

**A REVIEW OF CONSTRUCTION WORK SAMPLING METHODS  
AND AN INVESTIGATION INTO THEIR USE  
IN SOUTH AFRICA**

**Submitted in Partial Fulfilment of the Requirements for the degree:  
Bachelor of Science (Building Management)**

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## 1. INTRODUCTION

The problem of productivity on construction sites has received increasing attention in recent years. However, the question facing construction managers is, from which area of focus can the greatest improvement be achieved?

Three main areas have been identified where the most significant improvements in productivity can be brought about. Firstly, productivity of method, secondly productivity of the entire system or organization on a project, and lastly, productivity of design [1]. The first two challenges mentioned are in the hands of construction managers, and it is in these areas that the use of Construction Work Sampling as an analytical management tool is most appropriate.

Construction Work Sampling can establish with statistically determined accuracy, the proportion of time spent on the various activities that make up a task. At the same time it identifies delays caused by the inefficiencies of the methods being used, as well as poor management of the system or organization.

The accuracy of Work Sampling stems from the theory of probability which states that with an increasing sample size, the probability of a sample showing the characteristics of the entire population will increase [2]. The size of the sample needed will depend on the degree of accuracy required for the study and can be determined using the curve of normal distribution.

Relating these principles to construction, enough observations taken of men and machines on site and at randomly selected times; if classified into the required categories, will give management an accurate picture of how much time is spent on each category of work throughout the study period.

One of the most significant benefits of Construction Work Sampling is the relatively short time needed to produce reliable data for the work still taking place. This enables management to take

immediate and appropriate action where necessary and thereby make improvement and cut unnecessary costs. In this respect Construction Work Sampling compares favourably with the widely used cost reporting systems as a tool for productivity improvement.

Work sampling can help to create an awareness amongst management of their own inefficiency and that of the methods being used on site. If Work Sampling is implemented correctly it can provide a measure of management's ability to plan and schedule work, to allocate manpower, to provide the necessary equipment and materials, and effectively supervise the many daily tasks [3].

This being said, Construction Work Sampling even in its simplest form is not without problems, and, by the nature of the construction process, the methods of sampling used will always be subject to the many and variable conditions presented on a construction site.

Work sampling had its origin in industrial engineering; however its use in construction has increased greatly during the 1970's and 1980's [4]. Research would suggest that most of the innovation in this field is taking place in the United States. The basic methods of Work Sampling have been developed to suit the peculiarities of the construction site as opposed to the production line or factory where it was first used.

The objectives of this report are as follows:

1. To review the existing methods of Construction Work Sampling as well as discuss further aspects and problems which should be considered when undertaking a Work Sampling study.
2. To compare Construction Work Sampling with other methods of measuring productivity.

3. To evaluate by means of a case study the ease of applicability of the sampling methods to a South African construction site, and at the same time to identify differences between the description of the methods in theory and their use in practice.
4. To establish by means of a questionnaire the extent to which Construction Work Sampling methods are already in use in South Africa as well as other related information.

Information for this report was obtained from journals, manuals, text books, interviews, and the case study and questionnaires mentioned.

List of References - Introduction

1. Professor M.C.Vorster, Professor of Construction and Project Management, Department of Civil Engineering, University of Cape Town, Paper: "The Productivity Problem" presented at the symposium "Productivity in the Construction Industry", 1984.
2. L.G.Underhill, Introstat.
3. The Business Roundtable, Work Sampling and Foremen Delay Surveys (Tools for improving productivity at construction sites).
4. H.R.Thomas and J.M.Guevara, "Improving Productivity Estimates by Work Sampling", Journal of Construction Engineering and Management.

## 2. THE STATISTICAL THEORY OF WORK SAMPLING

At this stage of the report it is necessary to present the statistical theory by which the size of sample needed must be determined before the methods of sampling are discussed.

As the name implies, Work Sampling involves observing and classifying a small proportion or sample of activity on a project [1]. From this sample the level of activity of the whole project or a segment of it can be predicted. Sampling is based on the theory of probability, therefore the size of the sample will determine the degree of accuracy with which the project as a whole can be predicted.

Obviously it is desirable to achieve the maximum accuracy possible. However, a trade-off must be made between the level of accuracy and the time and cost associated with obtaining the larger sample [2].

The size of the sample needed will also be determined by the parameters of accuracy we wish to achieve, namely the Confidence Limits, the Limits of Error and the Category Proportions expected from the sample. Explanations of these concepts as well as other statistical considerations are provided below. The statistical concepts set out in this section will apply to the Work Sampling methods discussed in section 3 of this report unless otherwise stated.

### 2.1 Confidence Limits

Confidence limit is a term expressing the dependability of the result obtained by sampling [3].

Confidence limits are determined by the curve of normal distribution. Description of these curves depend on two factors:

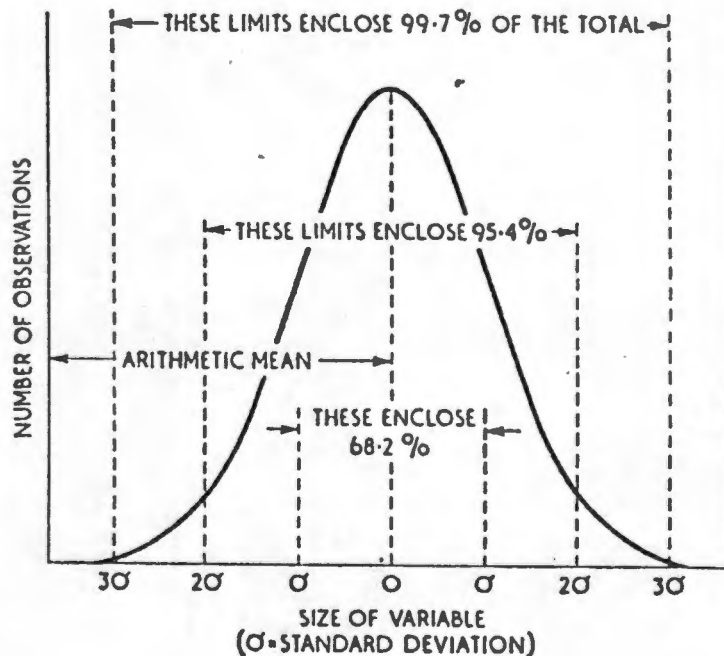
$\bar{X}$  - the average of the observations and  
 $\sigma$  - the deviation from the average or standard deviation.

$\sigma_p$  - is the standard deviation of the proportion  $p$  which has been sampled.

The number of standard deviations away from the average will determine the percentage of the area under the curve to be included. As we move further away from the average, more observations are necessary to classify those parts of a population deviating from the average. Figure 1 shows the curve of Normal Distribution.

From the curve we can see that:

Figure 1. The Curve of Normal Distribution [4]



$$\bar{X} \pm 1 \sigma_p = 68.27\%$$

$$\bar{X} \pm 2 \sigma_p = 95.45\%$$

$$\bar{X} \pm 3 \sigma_p = 99.73\%$$

Reversing the calculation, for example, 95% of the area under the curve equates to 1.96 standard deviations on either side of the average  $\bar{X}$ .

Thus at a 95% confidence limit the answer can be relied upon 95% of the time or may be wrong 5% of the time. A confidence limit of 95% normally provides the degree of statistical accuracy needed for Construction Work Sampling [5].

## 2.2 The limits of error/accuracy

This is a measure of the percentage variation on either side of the value obtained by sampling within which the true value can be expected to fall. For example, if the limit of error  $L$  is 5% and the percentage  $p$  obtained from sampling is 25%, the true value for  $p$  could fall between 20% and 30% [6]. If a smaller limit of error is required the sample size must be increased. A 5% limit of error is normally acceptable for Construction Work Sampling.

## 2.3 The category proportion

This is the proportion of the sample having a given characteristic. For example if 100 out of 500 men observed are not working, the category proportion for those men is 20%. The category proportion also affects the size of the sample required in order to meet the parameters set by the confidence limit and the limit of accuracy/error.

Very often a pilot study must be conducted in order to obtain an estimation of the category proportion in advance from which the sample size required may be calculated.

Normally category proportions of between 40% or 60% are acceptable for construction activities [7].

#### 2.4 Determining the sample size

Table 1 shows the size of sample required in relation to the category proportion and the Limit of error for a 95% confidence limit. It can be seen that at the 5% limit of error and a category proportion of 50% , the maximum number of observations required is 384.

Table 1. Sample required for a 95% confidence limit [8]

Category proportion (%)	Limit of error (+/- %)				
	1	3	5	7	10
90	3456	384	138	71	50
80	6144	683	246	125	61
70	8064	896	323	165	81
60	9216	1024	369	188	92
50	9600	1067	384	196	96
40	9216	1024	369	188	92
30	8064	896	323	165	81
20	6144	683	246	125	61
10	3456	384	138	71	50

Calculation of the required sample size, as for Table 1, can be done by the use of a simple formula:

$$N = \sqrt{\frac{4p(100 - p)}{L^2}}$$

Where  $N$  = Number of observations required.

$4$  = The number of standard deviations required to give a 95% confidence limit.

(1.96 rounded to +/- 2 on either side of the average  $\bar{X}$ )

$p$  = The percentage reading (category proportion) taken from the pilot study.

$L$  = The limit of error required [9].

