however, as direct readings might have been. The following quotation from "Shop Management"[35] describes the Barth method:

The writer has found that when some jobs are divided into their proper elements, certain of these elementary operations are so very small in time that it is difficult, if not impossible, to obtain accurate readings on the watch. In such cases, where the work consists of recurring cycles of elementary operations, that is, where a series of elementary operations is repeated over and over again, it is possible to take sets of observations on two or more of the successive elementary operations which occur in regular order, and from the times thus obtained to calculate the time of each element. . . .

If we take a cycle consisting of five (5) elementary operations, a, b, c, d, e, and let observations be taken on three of them at a time, we have the equations:

$$a + b + c = A$$
$$b + c + d = B$$
$$c + d + e = C$$
$$d + e + a = D$$
$$e + a + b = E$$
$$A + B + C + D + E = S.$$

We may solve and obtain:

$$a = A + D - 1/3S$$
$$b = B + E - 1/3S$$
$$c = C + A - 1/3S$$
$$d = D + B - 1/3S$$
$$e = E + C - 1/3S$$

The writer was surprised to find, however, that while in some cases these equations were readily solved, in others they were impossible of solution. My friend, Mr. Carl G. Barth, when the matter was referred to him, soon developed the fact that the number of elements of a cycle which may be observed together is subject to a mathematical law, which is expressed by him as follows:

The number of successive elements observed together must be prime to the total number of elements in the cycle.

Namely, the number of elements in any set must contain no factors; that is, must be divisible by no numbers which are contained in the total number of elements. The following table is, therefore, calculated by Mr. Barth, showing how many operations may be observed together in various cases. The last column gives the number of observations in a set which will lead to the determination of the results with the minimum of labor.

No. of Operations in the Cycle	*No. of Operations that may be observed together*	*No. observed together that leads to a minimum of labor or is otherwise preferable*
3	2	2
4	3	3
5	2, 3, or 4	3 or 4
6	5	5
7	2, 3, 4, 5, or 6	4 or 6
8	3, 5, or 7	5 or 7
9	2, 4, 5, 7, or 8	5 or 8
10	3, 7, or 9	7 or 9
11	2, 3, 4, 5, 6, 7, 8, 9, or 10	5 or 10
12	5, 7, or 11	7 or 11

[35] *Shop Management, op. cit.*, pp. 172-174.

The other advantage claimed for hour decimals has to do solely with calculation of task time. If this were the only purpose of time-study data, the advantage might be considered important. We must not lose sight of the fact, however, that workers are accustomed to thinking of most of the things they do in terms of minutes. As experience has shown, it is important that they be able to check their performance piece by piece on short jobs, or at successive stages on long jobs. Their own time pieces read in hours and minutes and for this reason the instruction card should show items or suboperations in minutes and task time for the entire lot, or job, in hours. Conversion of minutes and decimals thereof into hours is so simple a calculation that it is not a consideration of primary importance. At most it need only be done for each job as it is planned and may be facilitated by the use of slide rules, or preferably by conversion tables. Where work is put through either a number of times at intervals, or continuously, it is common practice to show on the instruction card the time for customary quantities.

Another disadvantage of using decimals of hours is that it requires four decimal places instead of two. This I should not consider serious, however, if other things were equal. In view of the foregoing the minute decimal measurement seems preferable.

One of the commonest faults of time study is the failure to break an operation down into sufficiently fine divisions. A critical study of even the best published illustrations of actual time studies shows that too often several true elements are combined as one for observation. For example, "Get stud from table and place in chuck" is given as one unit. Obviously this is composed of two distinct elements: (1) pick up piece; (2) place in chuck. The next item of this study reads: "Tighten chuck with socket wrench" which might better be stated as four elements: (1) pick up socket wrench; (2) place socket wrench in position to tighten; (3) tighten; (4) return wrench to tool stand.

In another study for machine molding I find as a unit: "Strike off and put cope board in place" which includes three elements: (1) pick up cope board from table at left; (2) strike off cope with edge of board; (3) place cope board in position.

The examples given by Taylor in "Shop Management" show an inconsistency in this respect which is understandable considering the then newness of the art, but which ought not to exist in present-day practice.

As is well known to the experienced, it is difficult to record directly a number of successive elements each of which requires less than .03 minute to perform. In other words, if the time consumed in doing an element is less than the time it takes to write the figures, we must either resort to some means other than pencil and paper for recording or else use the Barth method. To this difficulty may be attributed the tendency to lump together two or more true elements in one observed unit. At this point I should state, however, that in writing instruction cards and setting tasks there is no objection to combining, within reason, several elements which are always performed in the same combination, such as those cited or, for further example, the following: "Put drill and sleeve in spindle"; "Put clamp on work and tighten." We need a term to distinguish such combinations from simple elements. For this purpose I suggest the word "group."

It may safely be stated that the more nearly work to be studied is resolved into true elements, the greater will be the accuracy of the resultant time units, the more readily will irregularities and their causes be detected and the more extensive will be the uses for the results of the studies. For example, if we should observe as a single unit "Put bushing (of a given size) in chuck (on an engine lathe) and set to run true," we should have a time unit that, strictly speaking, might properly be used only in setting a bushing of the size and kind in question in the kind of chuck used and on that particular engine lathe. On the other hand, if this operation were resolved into its true elements we should have data on handling a piece of material of the class and weight to which the bushing belonged, on the use of a wrench of the kind and size used, on stopping and starting the machine, all of which would be applicable to other operations. Picking up and placing the bushing would apply regardless of the chuck used or the machine in which the job was done. Adjusting and tightening the chuck jaws, within certain limits, would apply to the use of the size and kind of chuck, regardless of the dimensions or character of the piece. Starting and stopping the machine to see to what extent the bushing was running out of true would be the same, for the speed in question, on any job, whether that of centering work, cutting, filing or polishing. Placing the implement used for gauging the degree of eccentricity would be the same for any job on which it might be used.

Irregularity in the time required to set the pieces and its causes would be obscured if we treated the complete procedure as the unit being observed. In one observation it might occur in one elementary operation and subsequently in others, and yet the times for the cycle might be reasonably uniform and hence regarded as satisfactory.

The objections to "over-all" time studies of complete jobs or operations are today quite generally recognized and understood. It does not seem to be generally realized, however, that the same objections hold good, though in a diminishing degree, in the timing of suboperations or groups composed of several elements as though they were single units.

It is, of course, impossible to perform a single element repeatedly. For example, if we are to study the picking up of an object, and it is necessary to have a number of observations, each piece must not only be picked up but must be placed somewhere, in order that the next piece may be picked up. For this reason, as well as for the purpose of obtaining uniform smoothness of action, we must observe a number of elements arranged in a natural sequence, as for example: "Start machine and stop machine"; "Pick up scissors, cut material; put down scissors, etc."

Study of Isolated Cycles versus Complete Operations

While, as I have stated, it is impractical to make time studies of individual elements singly, it is highly desirable that the individual unit or elementary time be "net." That is to say, it should not include such things as are covered by the rather loose term "percentage of allowance." Leaving out of consideration any such allowance for fatigue, personal needs of the operator and unforeseen delays, it will be found that a "first-class" operator working efficiently on, say, fifty different elementary operations will consume a longer time than the sum of the standard unit times. The ratio of