these tables is shown in Appendix I. It was decided to exclude classification number six, the weight or thrust factor, from the estimation of element complexity, as the weight or thrust involved in the element was not considered to affect the timed variation in this case.

A description of the elements with their secondary adjustment values is shown in Appendix II. The elements had been timed using the snap-back method with a decimal-minute stop watch, and these times are tabulated in Appendix III. Appendix III also includes a table of the total variance and the timed variance in the times for each element.

CHAPTER IV

STATISTICAL TECHNIQUES USED IN ANALYZING THE DATA

The total variance in the times for each element was calculated from the following equation:

$$\sigma^2_{total} = \frac{t^2 - n(\bar{t})^2}{n-1}$$

where σ^2_{total} = total variation in element times.

t = individual time values for each element.

n = number of observations for each element.

$\bar{t}$ = average time for each element.

Then the total variance is the sum of the timing variance and the timed variance, assuming that these two are independent.

$$\sigma^2_{timed} = \sigma^2_{total} - \sigma^2_{timing}$$

Since the times had been obtained using a decimal-minute stop watch, the value for the standard deviation was taken as 0.008 minutes (12).

that is,

$$\sigma_{timing} = 0.008 \text{ minutes}$$

$$\sigma^2_{timing} = 0.000064$$

$$\sigma^2_{times} = \sigma^2_{total} \quad — \quad 0.000064$$

The linear correlations between the timed variance and average element length, and between the timed variance and the element complexity were calculated and tested. The linear correlation coefficients were calculated using the equations

$$r_{yx_1} = \frac{N \sum x_1 y - \sum x_1 \sum y}{\left[N \sum x_1^2 - (\sum x_1)^2\right]\left[N \sum y^2 - (\sum y)^2\right]}$$

$$r_{yx_2} = \frac{N \sum x_2 y - \sum x_2 \sum y}{\left[N \sum x_2^2 - (\sum x_2)^2\right]\left[N \sum y^2 - (\sum y)^2\right]}$$

in which y refers to the values of the timed variance, x_1 refers to the average element lengths and x_2 to the element complexity values. N is the total number of elements correlated. To estimate the level at which these coefficients were significant, the t test was used.[1]

---

[1] Croxton, F. E., and Cowden, D. J. Applied General Statistics Prentice-Hall, Inc., p. 681.

The multiple correlation coefficient was calculated from the equation[2]

$$r_{y.x_1x_2} = \sqrt{1 - \frac{R}{R_{yy}}}$$

where

$$R = \begin{vmatrix} r_{yy} & r_{yx_1} & r_{yx_2} \\ r_{x_1y} & r_{x_1x_1} & r_{x_1x_2} \\ r_{x_2y} & r_{x_2x_1} & r_{x_2x_2} \end{vmatrix}$$

and R_{yy} is the minor of r_{yy} in this determinant.

$r_{yy} = r_{x_1x_1} = r_{x_2x_2} = 1$, while $r_{x_1x_2}$ was calculated in the same way as the other zero order coefficients, r_{yx_1} and r_{yx_2}.

The partial correlation coefficient for timed variance and average element length was calculated using the equation

$$r_{yx_1.x_2} = - \frac{R_{yx_1}}{\sqrt{R_{yy} \; R_{x_1x_1}}}$$

[2]Hoel, P. G. Introduction to Mathematical Statistics, John Wiley & Sons, Inc., New York., pp. 110-120.

where R_{yx_1} and $R_{x_1x_1}$ are the cofactors of r_{yx_1} and $r_{x_1x_1}$ in the above determinant.

The partial correlation coefficient for timed variance and element complexity, $r_{yx_2 \cdot x_1}$ was found in a similar manner.

CHAPTER V

RESULTS OF THE ANALYSIS

The correlation coefficients and the probability levels at which they are statistically significant are listed below.

Correlation Coefficient	Value	Significance Level
r_{yx_1}	-0·518	0·06
r_{yx_2}	-0·75	0·01
$r_{y\cdot x_1 x_2}$	-0·804	0·005
$r_{yx_1\cdot x_2}$	-0·435	0·15
$r_{yx_1\cdot x_2}$	-0·72	0·005

where:

r_{yx_1} is the zero order coefficient showing the relationship between timed variance and the variations in element lengths, when the element complexity also varies.

r_{yx_2} is the zero order coefficient showing the relationship between timed variance and the element complexity, when the element lengths also vary.

$r_{y \cdot x_1 x_2}$ is the multiple correlation coefficient showing the relationship between the timed variance and the variations in element lengths and complexities acting together.

$r_{yx_1 \cdot x_2}$ is the partial correlation coefficient showing the relationship which would exist between the timed variance and the element lengths, if the element complexities were held constant at their mean value.

$r_{yx_2 \cdot x_1}$ is the partial correlation coefficient showing the relationship which would exist between the timed variance and the element complexities, if the element lengths were held constant at their mean value.

The significance level is the fraction of the time we could expect a sample, drawn from a population with zero correlation, to give a correlation coefficient as high as that actually obtained.