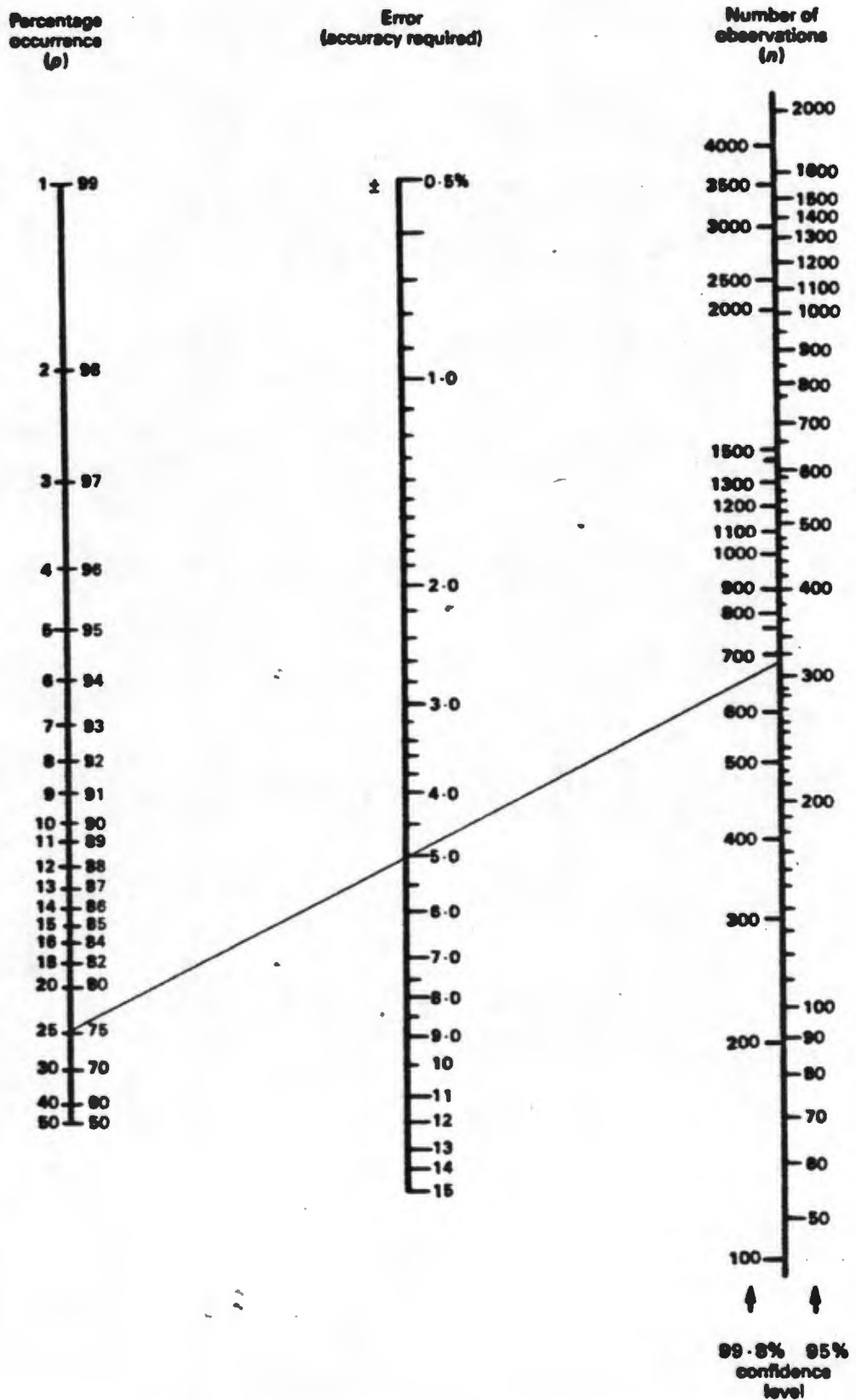
Using the same formula the limit of error can be determined:

$$L = \sqrt{\frac{4p(100 - p)}{N}}$$

An alternative method for determining sample size is by the use of a nomogram such as the one shown in Figure 2. This method is preferable to the calculation of sample size where the category proportion can be estimated in advance or where the limit of error must be determined for a category proportion that is different from that estimated [11].

To determine the sample size required a line is drawn from the percentage occurrence  $p$  to intercept the limit of error required and then extended to meet the number of observations required at the 99.8% or 95% confidence limit. For example, for  $p = 25\%$  and a 5% limit of error,

Figure 2. Nomogram for determining sample size [10]



approximately 315 observations are necessary to give a statistically valid sample at the 95% confidence limit.

## 2.5 Ensuring the statistical validity of the observations

In order for the observations to be valid they must be made at random times. Any pattern emerging during the making of observations will distort the result.

The following rules should be adhered to:

- The condition of each unit observed should be independent of that of any other unit.
- Each unit should have an equal opportunity of being selected for observation.
- The basic characteristics of the individual units should remain constant [12].

Random times may be obtained by using random number tables or by the use of a computer with a random number generator.

List of References - Section 2

1. Henry W. Parker and Clarkson H. Oglesby, Methods Improvement for Construction Managers, p40.
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4. R.E. Calvert, Introduction to Building Management, p.202.
5. International Labour Office, Introduction to Work Study, p.195.
6. *op. cit.*, 1, p.42.
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8. *op. cit.*, 3, p.2.
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11. *op. cit.*, 1, pp.42-43.
12. *ibid*, 8.

### 3. A DESCRIPTION OF THE CONSTRUCTION WORK SAMPLING METHODS

Section 3 of this report will lay out the basic principles, objectives and possible benefits and disadvantages of the most commonly known methods of Work Sampling. More generalised considerations which relate to these methods and are important to the successful completion of a Work Sampling study are discussed in section 4.

The effectiveness of a Work Sampling study may be determined by the suitability of the sampling method chosen to the objectives of the study. There is no standard laid down as to what method should be used for a particular type of activity since the applicability of a particular method will change from site to site and from activity to activity. Furthermore, the methods themselves should be 'tailored' to suit the particular requirements of the activity/ies under study.

#### 3.1 Field ratings

(Also known as Head counts and Activity ratings)

Field ratings, the simplest of the techniques involve the observation and classification of workers or machines as 'Working' or 'Not Working' at the moment of observation. A tally of workers falling under each classification should be kept by means of 2 mechanical counters or by the use of a simple tick sheet.

The tally may be made of all personnel, or when greater detail is desired the tally should be made and reported by crafts, by areas, or by crews [1]. Further discussion of the study approach takes place in section 4.5 of this report.

It will not be possible to observe every worker on site in one tour. It is generally accepted that 90% of workers

should be observed for a tour to be effective. A number of tours made at random times during the day will increase the sample size and improve the accuracy of the study.

### 3.1.1 Worker classification

The observer should have a clear idea on commencing the study which activities he will classify as 'Working' and 'Not Working'. These will change depending on the particular activity being observed, this is especially so in the case of single crew observations.

The following classification might be used for overall site observation [3]:

To qualify as "working," personnel should be engaged in such activities as

1. Carrying material, or holding or supporting material.
2. Participating in active physical work, including
  - a. Measuring, laying out, reading plans, filling in time cards, writing orders, instructions.
  - b. Holding a fishline or supporting a ladder.
  - c. Operating a machine or piece of equipment (while actively engaged).
3. Discussing the work, provided it can be positively determined that such is the case.

Activities such as the following would be listed as "not working".

1. Waiting for another to finish work, such as a labourer waiting for his wheelbarrow to be loaded or waiting for a hoist.

2. Talking while not actively working.
3. Operators attending self-operating machines, unless engaged in a useful task.
4. Walking about empty-handed.
5. Riding on a vehicle.

### 3.1.2 Analysis of results

The results of the Field Rating are represented as a Field Rating Index giving the percentage of working observations of the total observed. The accuracy of the index will depend on the sample size obtained (384 observations are acceptable, as discussed in section 2.4).

Typical results are shown on Figure 3.

Figure 3. Field Rating summary [4]

FIELD RATING			
OBSERVATION NUMBER	NO. OF MEN OBSERVED	NO. WORKING	NO. NOT WORKING
1	21	12	9
2	21	10	11
3	21	10	11
4	18	7	11
5	18	8	10
6	18	12	6
7	18	9	9
8	21	12	9
9	21	8	13
10	21	9	12
11	21	9	12
12	21	7	14
13	21	8	13
14	21	15	6
15	21	11	10
16	21	10	11
17	21	9	12
18	21	11	10
19	19	10	9
20	19	11	8
<b>TOTALS</b>	<b>404</b>	<b>198</b>	<b>206</b>
Number of Observations:			404
Number of Men Working:			198
Percentage Working (198/404):			49%
Add Foremen & Personal time:			10%
			-----
			<b>FIELD RATING INDEX</b>
			59%

The calculation shows a 10% allowance for foreman and personal time. Both of these are variable at the discretion of the observer. For example 'foreman' might vary with the level of supervision on the job. Personal time is allowed for according to company policy. Any index of less than 60% is generally considered unsatisfactory [5]. Further discussion of the analysis of results takes place in section 4.7 of this report.

### 3.2 Activity Sampling

Activity sampling is the most commonly used method of Work Sampling. Activity sampling is a development of the Field rating described above since it breaks down the basic 'Working' and 'Not-Working' categories into a larger number of more informative categories. The categories chosen should be suited to the type of activity being carried out and to the study approach to be used. A more detailed discussion of the selection of categories and the study approach is given in sections 4.2 and 4.5 respectively.

The number of observations necessary when making an activity sampling study will be determined using the statistical guidelines set out in section 2 of this report.

Figure 4 shows typical categories that might be used for an activity sampling study. The Direct work categories would correlate to the "Working" ; and the Waiting and Personal categories to the "Not Working" classification of the Field Rating. Further discussion of the selection of categories takes place in section 4.2 of this report.

The results of an activity sampling study are normally calculated as percentages. Any categories that seem to show abnormal percentages may then be investigated by management. Section 4.7 provides further discussion of the analysis of results.

**Figure 4. Activity Sampling categories [6]**

CATEGORY	%
<u>Direct work</u>	
Handling of tools	
Transportation	
Giving/receiving instructions	
Referring to plans	
Travelling	
<u>Waiting:</u>	
Others in crew	
Equipment, tools	
Instructions	
Quality control	
Other crafts	
Weather	
<u>Personal breaks:</u>	
Conversation	
Refreshments	
Rest	
Early finish/late start	

### 3.3 The Productivity Rating

The productivity rating is a further development of activity sampling. It compares the percentages of the categories with the quantity of work completed during the study. The productivity rating provides a formal way in which unnecessary delay and inefficiencies, which are easily missed by management who are too close to the work to pick them up, can be identified and rectified [7].

