An Experiential Exercise in Work Measurement

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Abstract

This paper describes an experiential exercise that addresses a fundamental question in operations - how long should work take? This exercise has been used in management classes to draw out some of complexities involved in answering such a seemingly straightforward question. Results from the exercise, collected from approximately 120 participants, are presented and discussed.

Introduction

This paper describes an experiential exercise that addresses a fundamental question in operations - how long should work take? This inexpensive exercise has been used with both undergraduate and graduate management classes to draw out some of complexities involved in answering such a seemingly straightforward question. The question is an important one. Time standards have many important uses, for example, in planning, as the basis for rewarding work output effort and in benchmarking. Industrial disputes have often hinged on disagreements about productivity that have at their root different ideas about how long work should take.

Historically, the use of time standards has given rise to much controversy, especially their use for repetitive piece work. The aggressive use of time standards for repetitive factory work and the adverse affect on workers' well-being, has been described by a number of writers. Fredrick Taylor, the father of "scientific management" was called before a US congressional tribunal to defend the application of his new work methods (Taylor, 1913 and Dean, 1997). Time standards can be considered as an integral component of job design and there have of course been major developments in job design theory and practice since the development of the industrial engineering approach in early 1900s.

A detailed discussion of the development of job design is beyond the scope of this paper. However, an important learning objective of the exercise is for participants to understand how time standards fit into the larger context of job and work design. Therefore it is desirable that theories leading to a systems view of work, such as the socio-technical perspective (for a contemporary application see Appelbaum, 1997) are discussed in the exercise. It is noteworthy that despite a considerable body of knowledge related to job and work design in areas such as motivation theory, ergonomics and group work, there are still problems emerging with call centres that bear a remarkable similarity to those experienced in the industrial setting of the 1900s mentioned above.

The literature review includes an explanation of the different, and often overlapping, approaches to job design. The concept of a time standard and various ways in which a time standard can be formulated is explained. An Australian example of work on the waterfront that illustrates the complexity that is often involved in deriving and using time standards is presented. Support for the inclusion of experiential exercises in operations management curricula is presented. The methodology provides a detailed explanation of how the exercise is carried out. The results section presents observations and descriptive statistics from data collected from approximately 120 participants over the last few years. This is followed by a discussion of the results, which includes the main point of learning and conclusions.

Literature Review

Basic Approaches to Job Design

The context of this exercise is job design. An operations management view of contemporary approaches to job design can be found in most operations management texts (e.g. Slack, Chambers and Johnston 2004).

The scientific management approach (sometimes called the work study or industrial engineering approach) has its origins in the work of Fredrick Taylor and Frank and Lillian Gilbreth. The work study framework is usually used to

implement this approach. Work study is divided into two related aspects, method study and time study. Method study is a systematic approach to evaluating a new job or improving an existing one. Time study is the process of determining a standard time for the job. Ways of determining a standard time are discussed below.

The ergonomic (or human factors) approach to job design focusses on the relationship between workers and the work environment. Ergonomics covers a surprisingly broad range of issues. Main topic areas include; physical and cognitive aspects of machine-user interface, workplace design and layout, affect of the work environment on human performance, job design, worker selection and training and provision of data on the size, form and performance of humans (Galer, 1998).

The final general approach to job design described here is the behavioural approach. This approach emphasises the importance of worker motivation and worker interaction in the design of jobs and work. It includes ideas such as job enlargement, job enrichment, empowering workers in decision making and various strategies of team working including self-managed teamwork.

Determining a Standard Time for a Job

The time study component of the work study approach explains that a standard time for a job is made up of work content time plus various allowances. A major difficulty in applying this concept is determining what the standard work content time should be for a particular job. This is because of worker variability. Different workers will perform the same tasks at different speeds for a variety of reasons e.g. due to differences in ability, training, motivation etc. Furthermore, the performance of a particular worker doing a manually paced job will vary over time. The ways in which worker variability is dealt with in different approaches to time study in order to arrive at a standard time is explained below. Wild (1983) provides a useful distinction between direct and indirect methods of time measurement. With direct methods a standard time for a job is determined from direct observation and measurement of the worker performing the job. This is the approach used in the exercise described in this paper. Indirect methods of determining a standard time for a job use existing data and do not require observation or timing of actual work. Baines (1995) provides a brief review of work measurement methods. The main methods will now be described.