From the values of r_{yx_1}, r_{yx_2}, and $r_{y \cdot x_1 x_2}$ there seems to be a significant relationship existing between:

1. Timed variance and average element length.
2. Timed variance and element complexity.
3. Timed variance and the average element length and complexity when these are acting jointly.

However, the simple correlation coefficient between any two of the variables does not give the true relationship between them. A better estimate of the true relationship between them is the partial correlation coefficient, in which the third variable is held fixed at its mean value.

The partial correlation coefficient $r_{yx_1.x_2}$ has a value of -0·435 which is only significant at the 0·15 level, so this analysis does not prove that a definite relationship exists between the timed variance and the average length of the element. In order to test further the effect, if any, of the average element length on the timed variation, the linear correlation coefficient was calculated for those points which have a common value for their element complexity. There are ten points which have a complexity value of seven and the linear correlation coefficient for these ten values of timed variance and element length was calculated to be -0·427. This is statistically significant only at the 0·25 level; thus again there is no evidence of any relationship between the timed variation and the length of the element.

The partial correlation coefficient $r_{yx_1.x_2}$ has a value of -0·72 with a significance level of 0·005. This would suggest that the timed variance and the element complexity are interdependent. However, this coefficient can only be interpreted rather cautiously as a measure of the relationship because of the limited range of the values for element complexity applicable in this study. The total range of secondary adjustment values which could be applied to various elements is 0 - 28, but the nature of the elements studied here only gave values of five, six and seven. This is such a small part of the total range that no general conclusion can be drawn.

CHAPTER VI

COMMENTS AND CONCLUSIONS

Certain limitations must be placed on any conclusions drawn from this study, mainly because of the difficulty in collecting data and the type of data collected. As stated, the procedure was to collect data compiled by one time study observer from manual operations being done by one operator. The amount of such data available was limited, and had been collected over a period of two years, so that the experience of the observer and operator had increased, with a probably increase in ability of both. This may have introduced extra variables of which no account was taken in the analysis.

Also, while using data from a factory had the advantage that it could be considered a representative sample of the type of data normally obtained under working conditions, it had the disadvantage that some variable factors affecting the data may not have been considered worthy of note by the time study observer. In other words, we do not know all the facts about the conditions prevailing when each of the studies were made. These external unrecorded variable conditions, if any existed, could probably have been better controlled if the time studies had been performed under experimental conditions. Furthermore, in an experiment, more data covering a greater range of values could have been compiled, resulting in a more conclusive statistical analysis; there would then be difficulty though, in ascertaining the extent to which the results from a controlled experiment were related to the corresponding results that would be obtained from actual operating conditions.

To consider the type of data collected, for each element a histogram was prepared showing the distribution of the varying observed times. These histograms are shown in Figs. 1, 2, 3 and 4. If each group of recordings had been affected by only minute random variations in the method, pace, etc., a normal distribution of element times symmetrical about the mean value might reasonably have been expected; these histograms seem to show that a degree of inconsistency existed, since none of them resemble the typical normal distribution. This suggests that an undue variation in conditions was present from the point of view of obtaining statistically stable data, but these variations must have been acceptable to the company concerned. As was stated previously, the writer had no way of evaluating what level of conditions was regarded by the company as standard. Elements numbers three and twelve in the study particularly give histograms which suggest that variable conditions existed without being noted by the time study observer. But although these histograms show a measure of inconsistency, the values for these elements were not excluded from the present study as this is an analysis of typical samples of time study data acceptable under normal operating conditions.

One set of values that was excluded from the statistical analysis was that of element number seven. In this case the total variance was 0·00003 minutes, which is less than the typical timing variance value of 0·000064 minutes. The reason suggested for this occurrence is that the average length of this element was 0·026 minutes, which is below the recommended minimum element length of 0·04 minutes measurable with a decimal minute stop watch. Elements shorter than 0·04 minutes are measurable with the decimal minute stop watch only at a sacrifice of accuracy and reliability. There is no evidence that the timing variance value of 0·000064 minutes applies to such a short element, so it was decided to exclude this element from the statistical analysis.

Although the element complexity seemed to have a highly significant correlation with the timed variance, this correlation must be regarded cautiously because of the limited range of the values and also because of the technique used to measure the complexity of the elements. Mundel's secondary adjustments are a measure of the difficulty of an element, not its complexity; even if the secondary adjustments did give a measure of the complexity of an element, the work of developing these secondary adjustments is, in Mundel's words, 'by no means complete (13)'. However, the use of secondary adjustments in this study is justified by expediency, since no other technique for measuring element complexity exists to the knowledge of the writer. This means of evaluating element complexity, crude as it may be, is more reliable than any mental evaluation, which would be purely subjective.

The use of the modal value as a measure of the true element length may be a better estimate than the arithmetical average element length in the case of elements which have isolated values or a wide range of values, for example, element number three; but figs. 2, 4 and 5 show that there would have been difficulty in selecting the modal values for elements numbered four, five, thirteen and fifteen. To achieve consistency in method, the arithmetical average element length was used in all cases as a measure of the true element length.