A productivity rating categorizes an operatives time into three main groups:

DIRECT ACTIVITY  
SUPPORT ACTIVITY  
DELAYS

Please see Appendix I for a detailed breakdown of these groups [8].

Activities should be placed in the category that best indicates their degree of productivity for the task at hand.

The focus created by the classification of activity can be varied and may help to bring inefficiencies to the fore. For example if a man who is more than 15 meters from his location is classified ineffective, problems with material location for example might be brought to the fore [9].

The study consisting of a number of sampling sheets can be summarized onto a single summary sheet giving the total number of observations for each part of the activity being observed. Percentages are then calculated and compared to the quantity of work completed during the study period.

Figure 5 shows a Productivity Rating summary sheet for the erection and striking of formwork.

**Figure 5. Productivity Rating Summary sheet [10]**

Operatives/Plant: 6 shutterhands		Reference: Formwork 1, 2, 3, 4 & 5. Date: April 1985 Round interval: 3 minutes	
Total time: 40 hours	Total obs: 4788		
ACTIVITY	TOTAL	PERCENTAGE	QUANTITY
<b>PRODUCTIVE (DIRECT)</b>			
Fix metal props	507	11	
Fix timber bearers	512	11	
Fix waffle moulds	486	10	56m <sup>2</sup>
Strike metal props	186	4	
Strike timber bearers	89	2	
Strike waffle moulds	86	2	16m <sup>2</sup>
<b>PRODUCTIVE (INDIRECT)</b>			
Move formwork	195	4	
<b>NON-PRODUCTIVE</b>			
Idle/relaxation	2538	53	
Absent	179	3	
<b>Totals</b>	4788	100	

Productivity ratings can be misleading in that they may show activity levels to be high, however, due to disorganization of the work, the actual rate of output will not match up to productivity levels. Also differing methods used for the same job will show different percentages of productive time i.e. different proportions of Direct, Support and Delay activity.

Using productivity ratings continuous samples can be taken with a round interval of five to ten minutes, where a group of less than ten operatives (crew), located in the same area are being observed. Random samples can be taken with the interval between rounds chosen in relation to random numbers. This type of study is best applied to the whole site or where there are more than ten operatives [11]. Further discussion of the study approach takes place in section 4.5 of this report.

The breaking down of work into small categories or elements enables the assumption to be made that an operative will work at a standard rate throughout the study period. Management should be more concerned with the 'not working' element rather than the 'working element' within a task [12].

### 3.4 The Five Minute Rating

The Five Minute Rating is used for making a quick appraisal of an activity. The short period of study renders too few observations to offer any exact statistical reliability but the method is still very effective where immediate action on the results is able to cut costs.

The five minute rating creates management awareness of delays:

- that impede the progress of the job such as crafts interfering with one another, poor methods, material and equipment shortages and incorrect drawings.
- that affect the cost of the job and not the progress, for example overmanning on an activity [13].

The five minute rating also measures the effectiveness of a crew by totaling the number of effective units observed during the study period. It may also help to identify areas for possible further detailed study. Figure 6 shows a typical example of a five minute rating made for concrete formwork erection [14].

#### 3.4.1 Procedure for making a Five Minute Rating

- a. The observer should position himself where he can observe the whole crew.
- b. The crew is observed for consecutive periods of 30 seconds or even several minutes at a time. Alternatively, the observer can use the time taken to complete a single cycle of a repetitive task.
- c. The study should continue long enough to ensure that each operative is observed for at least 5 minutes. Thus the name 5 minute rating.
- d. For each observation period the activity of each operative is evaluated in terms of "working" or "not" working for that period.
- e. If an operative is observed to be "working" or "not working" for more than 50% of the observation period, that operatives' time-block

Figure 6. Five Minute Rating sheet [14]

CONCRETE FORMWORK ERECTION  
FIVE-MINUTE RATING

TIME	CARR. Y. HELPER W. CARR. W. CARR. W. HELPER G. CARR. B. HELPER B+W. CARR. Y+R. HELPER W.										
	START	1	2	3	4	5	6	7	8	9	
8:05	✓										Carpenter measuring and crew not on site
8:06	✓	✓									Jack hammering existing concrete slab
8:07	✓	✓								✓	Measuring and jack hammering
8:08	✓	✓		✓				✓			Cutting sheet of 4'x8' plywood
8:09	✓	✓	✓		✓			✓		✓	Cutting 2"x4" and jack hammering
8:10	✓		✓	✓				✓			Jack hammering and crew not on site
8:11		✓		✓							Crew not on site (apparently left to get supply)
8:12		✓								✓	Crew not on site (apparently left to get supply)
8:13		✓	✓								Crew not on site (apparently left to get supply)
8:14	✓	✓	✓		✓						Jack hammering and transport lumber
8:15	✓	✓	✓					✓		✓	Jack hammering and transport lumber
8:16	✓	✓		✓						✓	Jack hammering and transport lumber
8:17	✓	✓						✓	✓		Jack hammering cutting and nailing forms in place
8:18	✓		✓	✓			✓	✓	✓	✓	Nailing forms in place
8:19	✓	✓							✓		Measuring and cutting lumber
8:20	✓	✓	✓	✓	✓	✓		✓	✓	✓	Nailing lumber and jack hammering
8:21	✓	✓					✓		✓		Measuring and cutting lumber
8:22	✓			✓			✓	✓	✓	✓	Nailing vertical forms and measuring
8:23		✓	✓				✓		✓		Cutting plywood 4'x8' and jack hammering
8:24	✓	✓	✓		✓	✓	✓	✓	✓	✓	Nailing 4'x8' sheets (decking)
8:25	✓	✓					✓		✓	✓	Measuring & bracing
Total	17	17	9	7	4	7	8	9	10		Effective unit totals
											Total man units 189
											Effective 88
											Effectiveness 46.5%

will be classified as effective or not effective for that time period.

- f. Large crews should be divided into subgroups for easy identification of workers.
- g. A number of ratings should be taken throughout the day to give the desired accuracy of result.
- h. The total of effective units taken as a percentage of total units observed will give an indication of crew effectiveness.
- i. Average effectiveness should be calculated for all ratings [15].

### 3.5 Setting Time Standards using Work Sampling

In this application the use of work sampling is carried a step further from its normal use. A sampling study made with the required degree of accuracy which is designed to give percentages of time spent on Direct Work, Delays and Personal time may be used to determine a standard time for the activity under study.

#### 3.5.1 Procedure for calculating standard time

Requirements:

- a. Obtain percentages of Working time, Delays and Personal time using sampling.
- b. Record the total time of the study in minutes.

- c. Record the number of units produced or quantity completed during the study period.
- d. Estimate the average performance rating of each operative being studied.

Appendix II shows the various rates of working on the principle rating scales. The 0 - 100 Standard scale is most commonly used [16].

From the above information Normal time can be calculated.

$$\text{Normal time} = \frac{\left[ \begin{array}{l} \text{total time} \\ \text{of study} \\ \text{in minutes} \end{array} \right] \cdot \left[ \begin{array}{l} \text{work time} \\ \text{in decimals} \\ \text{from sampling} \end{array} \right] \cdot \left[ \begin{array}{l} \text{average} \\ \text{performance} \\ \text{rating in decimals} \end{array} \right]}{\text{total quantity produced}}$$

$$\text{Standard time} = \text{Normal time} + \text{allowances for Delays, Fatigue, and Personal time [17].}$$

**Notes:**

Delays and personal time (including fatigue) can be calculated from sampling studies, however, care should be taken that the percentages obtained for these are not beyond normally acceptable levels since this may indicate the need for method study to ensure that the best method is being used before time standards are calculated [18]. Appendix III gives percentages for allowances for various classes of work [19].

Performance rating should only be made by an experienced observer if accurate standards are to be set. The performance rating has the effect of

adjusting the working time to that which an average worker would be achieving.

### 3.5.2 The advantages and disadvantages of Work Sampling as compared with Time Study.

- A major advantage of work sampling over Time Study when determining time standards is that no stopwatch is used. There is a significant psychological effect on operatives when using a stopwatch.
- Several studies may be conducted simultaneously by one observer.
- Work of a long cycle time may be studied with fewer observer hours.
- The study may be temporarily delayed, at any time, with little effect.
- When cycle time is short, time study, rather than work sampling is more appropriate.
- Work sampling does not provide as complete a breakdown of elements as time study.
- A potential draw back is that the basic assumption in work sampling is that all observations pertain to the same static system. If the system is in the process of change, work sampling may give misleading results [20].

### 3.6 Craftsman Questionnaire Sampling

Craftsman Questionnaire Sampling (CQS) is a new and so far little tested method of evaluating management efficiency and measuring site productivity.

It combines two useful and well known methods namely: The Craftsman Questionnaire and Work Sampling. CQS seeks to maximize the benefits of Craftsman Questionnaire and Work Sampling and to minimize the problems associated with these methods [21].

The Craftsman Questionnaire is discussed in section 6.2 of this report. Problems with the use of work sampling are discussed in section 5. Briefly, the pertinent problems are:

#### Craftsman Questionnaire

- Numerical results lack validity.
- It requires craftsmen to leave the work area and causes delay and disruptions.

#### Work Sampling

- The suspicion by workers that they are being constantly spied upon.
- Problems with classification of the observed activities
- Further effort is needed to seek the causes of the problems that are observed [22].

#### 3.6.1 The basic logic for using Craftsman Questionnaire Sampling

The craftsman questionnaire used in CQS is a means of data collection to substitute observation. At the same time the questionnaire seeks to track down the causes of delay, since craftsmen are much closer to the work than the observer and can easily determine the nature of activities and causes for delay.