Time Study Approach

This is a direct approach involving observation of a worker carrying out the job. The job is usually divided into elements. This is because the worker will usually perform different parts of the job at different work speeds due to his/her particular skill mix. Also, dividing a job into elements provides useful data for improving the method. The worker being observed should be properly trained in the job and be using the correct method. The problem of worker variability is addressed by the process of rating the speed of the worker, this allows the observed times to be standardised for the "standard worker". For each element of the job the work analyst, using a stop watch, records the actual time the worker takes and also rates the speed of the worker against the concept of "normal speed". The international Labour Office publication "Introduction to Work Study" (ILO. 1969) provides the following definition of "rating" and "standard performance" that guides the consistency of the rating process:

Rating *is the assessment of the worker's rate of working relative to the observer's concept of the rate corresponding to standard pace.*

Standard performance *is the rate of output which qualified workers will naturally achieve without over-exertion as an average over the working day or shift, provided that they know and adhere to the specified method and provided that they are motivated to apply themselves to their work. This performance is denoted as 100 on the standard rating and performance scales.*

Clearly the work analyst needs to be trained in the skill of rating and this was traditionally carried out by testing rating accuracy using filmed job sequences run at different speeds. After rating the observed times are standardised for the speed of the worker by applying the rating factor. Suitable times for intermittent and miscellaneous work elements are also allocated, usually on a pro-rata basis, to the job content time. The sum of all the standardised work elements of the job constitute the work content component of the standard time (sometimes referred to as the "basic time"). To obtain the standard time a suitable allowance has to be added. Types of allowances are explained below.

It can be appreciated that the process of rating the speed of the worker in order to obtain a standard time using this method is to some extent subjective given that rating is a skill and subject to variability.

Pre-Determined Motion Time Systems (PMTS)

This is an indirect method of determining a standard time for a job. The idea behind the method is that all manual work activities can be divided into basic generic elements, such as "reach" and "grasp". Cognitive work elements can also be included. Arguably, the best known system is MTM (Methods Time Measurement). An early PMTS system was devised by the Gilbreths in which the elements were called THERBLIGS and each was given their own symbol. In order to use the PMTS approach a job must be specified at an appropriate level of detail for the PMTS system being used. Users of PMTS need to be trained in the particular method. The economics of using PMTS also needs to be considered. Depending on the level of accuracy required (some systems offer different options that trade off accuracy against analysis cost) PMTS analysis can be expensive. One advantage of using PMTS is that the times are standardised thus negating the need for rating to be used. However, analysts using PMTS systems would need to be aware of the rating standard used.

Other Indirect Methods

Two other indirect methods of determining a time for a job are worthy of mention, these are synthetic times and analytical estimating. Synthetic times are usually associated with work in a particular industry e.g. the sewing industry. Synthetic times are compiled for specific work elements related to work in the industry. A time for a particular job is compiled from the times of synthetic time elements that make up the job. Analytical estimating uses knowledge of process times to build up a time for a job. For example a time for a machined part can be estimated from the speeds and feeds of the machine used to make the part and the amount of material that has to be removed.

Allowances

As mentioned above a standard time consists of the standardised work time plus appropriate allowances. The International Labour Office publication, "Introduction to Work Study" (ILO. 1969) provides guidance on allowances. Allowances can be made for the individual, the nature of the work and the working environment. Special allowances can also be made e.g. a learning allowance for a trainee. Allowances may also be the subject of negotiation between employees (or their representatives) and employers.

The Importance of Work Context

As stated above an objective of the exercise described in this paper is to help participants to understand how time standards fit into the larger context of job and work design. The first major industrial test of the Australian Workplace Relations Act 1996 (Hawke, 1999), is a good example of the complexity that surrounds the application of new technology intended to increase productivity and competitiveness. This case involved the Maritime Union of Australia and Patrick Stevedores in a bitter dispute over labour productivity involved in container movements on the waterfront. The case illustrates in particular the affect of industrial relations agreements and political involvement on work productivity. The question - "what should be the labour standard for moving containers" is a central question to waterfront productivity, but the answer to this question is clearly a complex one. Productivity depends on a myriad of factors – the design performance of the container handling technology including maintenance requirements, labour agreements, workforce performance (including planning and control by management) and factors difficult to control, such as weather and disputes in related operations both in Australia and elsewhere in the world. However, the question of measuring how long work should take is important, in this case, as in all real life cases assumptions have to be made and there is risk of those assumptions being wrong. Negotiation also clearly plays an important role in establishing the way time standards are used in complex work situations.