The calculation of a linear correlation coefficient is based on the "method of least squares", which gives undue weight to isolated values. Fig. 6 shows that element number fifteen, with an average length of 0·4313 minutes is one such isolated value. To counteract the excess effect of this one point, some elements would be required which have an average length in the range 0·25 minutes to 0·40 minutes; but data of this nature was not available under the other limitations placed on the type of data used.

One other factor which was not taken into consideration is the possibility of the elements in a cycle of operations not being independent. Since the assumption in this study was that the element times were independent of the other elements in the study, there may have been an effect of unknown magniture introduced into the data. This may account for part of the timed variation.

With reference to the tentative assumption of Lehrer and Moder, previously mentioned in Chapter II, that the timed variation has a standard deviation of approximately 0·008 minutes, the timed variations of the elements in this study are much greater. The following table shows the range of values of the standard deviations of the timed variations in this study.

Timed Variation	Variance	Standard Deviation
Lowest value	0.000144	0.012
Highest value	0.001161	0.034
Average value	0.000527	0.023

This table indicates that an assumed standard deviation of 0.008 minutes for the timed variance would have been too low for the elements in this study. Hence the curves developed by Lehrer and Moder giving an estimate of the number of cycles to be observed to obtain accurate element times, would have given too low a value for the number of cycles to be timed. These curves had been developed on the assumption that the timed variation had a standard deviation of 0.008 minutes.

In brief summary of this analysis, it has been shown that the timed variation for the range and type of elements studied has a standard deviation which is in excess of 0.008 minutes; no relationship could be shown to exist between this timed variance and the lengths of the elements being studied. Statistically, a highly significant relationship existed between the timed variance and the complexity of the elements studied. But, as stated previously, when attempting to interpret this relationship, some highly restrictive reservations must be remembered.

CHAPTER VII

RECOMMENDATIONS

In this study, the standard deviation of the timed variation in the observed element times varied from 0.012 to 0.034 minutes. Since the timing variation has a typical standard deviation estimated at only 0.008 minutes, it would appear that in order to more fully understand the nature of variation in time study data, research should be concentrated on the timed variation rather than on the timing variation.

One of the results of this analysis was, that as the complexity of the element increases, the timed variation decreases. In order to investigate this rather unexpected result, perhaps some controlled experiments should be conducted. A controlled experiment may show that the negative correlation between the timed variation and the complexity of the elements in this study was due to the effect of some variable condition which was unrecorded when the data was collected.

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APPENDIX I

Table 1. Mundel's Secondary Adjustments for Time Studies

Category No.	Description	Condition	Per Cent Adjustment
1	Amount of body used	Fingers used.	0
		Wrist and fingers.	1
		Elbow, wrist and fingers.	2
		Arm, etc.,	5
		Trunk, etc.	8
2	Foot pedals	No pedals or one pedal with fulcrum under foot.	0
		Pedals or pedals with fulcrum outside foot.	5
3	Bimanualness	Hands help each other.	0
		Hands work simultaneously.	10
4	Eye-hand coordination	Rough work.	0
		Moderate vision.	2
		Constant but not close	4
		Fairly close	7
		Within 1/64"	10

Table 1. Mundel's Secondary Adjustments for Time Studies (Con't)

Category No.	Description	Condition	Per Cent Adjustment
5	Handling Requirements.	Can be handled roughly.	0
		Only gross control.	1
		Must be controlled but may be squeezed.	2
		Handle carefully.	3
		Fragile.	5

APPENDIX II

ELEMENTARY DESCRIPTIONS AND SECONDARY ADJUSTMENT VALUES

The general description of the operations from which the elements were taken is:

Bundles of shirt parts such as collars, cuffs and gussets, were picked up from a storage bench, placed on a work bench, tied into lots of 120 dozen with tapes and then placed aside in a stack.

Element No. 1. Position 6 tapes on table.

Left Hand	Right Hand	Sec. Adj.
Hold tapes and assist right hand.	Grasp end of one tape.	
	Spread tape on table.	5
	Release tape.	

Repeat six times.

Next, the bundles of collars were picked up from the storage bench, positioned on the tapes and the tapes tied round each bundle. The times for these were considered to be unsuitable for this analysis due to wide variability in the rating factors used.

Element No. 2. Aside bundle of collars.

Left Hand	Right Hand	Sec. Adj.
Grasp bundle.		
Carry to stack.	Same as left hand.	6
Drop bundle on stack.		

Element No. 3. Position 2 tapes on bench.

Left Hand	Right Hand	Sec. Adj.
Holding tapes.	Grasp end of 1 tape.	
Assist right hand.	Spread tape on table.	5
	Release tape.	
	Repeat with second tape, placing it across the first.	

Element No. 4. Get bundles of pockets and place on tapes.

Left Hand	Right Hand	Sec. Adj.
Pick up bundle of 120 dozen pockets.		
Place on tapes.	Same as left hand.	7
Adjust position on tapes.		

Element No. 5. Tie first tape.

Left Hand	Right Hand	Sec. Adj.
Grasp tape end.		
Lead end around bundle to top of bundle.	Same as Left Hand.	
Tie knot while pressing down on bundle.		7

Element No. 6. Tie second tape.

Same as Element No. 5.

Element No. 7. Aside bundle of pockets.