The questionnaire may also provide information such as the amount of time spent on rework and the necessity of work performed.

An important factor associated with a questionnaire is the atmosphere of participation created by its use.

The other aspect of CQS is Work Sampling. The person carrying out the study walks around the site and randomly selects a crew to answer the questionnaire. Thus the CQS based on random sampling is able to provide statistical reliability of results as does Work Sampling. For example if 300 out of 1000 participating craftsmen indicate "waiting" on the questionnaire we can conclude that 30% of craftsmen's time is spent waiting. It must be noted that the basic unit of sampling when using Work Sampling is a craftsman while CQS uses the crew as the basic unit (each crew has equal opportunity to be selected) [23].

### 3.6.2 The basic procedure when using Craftsman Questionnaire Sampling

- a. The administrator walks around site and randomly selects a crew/team leader, (random-time, place and crew).
- b. Brief explanation is given and the crew are quickly assembled by the leader.
- c. The crew must be given a brief introduction explaining the purpose of the study, and the questionnaires handed out.
- d. Two types of questionnaire must be used. One to be filled in by the leader: (See Figure 7) -

this gives details of the crew and supplies information on members of the crew absent at present. The other questionnaire is filled in by the craftsmen: (See Figure 8) - this divides work into Productive and Non productive tasks following through to the nature of work and the causes of delays.

- e. The questionnaire requests information on activity carried out for the minute before the team was convened [26].

### 3.6.3 Advantages of Craftsman Questionnaire Sampling

- a. Time saving over a conventional Craftsman Questionnaire.
- b. The questionnaire is filled in at workplace and therefore takes less of a workers time than does a conventional Craftsman Questionnaire.
- c. Greater reliability of results due to a shorter period of recall (one minute) than with a conventional questionnaire.
- d. The CQS takes advantage of the crew leaders knowledge.
- e. Time is put to the data - this may be of help to management during analysis.
- f. The CQS can provide the causes behind delays or activities where normal Work Sampling often does not.

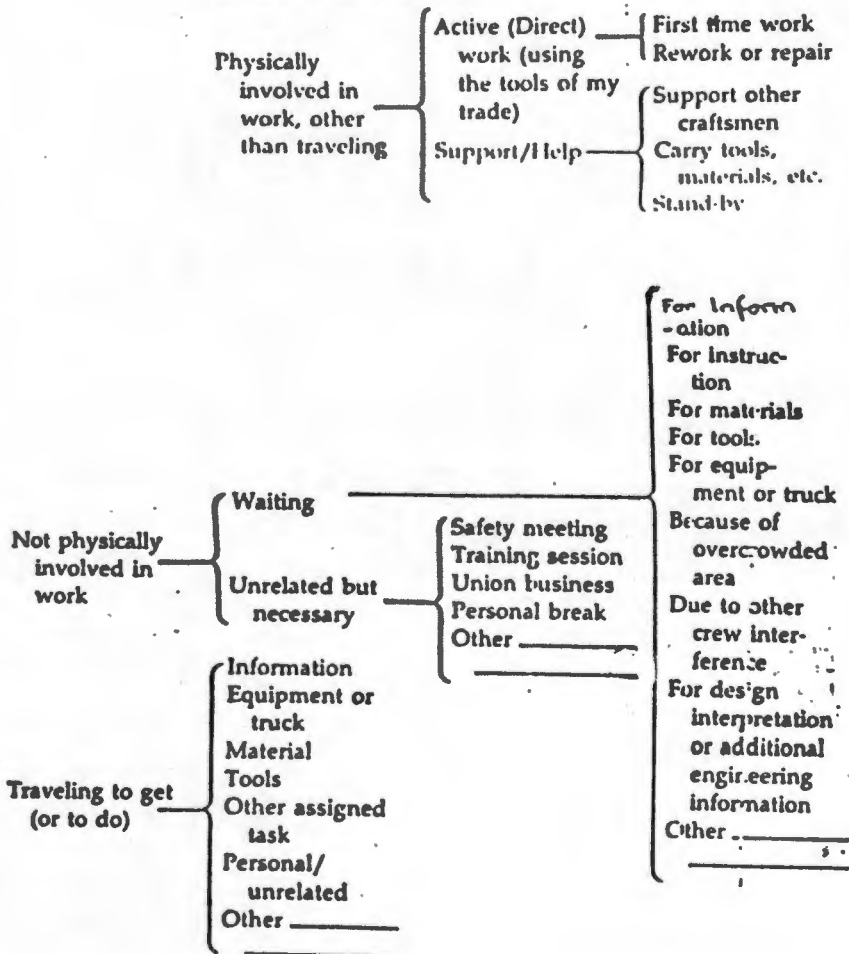
**Figure 7. Questionnaire filled in by crew leader [24]**

1. How many craftsmen belong to the crew?  
 1  2  3  4  5  6  7  8  9  10  11  12
2. How many craftsmen are now answering the Questionnaire in the crew's work area?  
 1  2  3  4  5  6  7  8  9  10  11  12
3. For the craftsmen not in the work area unable to answer the questionnaire, please answer the following:
  - How many on leave, vacation, or excused absent?
  - How many absent, unexcused?
  - How many away from work area due to?
    - Union business
    - Attendance at safety meeting
    - Performing necessary personal activities
    - Attendance at a training session
    - Other, please specify \_\_\_\_\_
  - How many on assignment to get?
    - Material
    - Tools
    - Equipment
    - Additional engineering information
    - To other work area because another crew was still working in the area the craftsmen were assigned to
    - Other (Please specify and explain why) \_\_\_\_\_

**Figure 8. Questionnaire filled in by craftsmen [25]**

Directions:

Work from left to right as the lines lead you. Circle the description that best defines what you have been doing for the last 1 minute before you were invited to come here.



- g. A 'Bottom up' management philosophy of worker participation may have motivational benefits [27].

#### 3.6.4 Disadvantages of Craftsman Questionnaire Sampling

- a. Time taken for the introduction of the procedure; however this is not necessary once the system is integrated.
- b. Time taken to fill out the questionnaire.
- c. Time taken to gather the crew.
- d. Further explanation of activity than is provided for in the CQS would be beneficial. More detail is provided by a conventional questionnaire.
- e. More interruption than with Work Sampling. A trade off between interruption and the benefits of additional information is necessary.
- f. Problems of literacy, language, education amongst craftsmen required to participate [28].

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#### 4. FURTHER CONSIDERATIONS FOR THE USE OF CONSTRUCTION WORK SAMPLING

##### 4.1 Defining the objectives of the study.

It is essential that a detailed statement of objectives is made before commencing with a work sampling study. The objective should be a reflection of what management wishes to achieve with the data that is collected. It would follow that the design of the study program must facilitate the objective. For example, in the selection of the categories of work within an activity, and the choice of the activities themselves [1].

A written statement of objectives should accompany the analysis of data to be studied.

Examples of work sampling program objectives:

- To provide management with an indication of the general level of activity on the project on a continuous basis.
- To identify potential problem areas (geographical) on site. This will require more detail as to the areas to which workers have been assigned to avoid distortion of results by 'outsiders'.
- To identify the utilization of time by a particular craft or crew. This requires a detailed breakdown and categorisation of the activities involved in a particular task.
- To identify the causes of delays by use of the Craftsman Questionnaire Sampling method.

#### 4.2 Selection of the categories of work

The results of work sampling may fall short of expectations due to incompatibility between the study objectives and the work categories chosen. The categories or work into which an activity is subdivided should both enhance the achievement of the programme objectives and provide the manager with the type of information needed to take appropriate action [2].

The activity categories must be chosen to include all possible states of being of the people or equipment being studied, i.e. a narrative description of what the craftsmen do during the study period; therefore, everything that is observed to be able to fit into one of the categories selected [3].

The level of detail required for the categorization of activities will depend on the objectives. Generally speaking the more detailed the categories the more useful the information will be.

Analysis of the percentages of activity under the various categories may focus the attention of management on a particular area of concern. This area could then be further investigated by increasing the level of detail within that/those categories and further studies conducted thereafter.

The exact number of categories is difficult to determine and will obviously vary with the activity. Too few categories will cause problem areas to be grouped together and make them more difficult to identify. On the other hand too many categories will cause excessive fragmentation and will increase the possibility of observer error when classifying an observed activity. Care should be taken when selecting categories not to over emphasise i.e. break down

into too many parts, those parts of activities that are not going to provide solutions to the problem e.g. Personal time. Finding out or zoning in on the causes of delays is far more important, as is the minimization of support work so that a greater percentage of time can be spent on direct work.

Tradeoffs as to the number of categories will have to take place between factors such as:

- the study objectives
- the experience of the observer
- the complexity of the work
- the degree of site congestion [4]

The following examples show how the selection of activity categories can be suited to a study where:

- General levels of activity are obtained using a tour of the site (See Figure 9).
- Detailed study is carried out on a particular crew and even for a particular craft (See Figure 10).