Experiential Exercises for Operations Management

The literature suggests that experiential exercises are a useful addition to an operations management curriculum. Concepts that are difficult to explain in words and numbers can be experienced through the use of a hand-on exercise. Many exercises may be developed at low cost, see for example Heineke (1995). A good review of the literature on assessing experiential learning effectiveness is presented by Gosen and Washbush (2004). They

reported that the empirical research reviewed supports the notion that experiential learning is effective. However, they heed caution in accepting this position as generally the studies reviewed did not meet the highest research design and measurement standards. In a recent article Polito, Kros, and Watson (2004) claim that an experiential learning activity based on running a "mock factory" had a significant affect on participant's recollection of key concepts compared with a control group who learned in a different way.

Method

The exercise is based on an individual manual task; an origami exercise making paper boxes (see Figure 1). Student are divided into pairs, one is the worker who makes the boxes and the other, the timer, times how long the boxes takes to make and rates the speed of the worker. The idea of rating the speed of the worker is explained to the class using the standard work study definition of "standard speed" explained above. Timers are not trained in rating but rather are told to use their own judgement based on the definition of "standard speed" provided. Timers are instructed not to assist the box maker. Workers make four boxes one after another. The first box called the prototype is timed but not rated, as the worker has to learn how to make the box using instructions provided. The last step in the box making process is tricky and some workers get stuck for a considerable time. Once the prototype is finished the workers make three production boxes, each box is timed and the speed of the worker rated by the timer. A standard form is supplied on which results are recorded. The instructor rates the quality of the production boxes (an average score for the three) on a scale of 1 to 10. Participants are not told that quality of the finished production boxes will be assessed. Results are compiled on an overhead for class discussion.

The materials needed per pair of participants are:

- four pieces of A4 paper to make boxes
- instructions for making the box, the exercise is taken from Bracey and Sandford (1986) but other origami exercises would be equally suitable
- results sheet

The Process

- Students are told they will be carrying out an exercise aimed at answering the question – how long should a job take to do?
- Participants are divided into pairs, worker and timer and their roles are explained. It is emphasised that the timer's job is to time and observe the worker and not to help the worker in any way
- The concept of rating the speed of the worker is explained using the ILO definition discussed in the literature review:- *Standard speed (rated as 100) is your notion of the speed that a motivated, fully trained worker would be comfortable performing as an average over the working day. For example, a rating of 50 means the worker is working at half standard speed and a rating of 120 means a work speed 20% greater than standard speed.*
- Materials, except the instruction, are handed out to the workers. Workers are told to begin making the prototype as soon as they receive the instructions. Timers are told the start timing the prototype from when workers start to read the instructions. The instructions are then handed out and the workers begin the prototypes.
- The instructor observes the behaviour and emotions of the participants as the exercise proceeds
- As workers finish the lecturer makes sure that the record sheets have been completed by timers. For each of the three production boxes the timer records the actual make time, the speed rating of the worker and calculates the "normal time" by multiplying the actual time by the speed rating (e.g. if actual time = 2.7 min, speed rating 70, then normalised time = 2.7 min x 70/100 = 1.89 min)
- When all workers have finished the instructor rates the average quality of the three production boxes
- Summary results for each worker are copied onto an overhead for discussion.
- Results are displayed and participants invited to make observations about the results and about their experience of the exercise.

Results

Numerical Results

Numerical results from approximately 120 student "workers" are presented in Figures 2 to 6. Figure 2 shows a large variation between the times in which workers complete the prototypes. Figure 3 shows that the first production box is on average made in a much shorter time than the prototype, although there is still considerable variability between workers. Figure 6 shows the learning curve affect; generally the workers make production boxes more quickly as they gain experience. Figures 4 and 5 show histograms of the actual times and normalised/standardised times to make the third production box. If timers were experienced at rating the speed of workers one would expect a significant reduction in variability after rating. If the rating was perfect the variability would be zero – all the normalised/standardised times would be the same. Clearly this is not the case, although there is a reduction in the variability after rating (from Std. Dev = 1.24 to Std. Dev = 0.83).