Same as Element No. 2.

Element No. 8. Position 2 tapes on bench.

Left Hand	Right Hand	Sec. Adj.
Holding tapes.	Grasp end of 1 tape.	
Assist right hand.	Spread tape on table.	
	Release tape.	5
	Repeat with second tape, placing it alongside the first.	

Element No. 9. Get bundles of gussets and place on tapes.

Same as Element No. 4.

Element No. 10. Tie first tape around bundle of gussets.

Same as Element No. 5.

Element No. 11. Tie second tape.

Same as Element No. 5.

Element No. 12. Aside bundles of gussets.

Same as Element No. 2.

Element No. 13. Tie bundles of shirt fronts and slide aside.

Left Hand	Right Hand	Sec. Adj.
Grasp tape end.	Same as left hand	
Lead end around bundle to top of bundle.		7
Tie knot while pressing down on bundle.		
Push bundle to stack on left.		

Element No. 14. Tie bundles of cuffs.

Same as element No. 5.

Element No. 15. Tie bundle of collars and turn over.

Left Hand	Right Hand	Sec. Adj.
Grasp tape end.	Same as left hand.	
Lead end around bundle to top of bundle.		7
Tie knot.		
Turn bundle over 180°.	Assist left hand.	

APPENDIX III

Table 2. Observed Times in Decimal Minutes for Element Number 1, Rated at 110

Times			
.13	.12	.18	.17
.15	.15	.18	.19
.11	.20	.15	.16
.16		.14	

Table 3. Observed Times in Decimal Minutes for Element Number 2, Rated at 110

Times			
.19	.19	.21	.21
.17	.21	.17	.19
.17	.17	.17	.20
.17	.25	.16	.19
.18	.23	.23	

Table 4. Observed Times in Decimal Minutes for Element Number 3, Rated at 110

Times			
.08	.06	.09	.06
.11	.10	.09	.20
.08	.09	.09	.15
.09	.09	.08	.09
.13	.13	.13	.14
.09	.09		

Table 5. Observed Times in Decimal Minutes for Element Number 4, Rated at 110

Times			
.15	.17	.15	.14
.17	.11	.16	.14
.16	.15	.15	.17
.15	.16	.17	.17
.18	.18	.20	.16
.19	.18		

Table 6. Observed Times in Decimal Minutes for Element Number 5, Rated at 120

Times			
.16	.13	.13	.10
.17	.17	.11	.09
.15	.11	.15	.15
.12	.12	.11	.13

Table 7. Observed Times in Decimal Minutes for Element Number 6, Rated at 110

Times			
.12	.09	.15	.13
.11	.12	.10	.10
.15	.14	.10	.13
.12	.12	.18	.13
.12	.13	.11	.10
.14	.11		

Table 8. Observed Times in Decimal Minutes for Element Number 7, Rated at 115

Times			
.03	.02	.03	.02
.03	.03	.02	.02
.02	.02	.02	.02
.02	.02	.03	.03
.03	.03	.03	.04
.02	.03	.02	.03

Table 9. Observed Times in Decimal Minutes for Element Number 8, Rated at 110

Times			
.09	.08	.08	.12
.07	.10	.15	.07
.09	.10	.10	.14
.07	.10	.16	.09
.07	.09	.10	.10
.09	.11	.12	.09
.08	.10	.10	.10
.12	.10	.12	.13
.11	.07	.09	.17
.14	.10	.09	.13
.07	.08	.06	.12
.08	.10	.11	.09
.11	.09	.10	.08
.09			

Table 10. Observed Times in Decimal Minutes for Element Number 9, Rated at 120

Times			
.29	.25	.32	.27
.26	.25	.27	.29
.27	.28	.29	.28
.27	.30		

Table 11. Observed Times in Decimal Minutes for Element Number 10, Rated at 110

Times					
.16	.19	.19	.20	.17	.20
.19	.19	.15	.15	.22	.15
.21	.18	.17	.19	.20	.16
.21	.18	.17	.20	.22	.18
.20	.18	.18	.15	.15	.19
.17	.17	.16	.20	.21	.15
.21	.18	.17	.16	.17	.24
.18	.22	.18	.19	.17	.18
.19	.20	.15	.19	.19	

Table 12. Observed Times in Decimal Minutes for Element Number 11, Rated at 110

Times					
.18	.18	.13	.19	.16	.17
.12	.21	.14	.16	.17	.13
.15	.12	.18	.16	.13	.13
.11	.15	.11	.13	.15	.14
.16	.12				

Table 13. Observed Times in Decimal Minutes for Element Number 12, Rated at 110

Times					
.05	.05	.05	.04	.04	.04
.16	.08	.03	.06	.06	.03
.10	.04	.04	.04	.04	.05
.05	.04	.04	.05	.06	.03
.04	.07	.05	.04	.05	.08
.05	.05	.06	.08	.03	.04
.05	.04	.03	.15	.04	.04
.05	.04	.04	.04	.04	.05
.06	.03	.04	.04	.04	.05
.05	.03	.03	.03	.04	.04
.05	.04	.04	.05	.03	.05
.03	.03				