Figure 9. Activity Categories for a tour of the site [5]

Study 1	Study 2
Direct Work Idle/Unexplained Travel Waiting Late Start/Early Quit Transport Tools/Materials Receiving/Giving Instructions Breaks (Unauthorized) Planning Work Reading Drawings Personal	Direct Work Instructions/Prints Tools/Materials Transport Travel Idle/Unexplained Waiting Personal Breaks Late Start/Early Quits
Study 3	Study 4
Direct Work Work-Wait Work-Travel Waiting Travel Instructions Late Start/Early Quit Personal	Direct Work Travel Waiting Late Start/Early Quit Transport Tools/Materials Receiving/Giving Instructions Breaks (Unauthorized) Planning Work Personal

Figure 10. Activity Categories for crew or craft study [6]

Study 6	Study 7
Direct Work Handling of Tools Transportation Receiving Instructions Referring to Prints Foreman Instructions Foreman/Prints Traveling Foreman Traveling Waiting Others in Crew Equipment, Tools, Materials Instructions Engineering Quality Control Other Crafts Weather Personal Breaks Conversation Coffee Rest Early Quit/Late Start	Direct Work Obtain/transport materials/ tools within immediate area Give/receive instructions or plan work Direct crane operator Position furnels Assist vibrators Adjust foras Adjust reinforcing steel Other minor contributory work Travel empty-handed Obtain/transport materials/ tools outside immediate area Unexplained idleness or waiting Waiting for materials, tools, instructions Waiting for prerequisite work or another craft Authorized rest breaks Wait for concrete truck Delay caused by Creter Crane breakdown No contact

#### 4.3 Informing the workforce with regard to Work Sampling

It is important that the workforce is informed that a study is to take place. If the objectives of the study are explained to the workers and it is made clear that the observer is not spying on them or trying to push men out of their jobs, there should be no problems. The best way of informing the workforce is through the foremen.

Points to be communicated to craftsmen and supervisors.

- Data is impersonal and will not be used against any individual.
- Management is interested in hearing from the craftsmen what should be changed since they are the ones who have to do the work.
- The observer is the link between the craftsmen and the management, constructive ideas are appreciated as well as co-operation.
- The necessity to conduct studies over a period of time to enable sufficient data to justify the cost of changes to be made.
- The purpose of the sampling is to help eliminate the frustrations which craftsmen experience through shortages of tools, materials, equipment, information etc [7].

#### 4.4 Making the observations

The term "snap shot" has been used to describe the way in which observations must be made [8]. The observer should record only that which is happening at the instant of observation. Events happening just before or after the

observation must not influence the observer. The observer should not remain at the same place longer than it takes to make the observations. He should rather go away and return for example on the next tour/round, even if only one crew is being observed.

#### 4.5 The Study Approach

The term "Study Approach" refers to the way in which observations are made on site. The study approach must tie in with the objectives of the study. The most commonly used approaches are discussed below.

##### 4.5.1 The Tour Approach

The tour approach as the name implies involves the observer in planning a route or tour over the whole site. The route should enable the maximum number of workers to be observed in one tour. The applicability of the tour approach is limited to use in the 'Field Rating' method and also generalized applications of 'Activity Sampling' and the 'Productivity Rating'.

There are several advantages and disadvantages of the tour approach.

##### a) Advantages of the Tour Approach

- A large number of samples can be collected in a short period of time.
- The observer or management is given an indication of the level of activity or management effectiveness over the whole site since the information is not biased towards a craft or area or type of work [9].

- The results obtained can be used to evaluate the effectiveness of improvements made by management.

b) Disadvantages of the Tour Approach

- The results do not take into account the importance of the activities being observed. Information regarding the activities that are critical or important on the program is often more desirable than that for less important activities. Observations of the less important activities may have the effect of distorting the overall picture so giving management the impression that the more important activities are progressing at a faster or slower rate than is actually taking place [10].
- If a tour has been planned to cover a certain area for example on a large site, those workers assigned to the area, not present at the time when the tour is made due to personal or other reasons will not be observed, nor their activity noted. This is a serious downfall of the tour approach since time spent away from the work place is important information for management. On smaller sites where one tour can cover the entire site this problem is less likely to occur [11].
- Another more minor disadvantage is the effect of worker crossover from one area to another. If this is significant, false observations may occur in 'Travel' and

'Carrying of materials/tools' categories. The likelihood of worker crossover will increase where issuing of tools and materials on site is centralized [12].

#### 4.5.2 The Crew Approach

Using the Crew Approach, the observer limits the study so that the work of one or several crews only is observed. This approach is most appropriate for the use of Activity Sampling, Productivity Ratings, Five - Minute Ratings and setting of time standards.

##### a) Advantages of the crew approach

- Individual members of a crew can be identified and where workers are absent a special 'no contact' category is used. This category could provide useful information in itself.
- The crew approach provides an opportunity for a more detailed study of the work, especially with regard to delays [13].
- The crews to be studied can be selected on the basis of the importance of the activity with regard to the programme.
- Additional notes can supplement observations giving details on the work environment; for example, congestion in the area or difficulty of the work [14].

##### b) Disadvantages of the Crew Approach

- The crew approach does not provide the same coverage as does the tour approach and

therefore cannot provide data on activity over the whole site.

#### 4.5.3 The Modified Crew Approach

This approach was developed to 'bridge the gap' between the coverage of the tour approach and the detail provided by the crew approach.

Using the Modified Crew Approach the work of a particular craft is studied over the entire site. In order to obtain a cross section of activities, the craft's work is divided into work assignments.

For Example: Electrical Work

1. Installing conduits
2. Cable pulling
3. Fittings
4. Instrumentation [15]

Plumbing

1. Soil drainage
2. Waste drainage
3. Sanitary fittings
4. Hot water installation - Piping
5. Cold water installation

Crews involved with each type of work are than studied using the normal crew procedure.

It should be noted that the work sampling data will show the time distribution for only those crews selected for the study. The extent to which this represents the entire craft depends upon how well these crews reflect the work being done across the site. It also depends on how well the study crews performing a certain type of work, say cable pulling,

represent all other crews pulling cable [16]. On smaller sites it may be found that only one crew is in operation per work assignment or that one crew will complete all types of work required for that trade .

#### 4.6 The Study Time Frame

Definition of the time periods for sampling studies must also be given attention.

##### 4.6.1 Duration

The duration of a study will depend on the degree of statistical accuracy required, the number of observers employed, the objectives of the study, and the sampling method used.

A study carried out for example using the Five Minute Rating may only take one day especially where any improvements to be made should take place as soon as possible. An example of this might be during a series of concrete pours lasting for 3 days only .

A study of longer duration might be used to establish time standards for an activity or to ascertain the average productivity of a crew over time.

##### 4.6.2 Interval between studies

Work sampling is likely to be most useful when conducted continuously and carried out on a daily basis. This would enable management to evaluate trends in work patterns as well as establish an historical data base. At the same time frequent up to date reports on management effectiveness are provided. Continuous work sampling would involve the full time

employment of observers since management will not have the time available to carry out continuous sampling.

If the interval between studies is too long, for example a few months, the nature of a project may change significantly over that period. It would therefore be difficult to determine the causes for changes in the category percentages from those of previous data and the study would be of limited value [17].

When studies are made at intervals of a few days, for example 1 week, care must be taken to evaluate the nature of work being carried out before any comparisons are drawn with previously made sampling data.

#### 4.6.3 Times during the day for sampling

There are periods during the day in which little or no activity will be observed. For example, during scheduled breaks and in the half hour period after work starts and before it ends. The observer has a choice as to whether to include these periods in his study. However, results of normal work observations are likely to be distorted by sampling within these times and they should therefore be avoided unless it is the specific purpose of the study to evaluate work levels during these periods [18]. During these times workers are normally involved with drawing of tools fetching materials, receiving instructions and clearing up. Only where excessive 'slacking off' is suspected will action be necessary.

Sampling during scheduled breaks may be an unnecessary harassment to workers and should be avoided [19].

#### 4.7 The Analysis and Representation of the Data

Data analysis should be an exhaustive effort at summarizing and sorting data in numerous ingenious ways to expose factors that substantiate known or perceived causes of low productivity [20].

The most commonly used method of evaluating work sampling data is by calculating percentages for each category. Those categories with exceptionally high or low percentages should be considered more closely. Where no data is available to evaluate trends it may be difficult to judge whether percentages are abnormal or not. Acceptable percentages will vary with the nature of the work.

It is recommended that some form of observer critique is made during the observations and should be summarised and included with the work sampling summary sheet. If this is done problem areas can be more effectively evaluated and reasons for delays established.

Figure 11 and Figure 12 show examples of an Observer Critique and Sampling Summary Sheet. It should be emphasized that apart from the data evaluation the observer himself while making an objective study will also serve as an important source of information if he attempts to track down causes of serious problems he sees arising.

The likely outcomes of the data analysis could take the form of recommendations for changes in the following areas:

- Crew sizes
- Equipment location
- Investigation of transport facilities to site causing late starts
- Foremen to workmen ratios
- Regularity of quality checks



Figure 12. Sampling Summary sheet [22]

SITE: Houston DATES: 5/1/62 to 5/1/62  
 PROJECT #: 2973 ANALYST: P. Croston  
 Craft: All Size of Force: 516  
 No. of Observations: 1496

<u>Categories</u>	<u>Percentages</u>
Erection	<u>16.0</u>
Fabrication	<u>13.0</u>
Dismantle	<u>3.2</u>
Handle with Power Equipment	<u>1.1</u>
Rigging & Plopping	<u>0.1</u>
General Cleanup	<u>1.6</u>
<b>TOTAL DIRECT ACTIVITY</b>	<b><u>33.0</u></b>
Preparation	<u>5.1</u>
Handle In Job Area	<u>7.1</u>
Job Cleanup	<u>0.6</u>
Allowances	<u>11.1</u>
<b>TOTAL INDIRECT ACTIVITY</b>	<b><u>23.9</u></b>
Idle	<u>19.4</u>
Standby	<u>3.0</u>
Move Empty	<u>11.0</u>
Ineffective	<u>6.7</u>
Handle Outside Job Area	<u>4.0</u>
<b>TOTAL NONCONTRIBUTORY</b>	<b><u>43.1</u></b>

- Suitability of plant and equipment
- Matching and balancing of plant to manpower
- Further investigation using Method study - a Work Study technique
- Material location & handling

Evaluation of trends or changes using only the broad categories of Direct Work, Support Work and Delays may be more beneficial over a short time period than using individual categories, since they will tend to be less variable than the individual categories [23]. A variation of say 5% in the Delay category would be of more concern than one of 10% in the material delay sub-category over one week.