Table 1 shows correlations between the times taken to make each of the four boxes. As expected there were significant correlations between the actual make times for production boxes 1, 2 and 3 and there were no significant correlations between the prototype times and any of the production box times. This result supports the notion that making the prototype and making the production boxes are two different types of task.

Fig. 1. Finished Box

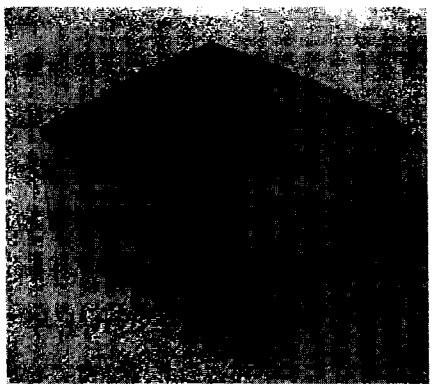

Fig. 2. Prototype times

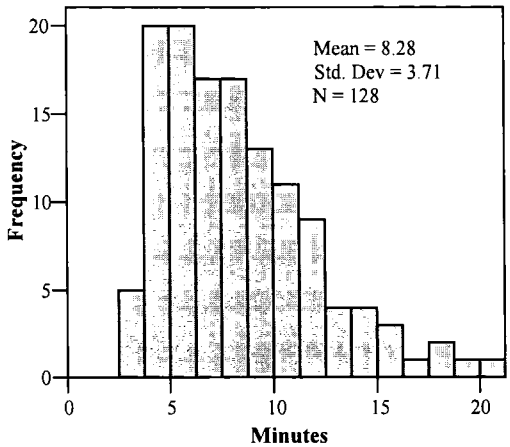

Fig. 3. 1st Prod. Box - actual times

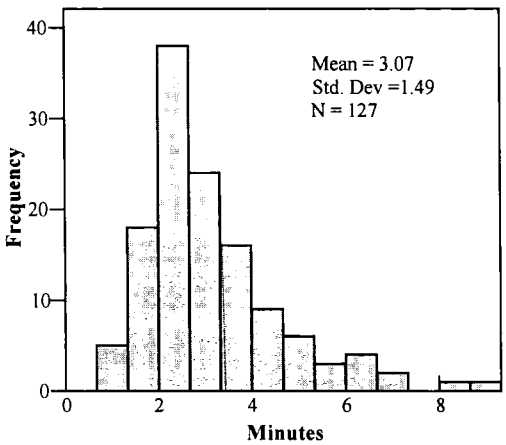

Fig. 4. 3rd Prod. Box - actual times

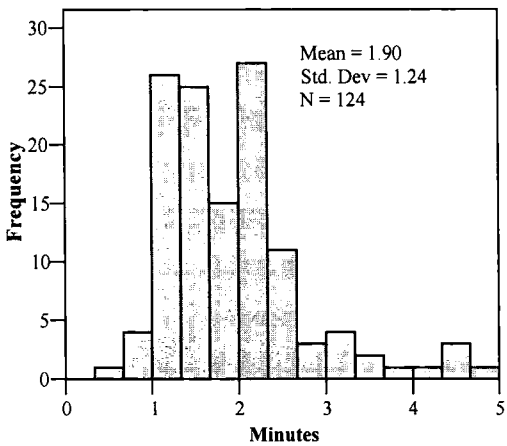

Fig. 5. 3rd Prod. Box - normalised times

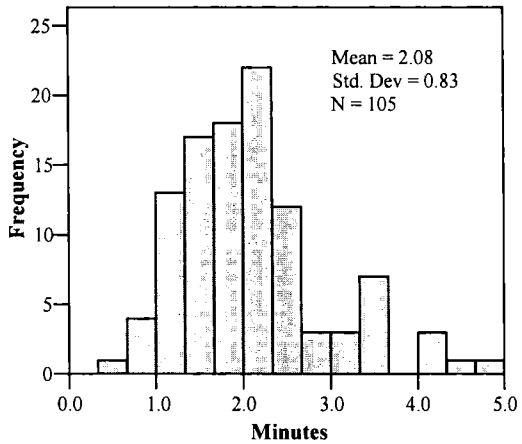

Fig. 6. Mean times for three prod. boxes

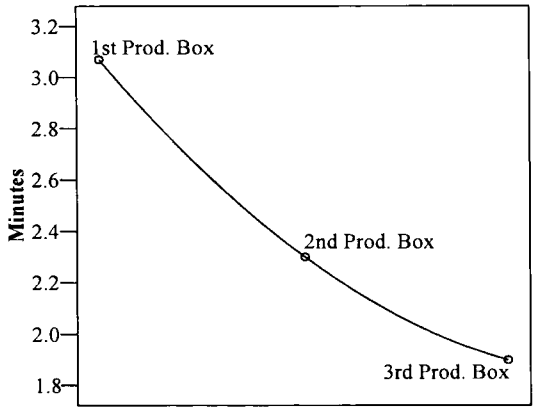

Table 1. Correlation between make times and quality rating

	Proto.	Prod. 1	Prod. 2	Prod. 3	Quality
Prototype		-.03	.14	.11	-.15
Prod. Box 1	-.03		.71**	.58**	-.20*
Prod. Box 2	.14	.71**		.80**	-.30**
Prod. Box 3	.11	.58**	.80**		-.11
Quality rating	-.15	-.20*	-.30**	-.11	

**Correlation is significant at the 0.01 level (Pearson, 2-tailed)
* Correlation is significant at the 0.05 level
Quality was rated on a scale 1 (poor) to 10 (good) as an average for each workers prod. boxes

Discussion

General Observations

There are usually a few workers in a group who cannot complete the prototype box. The last step in the process is tricky and requires some experimentation. As Figure 2 shows some workers make the prototype very quickly. Some workers who struggle with the prototype resort to "espionage" to find out from more successful workers how to complete the final fold-out process.

It is extremely difficult for a timer to watch his/her box maker struggle to complete their prototype and despite the requirement given by the instructor for the timer not to assist the worker they often do help. Sometimes the timer takes over the job of the worker, more frequently the timer gives the worker some assistance.

Specific Learning Points

The following points of learning usually emerge in discussion. Below each point is explained and discussed.

1. Worker variability

It is evident that there is considerable variability between workers performance both for prototype and production box times.