Table 14. Observed Times in Decimal Minutes for Element Number 13, Rated at 125

Times				
.21	.20	.24	.15	.17
.20	.19	.19	.22	.18

Table 15. Observed Times in Decimal Minutes for Element Number 14, Rated at 90

Times				
.22	.25	.24	.25	.25
.23	.24	.23	.24	.24
.24	.24	.27	.24	.26
.26	.26	.25	.27	.28
.28	.27	.29	.27	

Table 16. Observed Times in Decimal Minutes for Element Number 15, Rated at 130

Times				
.40	.42	.47	.43	.43
.41	.44	.44	.42	.43
.45	.44	.42	.43	.44
.44	.43	.43	.42	.47
.40	.45	.42	.43	

Table 17. Timed Variance in Minutes, Length in Decimal Minutes, and Complexity Value for Each Element

Element Number	Timed Variance y	Average Element Length, x_1	Complexity x_2
1	0.00062	0.1564	5
2	0.000568	0.1926	6
3	0.000985	0.1027	5
4	0.000314	0.1618	7
5	0.000463	0.1275	7
6	0.000376	0.1227	7
7	Unknown	0.026	7
8	0.001161	0.097	6
9	0.000308	0.2729	5
10	0.000724	0.1832	7
11	0.000144	0.1492	7
12	0.000627	0.0488	7
13	0.000586	0.1950	7
14	0.000253	0.2529	7
15	0.000252	0.4313	7

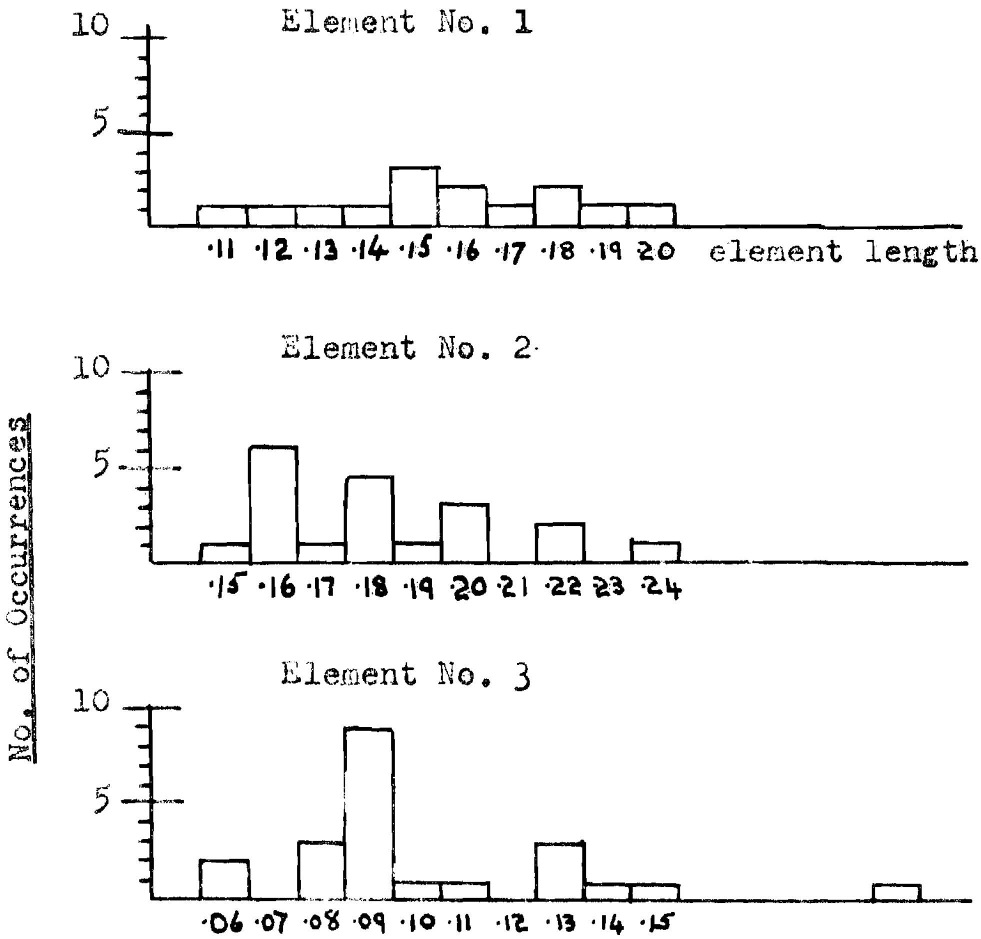


Figure 1. Distributions of Observed Element Times.