#### 4.7.1 The use of Labour-Utilization Factors

Work Sampling data may also be represented by using Labour-Utilization Factors.

In order to obtain the best labour-utilization factor, observations would have to show a very large proportion of Direct work observations. The factor does however take into account that some indirect contributory work must be done.

The calculation is as follows:

$$\text{Labour-Utilization Factor (1) [24]} \\ = \frac{(\text{Direct work}) + 1/4 (\text{Indirect work})}{\text{Total observed}}$$

Factors using only effective work have also been used.

## Labour-utilization factor (2) [25]

$$= \frac{\text{Direct work}}{\text{Total observed}}$$

Care should be taken when interpreting Labour Utilization Factors since they may be biased toward those types of work which by their nature involve a greater proportion of Direct work than others. For example, a painter as compared with a plumber or electrician [26].

However, if a data base were established factors could be compared with those already established for similar work and would therefore be of some use to management. It must be remembered that Labour-Utilization Factors offer a numerical measure of the quality of the foremen and of site management, not the quality of the workmen [27].

### 4.7.2 The use of the computer for analysis of results

The main use of the computer here would be in its data storage capabilities as well as the analysis of trends over time.

New data could be fed into the computer daily under the relevant headings. Programs could be designed to produce figures for changes in percentages for each trade as well as the calculation of Labour-Utilization Factors.

The use of the computer is most appropriate for continuous sampling. Figure 13 shows how sampling data could be represented using the Lotus 123 package.

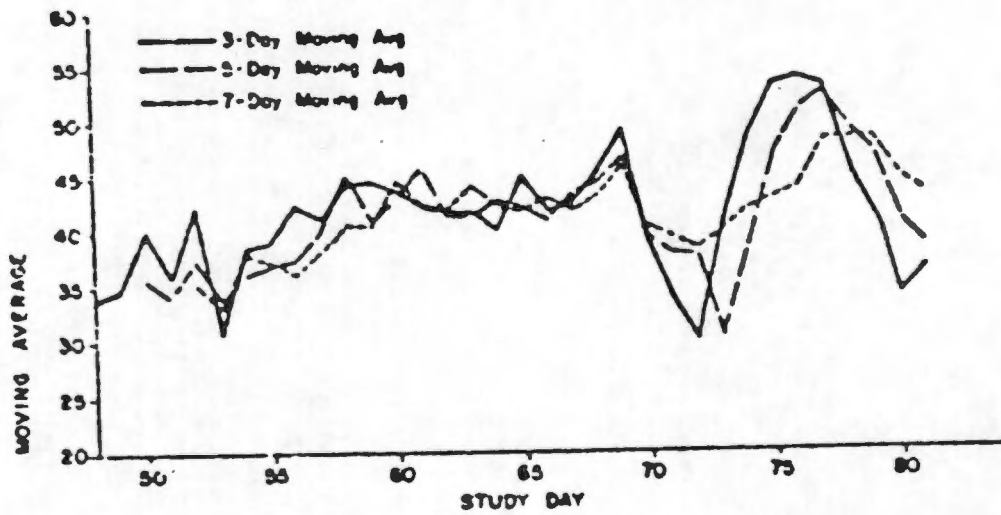
**Figure 13      Computer Sampling Analysis**

Trade : Bricklaying			
	Crew 1	Crew 2	Crew 3
<u>Present Week (No )</u>			
No of sampling rounds			
No of observations			
Limits of error			
<u>Direct Work</u>			
Present Week %			
Past Week %			
Moving Average %			
Percentage change			
<u>Support Work</u>			
Present Week %			
Past Week %			
Moving Average %			
Percentage change			
<u>Delays</u>			
Present Week %			
Past Week %			
Moving Average %			
Percentage change			

The use of moving averages to evaluate trends when involved in continuous work sampling can be useful and will provide a high degree of accuracy since large amounts of data are accumulated and used in the calculation of the averages.

The results can be represented using graphs such as shown in Figure 14.

Figure 14. Trend analysis using moving averages [28]



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## 5. PROBLEMS WITH THE USE OF WORK SAMPLING

### 5.1 Productivity

When trying to assess levels of productivity for an activity, it is normal to split the work into the three main subdivisions of Productive (direct), Indirectly productive (supportive) and Non-productive (delay). When looking at an activity in isolation and taking into consideration the work circumstances, an indication of productivity can be obtained. However, care should be taken when comparing these results to those of the same activity on a different site. Methods and equipment as well as the ability of the workmen and the pace set for the project will most likely vary, causing the percentages under the above mentioned subdivisions to vary.

Productivity should ultimately be measured in output/manhour rather than by the specific activities involved since activity and productivity are not synonymous. Bearing this in mind, the use of Work Sampling and more specifically Productivity Ratings as a diagnostic tool to supplement direct productivity measurement may be extremely useful to management.[1]

### 5.2 Determining the causes of delays

A problem arising from the lack of direct communication between observer and workmen, is the difficulty of determining accurately the causes of delays. Delays which are not obvious to the observer as to their cause can only be determined by direct communication with workers.

Therefore, if an obvious delay is observed, the observer should question the workman concerned as to the reasons for the delay. Care should be taken that workmen are not

stopped from working, nor should a crowd be drawn to the observer due to lengthy conversation with a workman. [2]

### 5.3 Original work and Rework

Without prior knowledge of the work done prior to the study the observer has no way of knowing whether the work being done is 'original work' or 'rework'. Large amounts of rework will distort any analysis of productivity by the observer [3].

### 5.4 The necessity of work being performed

Bad planning of the sequence of work may involve the workmen in work that might have been avoided if properly planned. For example, chasing for conduits which were not installed before brickwork commenced. A general or overall study approach would not take this into account and observation of workers involved in this type of work would distort the results.

### 5.5 Reaction to the study by workmen and foremen

Without adequate knowledge of the purposes and objectives of a Work Sampling programme there is likely to be suspicion amongst workers and their foremen as to the intentions of the observer. This may often result in the workers giving the impression that they are working while the observer is present [4].

List of References - Section 5

1. The Business Roundtable, Work Sampling and Foreman Delay Surveys, p.2-3.
2. John D. Borcharding, "Work Sampling", Manual for the course of Managing Productivity, p.22.
3. Luh-Maan Chang and John D. Borcharding, "Craftsman Questionnaire Sampling", Journal of Construction Engineering and Management, p.551.
4. op. cit.,3,p.543.

## 6. A COMPARISON OF WORK SAMPLING WITH OTHER METHODS OF MEASURING PRODUCTIVITY (Abstracted from [1])

The methods under comparison all focus their attention mainly on labour productivity. Labour may be considered one of the chief resources with which site management is able to affect the cost of a project. Changes in labour utilization are often more easily made by site management than changes in other resources such as materials and plant which may have to be approved by the client or by higher management.

Brief discussion of the methods is followed by comparison of the methods using a rating system.

### 6.1 Cost Reports/Unit Costs

A system of cost reporting whereby the cost of a portion or unit of work completed is calculated on a weekly or monthly basis is used by most construction companies. These reports are compared with the cost allowances made prior to the start of the project. This system provides management with an indication of whether the project will be profitable or not and provides an excellent historical data base. However, inherent in this system are a number of disadvantages as described below:

- Management can not be sure if the original estimates made are correct. An item which is reported as below the estimate may still be able to be reduced but will most likely not be brought to the attention of the management.
- The time delay between completion of the work and the cost report often makes it impossible for management to make timely improvement due to the changing mixture of the work.

- Changing environmental and economic factors which are likely to influence the costs of a project make cost comparisons difficult.
- Measurement of work which may be of a similar nature but due to size or situation involves varying amounts of labour, may prove difficult. For example; placing of concrete in surface beds or beams

## 6.2 Questionnaires

Questionnaires completed by workmen selected from various trades can be useful for identifying administrative and motivational problems on the site. Questionnaires may cover a wide range of topics such as the following:

- Personal Data
- Materials and Tools
- Rework
- Pre-planning/scheduling
- Absenteeism
- Labour shortages
- Overtime
- Supervisor Capabilities
- General comment

Problems with the use of questionnaires may be encountered when used on South African sites considering the degree of literacy and variation in language of the labour force. Furthermore, numerical results obtained from questionnaires may lack validity due to inadequate recall of the workmen. Another drawback is that the questionnaire requires workmen to leave the work area, causing delay and disruption.

### 6.3 Interviews

Interviews may be used to obtain specific information from selected workmen to supplement information gained from questionnaires. Interviews are not recommended for a large number of workmen, nor as a substitute for the questionnaire due to time considerations.

### 6.4 Foremen Delay Surveys

The Foremen Delay Survey (FDS) is a newly developed method mainly applicable to large sites. The FDS makes use of the foreman who is closest to the work to establish the sources of inefficiencies on a project.

Figure 15 shows an example of a typical FDS form.

The notable features of the FDS are as follows:

- They provide current estimates, since they ask for information at the end of each day.
- They can canvas an entire project, rather than just a sample of the work force.
- They are inexpensive and easy to administer, since only about five minutes of a foreman's time is required to complete the form.
- They provide information on specific items, such as materials, tools, etc.
- They identify delay difficulties by craft and crew, thus allowing management's attention to be directed to those crafts needing assistance.
- They provide a mechanism for two-way communication between project management and foremen. Follow-up

Figure 15. Sample Foremen Delay Survey Form [1]

<u>FOREMAN DELAY SURVEY</u>				
CRAFT: _____				
NAME OF FOREMAN: _____		GENERAL FOREMAN: _____		
(DATE) DAILY EVALUATION: _____		NUMBER IN CREW: _____		
PROBLEMS CAUSING DELAY				
	Number of Hours	MANHOURS LOST		
		x	Number of Men	Manhours
1.a Waiting for Materials (warehouse)	_____		_____	_____
1.b Waiting for Materials (outside fabrication)	_____		_____	_____
2. Waiting for Tools or Tools not available	_____		_____	_____
3. Waiting for Equipment	_____		_____	_____
4. Equipment Breakdowns	_____		_____	_____
5.a Changes/Redoing Work (design errors)	_____		_____	_____
5.b Changes/Redoing Work (prefabrication errors)	_____		_____	_____
5.c Changes/Redoing Work (field errors)	_____		_____	_____
6. Move to Other Work Area	_____		_____	_____
7. Waiting for Information	_____		_____	_____
8. Interference with Other Crews	_____		_____	_____
9. Overcrowded Working Areas	_____		_____	_____
10. Other	_____		_____	_____
_____	_____		_____	_____
_____	_____		_____	_____
COMMENTS: _____				
_____				
_____				
_____				

meetings to discuss survey results allow discussion of identified problem areas and avenues for solutions.