The task is a manual task and worker variability is a feature of tasks that are worker paced. Workers have different levels of ability and motivation. Besides variability between workers, an individual's work rate will vary over time.

This observation can lead to a more detailed discussion of why these kinds of variation occur and identifications of situations in which worker variability may need to be controlled or synchronised with other operations. Methods of achieving control of worker variability could be discussed e.g. mechanical pacing such as on some vehicle production lines.

2. Workers have different skill mixes

Some workers were better than others at making the prototype and others were better at making the production boxes. However, as supported by the correlation analysis (see Table 1) a worker who is good at making the prototype is not necessarily good at making production boxes.

The prototype task is different from the production box task. Making the prototype is requires cognitive skills; the worker has to interpret written instruction (that are not very clear) and employ a degree of exploration and experimentation, rather like learning to use a piece of computer software. On the other hand to make the production boxes quickly and neatly, once the procedure is learned, requires manual skills, particularly dexterity. There is usually also a considerable variation in the quality of production boxes produced.

As explained in the literature review in a traditional direct work study exercise of a short cycle repetitive job it is usual to split the whole job into elements and rate the speed of the worker on the different job elements. One reason for this is that individuals being timed may perform differently on different types of work element making up the job as illustrated by this exercise. To obtain an "accurate" standard time it is therefore necessary to rate the worker's speed on the different job elements. The idea of worker selection for a particular type of job or task is of course based on the premise that some workers match the requirements of a job better than others. In practice a range of worker attributes may need to be considered in the matching process e.g. manual skills, cognitive skills, aptitude toward the work. is skill variability between workers, not only variability in speed of work but in other aspects such as quality as well.

3. The concept of the learning curve

Results from the exercise will show that in most cases the time workers take to produce production boxes will reduce as they gain experience (see Figure 6).