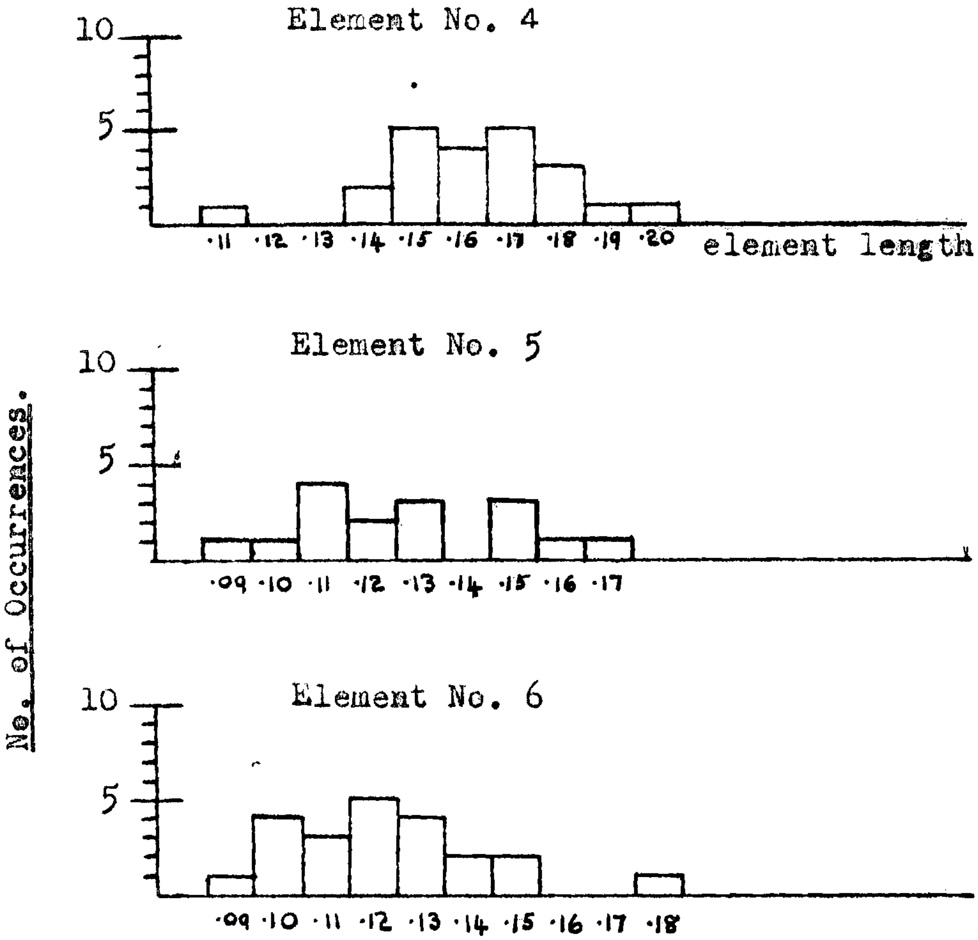


Figure 2. Distributions of Observed Element Times.