A disadvantage of the FDS is that no information is provided as to the efficiency of the methods used nor as to the competence of the work force. Furthermore foremen may be unwilling to disclose lost time due to their own inadequacies. Finally, the foreman to crew ratio may be such that foremen may not spend sufficient time with each crew to identify all delays.

#### 6.5 Method study using time-lapse photography as a substitute for visual observation

The use of time-lapse photography for method study provides a more economically and technically feasible alternative to visual method study when carried out on a large scale.

Time-lapse photography makes use of a slow speed movie camera which takes frames at preselected time intervals. The film can later be shown at a speed which will enable times to be obtained for specific activities. Furthermore the film enables an investigation of the methods used with the objective of bringing about improvements.

Time-lapse photography is best suited to those activities which are repetitive and which can easily be viewed from one camera position since it is desirable to leave the camera unattended.

#### 6.6 Comparisons of Methods

The various techniques for productivity measurement have different applications. Thus, any attempt at comparison must relate to their different applications. Comparisons are made for illustrative purposes in Tables 2 - 5.

**Table 2. Comparison of Techniques in Giving Information for Positive Action (3=Best Technique, 0=Worst Technique)**

	Action Level					
	Client	Project Manager	Superintendent	General Foreman	Foreman	Craftsman
Costs	3	2	1	0	0	0
Schedule	3	2	2	1	0	0
Work Sampling	2	3	3	2	1	0
Questionnaires (Craftsmen)	2	3	3	2	1	0
Interviews (Craftsmen and Foremen)	2	3	3	2	1	0
Foremen Delay Surveys	2	3	3	3	2	0
Time-Lapse Photography	1	2	3	3	3	2
Visual Observations	0	1	1	2	2	3

**Table 3. Cost Effectiveness of Information Obtained (3=Best Technique, 0=Worst Technique)**

	Cost to get Information	Speed to get Information	Job Record Usefulness	Accuracy of Information
Costs	2	0	3	1
Schedule	2	0	2	1
Work Sampling	1	2	1	2
Questionnaires (Craftsmen)	2	3	1	1
Interviews (Craftsmen and Foremen)	2	3	0	1
Foremen Delay Surveys	3	3	2	2
Time-Lapse Photography	1	1	3	3
Visual Observations	1	1	1	3

**Table 4. Comparison of Techniques in Identifying Heirarchy Levels of Problem Sources (3=Best Technique, 0=Worst Technique)**

	Principal Source of Problem					
	Craftsman	Foreman	General Foreman	Superintendent	Project Manager	Support Areas
Costs	0	0	0	0	0	0
Schedule	0	0	0	0	0	0
Work Sampling	0	2	2	3	3	0
Questionnaires (Craftsmen)	0	2	2	2	2	3
Interviews (Craftsmen and Foremen)	0	0	0	3	3	2
Foremen Delay Surveys	0	0	3	2	2	3
Time-Lapse Photography	3	3	3	2	2	1
Visual Observations	3	3	2	2	1	2

**Table 5. Comparison of Techniques in Identifying Types of Problems (3=Best Technique, 0=Worst Technique)**

	Methods	Administrative or Support	Motivational
Cost	0	0	0
Schedule	0	0	0
Work Sampling	1	2	0
Questionnaires	0	3	2
Interviews	0	2	3
Foremen Delay Surveys	0	3	1
Time-Lapse Photography	3	1	0
Visual Observations	3	2	0

Subjective ratings of 0 to 3 are given to the various techniques. A rating of 3 represents the best technique for that particular purpose, whereas a rating of 0 represents the worst technique.

Table 2 compares the techniques in providing information for positive action for the various participants in a project. Cost and schedule information is most useful to the client, while data from time-lapse photography and visual observation is of most interest to the craftsmen.

The costs and value of the information obtained are compared in Table 3. Foremen Delay Surveys are the least expensive. Foremen Delay Surveys, Questionnaires and Interviews provide the most rapid information. Cost data and time-lapse films are the most useful for job records. Data from time-lapse films and visual observations are the most accurate, although they are limited in scope.

A major purpose in any technique is to provide information regarding the level at which a problem occurs, or can be solved. A comparison of the techniques in identifying problem sources is given in Table 4. Only time-lapse photography and visual observations are useful in identifying problems caused at the craftsmen level. Cost and schedule information is of limited usefulness in identifying sources of problems.

Problem areas in low productivity can be categorized as methods, administrative or support, and motivational. The measurement techniques are compared, in Table 5, in their ability to identify problems in these categories. Again, although limited in scope, time-lapse photography and visual observations are the most useful in identifying poor methods or construction techniques. Foremen Delay Surveys and questionnaires are the most useful tools for evaluating administrative or support oriented problems. Questionnaires

and interviews are the most useful in identifying and evaluating motivational problems.

List of References - Section 6

1. R.L. Tucker et al, "Methods to Measure Productivity in Construction", Manual for the short course of Construction Productivity Measurement, pp.13-39.

## 7. CASE STUDY

(Site: Retirement village and central facilities -Constantia  
- Cape Town.)

### 7.1 Introduction

The objectives of carrying out this case study were, firstly, to become aware of the differences between the description of the Work Sampling techniques in theory, and the execution of them in practice and, secondly, to make a personal evaluation of the ease of applicability of these techniques to a South African construction site.

The site chosen was a retirement village with central facilities in Constantia, Cape Town. The village consisted of approximately 60 housing units at various stages of completion. The central facility is a double storey structure which is to house some accommodation, medical, recreation, cleaning and laundry facilities.

The study duration was 3 days. During that time period the methods as described in section 2 of this report were used on various activities in progress on site.

The summary sheets for each technique are accompanied by the findings and conclusions of the observer as regards the above mentioned objectives.

### 7.2 Field Ratings and Activity Sampling using the Tour approach.

A Field Rating and Activity Sampling were carried out simultaneously in order to illustrate the difference in usefulness of the results obtained. Observations were taken by making 10 tours through the central facilities building where an average of 40 workers were involved in a number of

diverse activities which included tiling, plastering, screeding, carpentry, ceilings and erecting of forms. The tours were made at random times and a tick sheet was used for both methods. As an observation was made it was entered under the correct category of the Activity Sampling sheet and then classified under "working" or "not working" on the Field Rating sheet, thus giving the same number of observations for both techniques. The 10 tours provided a total of 402 observations, sufficient to provide a sound statistical sample at the 95% confidence 5% limit of error .

Table 6 and Table 7 show summary sheets for each technique.

**Table 6      Field Rating Summary Sheet**

---

Date: 12-08-87  
Weather: Cold and Wet  
Start time: 08h17  
Finish time: 16h20

---

Tour Number	Number of Men observed	Number Working	Number Not-working
1	29	15	14
2	33	17	16
3	32	21	11
4	40	30	10
5	36	29	7
6	45	33	12
7	48	30	18
8	45	33	12
9	43	26	17
10	51	34	17
<b>Totals</b>	<b>402</b>	<b>268</b>	<b>134</b>

---

Number of Observations	402
Number of Men Working	268
Number of Men Not-Working	134
Percentage Working (268/402)	<u>67%</u>
(Foremen and Personal time included)	
<b>FIELD RATING INDEX</b>	<b>67%</b>

---

**Table 7 Activity Sampling Summary Sheet**

Date: 12-08-87 Weather: Cold and Wet Start time: 08h17 Finish time: 16h20		
CATEGORY	OBSERVATIONS	%
<u>Working Categories</u>		
Direct Work	220	55
Travel with Materials/Tools	36	9
Giving/Receiving Instructions	8	2
Planning of Work	4	1
	268	67
<u>Not-Working Categories</u>		
Waiting (for other craftsmen)	52	13
Travel empty handed	34	8
Late start/Early quit	7	2
Idle/Unexplained	37	9
Personal	4	1
	134	33
<b>TOTALS</b>	<b>402</b>	<b>100</b>

### 7.2.1 Analysis of Results

The Field Rating Index of 67% could be considered a satisfactory level of activity taking into account that the observations were taken for a number of diverse activities each likely to show differing percentages if studied individually. However, other than providing a very general indication of activity, this result is of little use to management.

The Activity Sampling summary sheet shows a number of subdivisions within the "Working" and "Not Working" categories. The total percentages of the two categories are the same as the Field Rating, however the subdivisions are far more informative. In the "Working" categories the percentages would not seem to cause any concern except perhaps the desire for a higher proportion of Direct Work. In the "Not-Working" categories, the 9% of Idle/Unexplained delay is of concern. The typical observation in this category saw workers standing idle and not attached to a particular activity. The observer at this stage of the study did not confront workers as to the reasons for their idleness. The percentage for the Idle/Unexplained category might indicate to management that a higher level of supervision is necessary in this area of the site, or perhaps that certain activities were overmanned during this time period. It should also be noted that the tours took place indoors and that the weather was inclement for part of the duration of the study. This may have caused workers to seek cover from the rain at times, leaving their assigned tasks.

#### 7.2.2 Problems encountered by the observer

The observer did not find difficulty in using the Field Rating since the activities observed were first categorized on the Activity Sampling sheet making it easier to determine the "Working" /"Not-working" decision.