The theoretical idea of the learning curve can be discussed. This idea has been applied to different kinds of work, from short cycle repetitive work like in this exercise to complex project work such a manufacturing commercial aircraft. Applying the idea is useful to estimate the how quickly learning (in terms of job completion time) occurs.

4. Rating the workers speed

If the timers understood and were able to apply rating properly to the production box times then the normalised times should be very similar. This is generally not the case (see Figure 5).

Why was rating so inconsistent? There are a number of possible reasons for this:

- The workers were not fully trained in the job – they should have been. If they had of been then the variability between workers would probably have been much less.
- Timers were not trained in rating. They had a definition of standard speed and had to use their judgement to apply this. Clearly timers had different interpretation of this definition.
- Some timers probably did not grasp the concept of rating.
- Even if timers had been trained rating is a subjective process requiring skill and judgement so some variation would be expected.

Participants are often sceptical about the rating process. They can be challenged to improve the definition provided for the exercise or to think of a better way of standardising times. This can lead to a discussion of other approaches to standardising work times for the speed of the worker e.g. the PMTS approach explained in the literature review.

5. Interpersonal relationships in work design

The natural tendency was for timers to assist struggling workers, even though they had been instructed not to.

This behaviour reinforces that it is important to consider the behavioural approach to job design, in this case the interpersonal relationship between the worker and timer. The socio-technical concept of work could be discussed – work is both a technical system and a system of social interaction. Here work is viewed as a complex system in which social interactions such as communication interact with and enable work to be carried out.

6. Work instructions

The workers were not told that quality was to be measured or what acceptable quality meant. The quality of production boxes varied considerable. Some are usually quite neat while others are quite grotesque. This can lead to a discussion of the importance of specifying the requirements and how this could be done in an effective way. Would specifying acceptable quality have changed the distribution of work times? The correlations in Table 1 are somewhat inconclusive on this point.

7. What is a suitable standard time for this job?

Given the wide spread of times (see Figures 4 and 5) what should the standard time be for this job? When this question is put to participant the usually responses focus on arguments for a particular time or some way of finding a suitable time e.g. averaging a number of observed timings.

A more appropriate response would be "it all depends". To begin to answer this question requires information about how the job is going to be organised within the broader work system and what the standard time will be used for. One way to progress the discussion is to present some scenarios and challenge participants to identify issues that relate to determining a suitable standard time for the job. This is a good time to explain more clearly the concept of a standard time, in particular that a standard time should include a suitable allowance as described in the literature review. Two scenarios will demonstrate the process:

- The job will be allocated to a particular workers who can expect to do long runs lasting several weeks, they will be paid on a an output basis but only for acceptable quality. Here boredom may be a problem how can this be addressed? As large quantities of product are involved and the standard time will be used as a basis for payment a reasonably accurate standard time is required. How could this be achieved? Will materials always be available? If there are shortages what allowance should be made for this? What types of allowances are appropriate?
- The job is carried out occasionally in small batches by a multi-skilled workforce who also perform many other jobs and are paid a fixed weekly wage. Here the time standard may only be used for planning purposes and given the small volume of these products a really accurate standard time is not required. As the job is only performed occasionally even workers who have previously carried it out may have forgotten how to make the product (see Nembhard and Uzumeri, 2000). Therefore clear instructions are important. Also, some learning allowance attached to the standard time would probably be appropriate.

The relationship between a time for a job and broader political and economic issues as highlighted in the waterfront example described in the literature review can be discussed.

Conclusions

Students can find a discussion of time study rather boring and perhaps think of the topic as a remnant of "Taylorism" not very relevant to contemporary ideas of job and work design. This kind of exercise is a way of addressing some of the key issues in this area in a way that students generally find enjoyable. The main objectives of the exercise are: a) to expose participants to some of the conceptual and technical aspects of determining a time for a job, b) to help them recognise the importance of considering the broader work context in the process of determining and using time standards and c) to be aware of the limitations that underpin the concept of a standard time for a job. No objective measure of the learning effectiveness of the exercise has yet been undertaken, although anecdotal feedback is generally very positive. It is not claimed that the conduct of the exercise described here is the best way or the most appropriate for all situations. The exercise can easily be modified to suit particular situations and learning objectives.

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