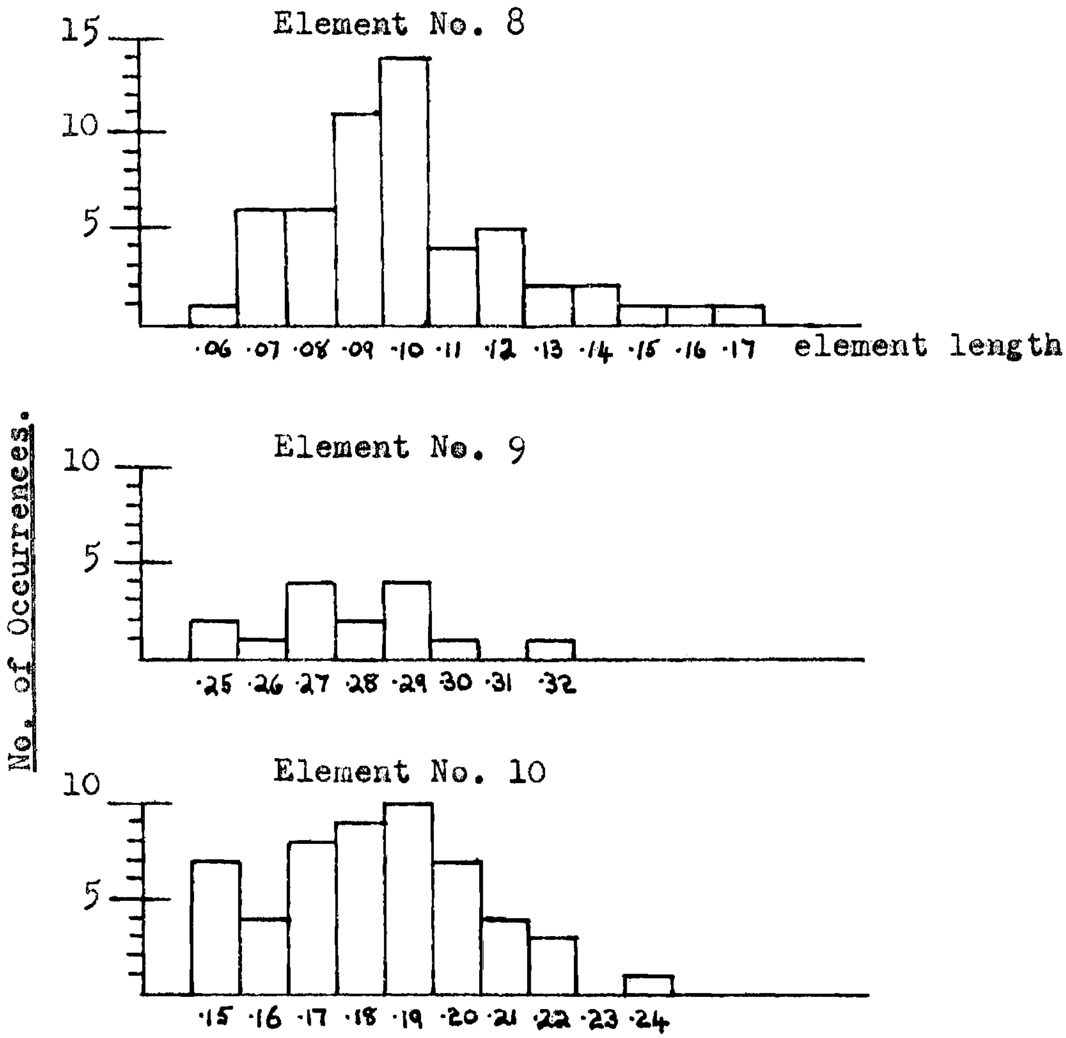


Figure 3. Distributions of Observed Element Times.

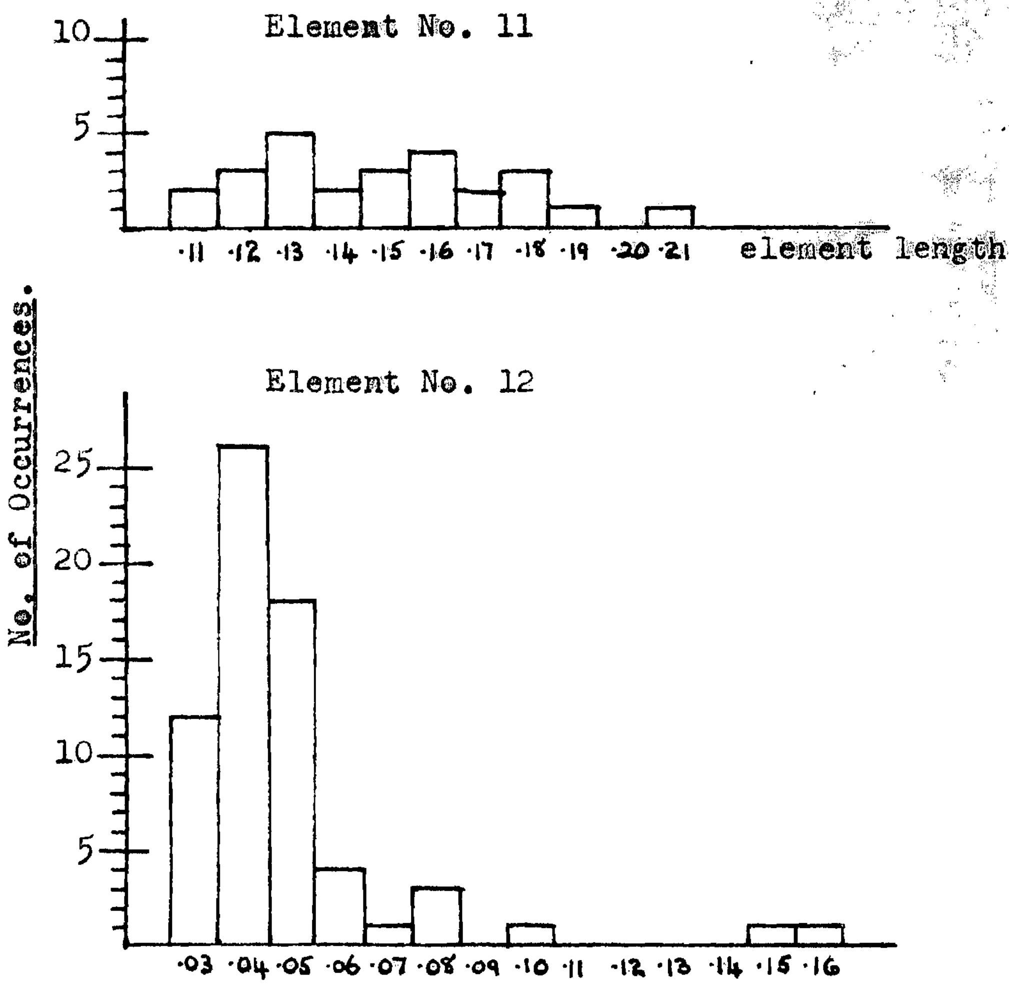


Figure 4. Distributions of Observed Element Times.

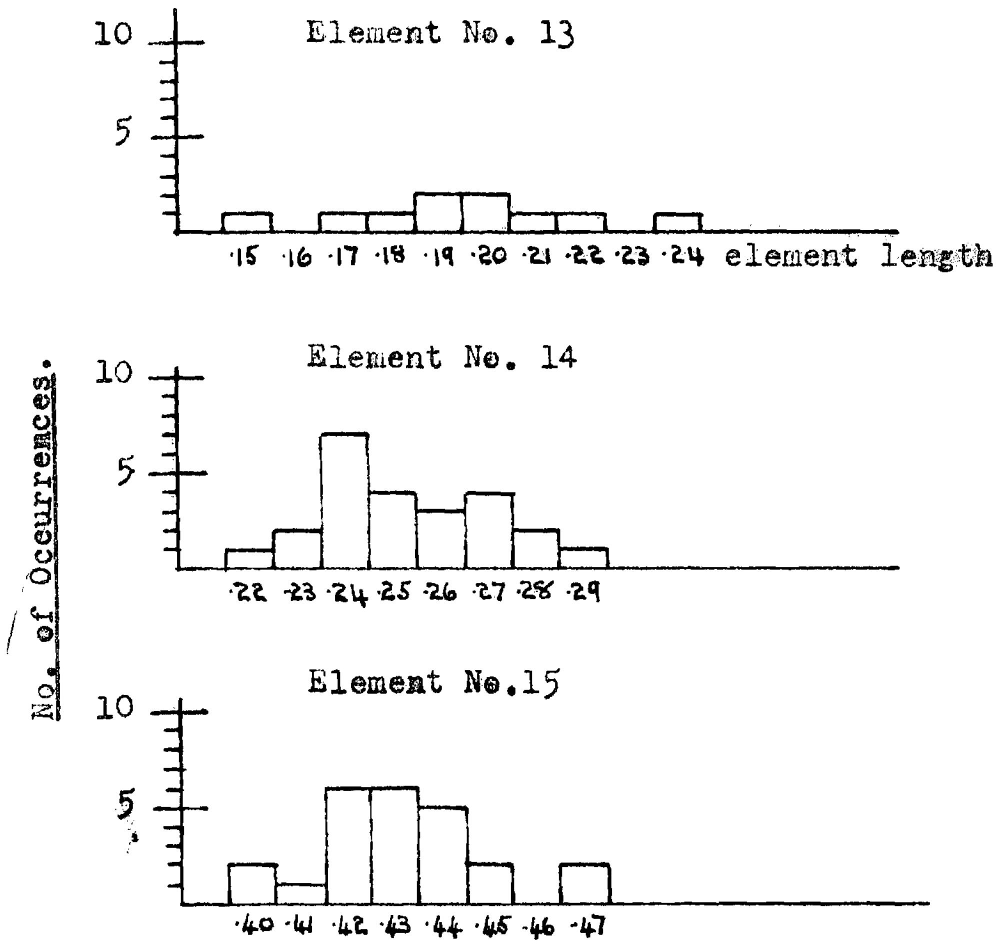
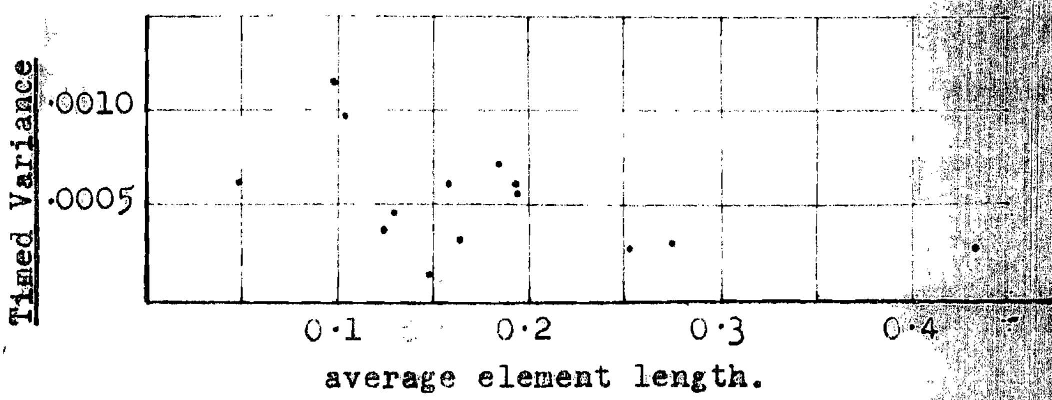


Figure 5. Distributions of Observed Element Times.



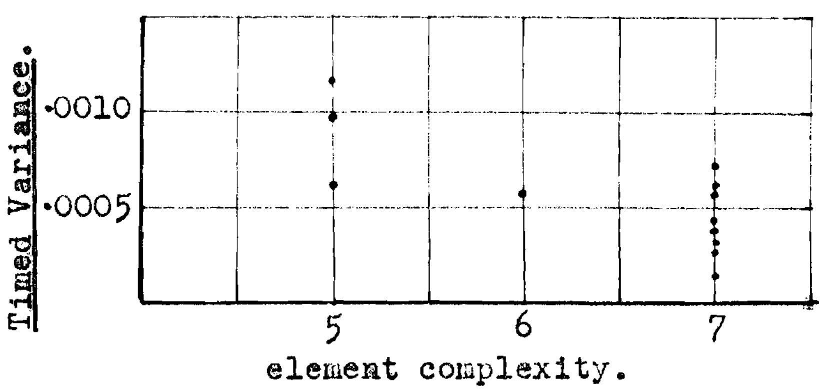


Figure 6. Timed Variance Plotted Against Average length of Element and Complexity of Element.