Difficulty was encountered initially in the selection of the Activity Sampling categories mainly because of the diversity of activities in progress. Selection of categories necessitated a few preliminary tours before categories could be finalized.

The observer encountered an initial inquisitiveness and perhaps suspicion by workers. This diminished as the study progressed. An initial reaction by workers in the presence of the observer causing workers to appear busy at the time of observation was noted. The observer overcame this by making the observation a few metres ahead and thereby appearing not to be looking when spotted by the workman concerned.

The categories of Travel empty handed and Idle/Unexplained were found inadequate in explaining the causes of these delays.

The observer does not find any special problems applying these techniques to a South African construction site since they do not involve the workmen in the study in any way. The observer does however see limitations in their usefulness, especially when used in isolation. Continuous use incorporating trend analysis might be of use to management.

### **7.3 A Productivity Rating using the Crew approach**

A Productivity Rating was carried out on 8 bricklaying crews working on the small housing units, in order to get an indication of the levels of activity for bricklaying generally. The size of the crews was between 2 and 4 bricklayers per crew. A total of 20 Bricklayers were operating in the area being studied. The average total labour force in the area was 50.4 (including bricklayers). Each crew was observed at 15 random times throughout the day making up a total of 756 observations, a statistically sound sample at the 95% confidence, 5% limit of error level. A total of 19 sub-categories were used under the headings of Direct, Support and Delay activity.

Table 8 shows the Productivity Rating summary sheet with percentages for each category and the approximate quantity of work produced over the study period.

**Table 8 Productivity Rating Summary Sheet**

ACTIVITY	TOT	%	QTY
<b>Date: 13-08-87</b>			
<b>Weather: Fine</b>			
<b>Start time: 08h00</b>			
<b>Finish time: 17h00</b>			
<b>Activity: Bricklaying</b>			
<b>Operatives: Ave 50 (8 crews)</b>			
<b><u>DIRECT ACTIVITY</u></b>			
Placing bricks/mortar etc	214	28	+/- 120m2
Adjusting fishline/taking levels	22	3	of 1 brick &
Reading plans	2	0.2	cavity
Taking/Giving instructions	7	0.9	walling
<b><u>SUPPORT (INDIRECT) ACTIVITY</u></b>			
Moving scaffolding	14	2	
Loading bricks at brickpile	27	3.6	
Unloading/stacking bricks	50	6.6	
Mixing mortar/loading boards	31	4.1	
Travel with tools	35	4.6	
Travel with materials	42	5.6	
Planning work	24	3.2	
Miscellaneous (frames & conduits)	56	7.4	
<b><u>DELAYS</u></b>			
Travel - empty handed	46	6.1	
Waiting within crew	75	10	
Material delay	10	1.3	
Labour delay	5	0.7	
Personal delay	77	10.2	
Late start/early quit	6	0.8	
Unexplained delay	13	1.7	
	<b>756</b>	<b>100</b>	<b>+/-120m2</b>

### 7.3.1 Analysis of Results

Looking at the results in Table 8, the Delay category should be of most concern to management. A total percentage of 30.8 would seem to be excessive.

The 10.2% for Personal activity is significant and was observed to consist mainly of talking where it did not concern the job and taking rest periods during working time. The material delay involved bricklayers waiting for the arrival of the correct sized lintels to continue with the job as well as minor delays for bricks and mortar. The labour delay was due to waiting for labour to adjust the scaffolding which was erected too close to a wall.

As far as productivity is concerned 20, bricklayers completed +/- 120m<sup>2</sup> of 1 Brick and Cavity walling over the study period. The brick size of 90mm wide X 110mm high X 220 mm long calculates to +/- 72 bricks per meter squared of double skin thickness. Therefore 20 bricklayers laid 120 X 72 bricks = 8640 bricks. This gives a rate of 432 bricks/bricklayer/day. The rate used for the programming of the job was 500 bricks/day using 1 bricklayer and 1.5 labourers. It should be noted that this rate is an average rate and is likely to differ with the difficulty of the work. The brickwork being observed included the building in of window and door frames as well as a number of corners. The height at which the work was carried out varied from ground level to 1 scaffold height(+/- 4m).

Using the manning ratio of 1.5 labourers per bricklayer, 20 bricklayers would need 30 labourers giving a total of 50 on site. This would appear to be accurate considering the average total labour force of 50.4. It must be noted that some workers involved with setting up door and window frames and final preparation of conduits were also included in the observations (+/- 4 workers).

### 7.3.2 Problems encountered by the observer

At the start of the study the observer introduced himself to each crew and explained briefly the purpose of the study, urging the workers not to concern themselves with his presence. This served to decrease the initial inquisitiveness by workers as encountered with the previous studies.

An initial observation period was necessary to decide on the categories to be used. Even after this, further categories were added as new activities were encountered.

The observer encountered difficulty with the "Travel - empty handed" category. Unless a worker who is observed travelling empty handed is watched until he reaches his destination the observer has no way of determining the purpose of the trip. Thus a worker walking to fetch materials which is in fact a Support activity would be classified as a Delay or Non-Productive activity. Alternately the worker walking to the toilet facilities or quitting early will be classified correctly. The observer found that a slightly extended observation of a worker often served to clarify the nature of the observed delay. When this was done care was taken not to change the classification if the worker started a different activity. Occasionally the observer questioned workmen as to the causes of delays e.g. Waiting for lintels. No difficulties were encountered with classifying activity in the Direct and Supportive categories.

It is suggested that if Productivity Ratings are to be carried out, they should not be done by management who have other assigned tasks since a study which necessitates observations to be made at intervals of

less than half an hour will consume most of the observers time. Furthermore reaction to the presence of an observer known to be part of management will likely increase. The observer feels that he was at an advantage not being known to the workers and not being employed by the company.

#### **7.4 Five Minute Ratings**

A number of Five Minute Ratings were carried out on different activities.

##### **Activity 1 - Nailing of ceiling brandering**

Only one rating was done for this activity since the workers were finishing off the brandering at the time when the study was made. Six workmen were studied for a period of 13 minutes. In this time activities observed were, nailing and sawing of ceiling brandering as well as some minor delays. The effectiveness of the study was 61% (See Table 9).

In accordance with the procedure for the Five Minute Rating a worker was classified as effective for 1 minute of study if he was observed to be working for more than half of that minute. Identification of the workers proved extremely difficult because the nature of the work involved the workers in changing position often and walking up and down the long scaffolding in the corridor where work was taking place. Furthermore, all of the workmen were involved in the same type of activity .

A further difficulty encountered was the method used of filling in all the blocks on the study sheet, classified as effective after each minute. The observer found that filling in of the blocks tended to encroach on the observing time for the next minute. Furthermore if a reasonable

**Table 9. 5 Minute Rating - Sheet No: 1.**

**Activity:** CEILING BRANDERING

**Date:** 12-08-87.

**Weather:** COLD

**Plant:** -

WORKMAN 1. 2. 3. 4. 5. 6.

Time	1.	2.	3.	4.	5.	6.	Notes on Activity
09h47	✓	✓	✓	✓	✓	×	Nailing brandering.
48	✓	✓	✓	×	×	✓	" "
49	×	×	×	✓	✓	✓	Nailing brandering & Sawing.
50	✓	×	×	✓	✓	✓	Nailing brandering.
51	×	×	✓	✓	×	×	End nailing
52	✓	×	×	✓	✓	✓	Stringing line.
53	✓	✓	×	×	✓	✓	Nailing.
54	✓	✓	✓	✓	✓	✓	"
55	×	✓	✓	×	✓	✓	"
56	✓	×	×	✓	✓	✓	"
57	✓	×	×	×	×	✓	Waiting.
58	✓	×	×	×	×	×	Waiting.
59	×	✓	✓	✓	✓	✓	
<b>Total</b>	9	6	6	8	9	10	<b>Effective unit totals</b>

**Total units:** 78

**Total effective units:** 48

**Effectiveness** 61 %

expectation is that an activity will have over 50% of effective units, it would be quicker to fill in the ineffective blocks after each minute. This approach was adopted in further studies and the effective blocks were filled in after completion of each rating. The observer also found that those workers who were not working usually stayed in the same place waiting or resting, and were easy to monitor; a working man is nearly always moving in some way.

The observer does not consider the results of the first study to be reliable considering the above mentioned difficulties.

### Activity 2 - Brickwork

Five ratings were made over one day for a brickwork crew consisting of 4 bricklayers and 3 labourers. The length of the studies made varied between 10 minutes and 24 minutes. The effectiveness of the crew for the five ratings was as follows (see Tables 10 - 14):

Rating:	1	85%
	2	58%
	3	70%
	4	74%
	5	81%

The average effectiveness was 74%.

The low percentage for Rating 2 can be attributed to the time at which the rating was made. (13h07 to 13h30). This was just before the scheduled break for lunch from 13h30 to 14h00. For the last two minutes there was no activity due to an early quit by the whole crew.

Ratings 1,3,4 and 5 showed no significant delays other than minor hold-ups due to the following:



Table 11. 5 Minute Rating - Sheet No: 2.

Activity: BRICKLAYING;

Date: 13<sup>th</sup>08-87.

Weather: FINE

Plant: -

BRICKLAYER 1. 2. 3. 4.  
LABOUR 1. 2. 3.

Time	BRICKLAYER				LABOUR			Notes on Activity
	1.	2.	3.	4.	1.	2.	3.	
13h07	✓	✓	✓	✓	×	✓	×	
08	✓	×	✓	✓	✓	✓	✓	
09	×	×	✓	✓	×	✓	×	
10	×	✓	✓	✓	×	✓	×	Bricklayers and labour idle, mostly without reason.
11	✓	×	×	✓	×	✓	×	
12	×	×	×	×	×	×	×	
13	✓	✓	✓	✓	✓	×	×	"
14	✓	✓	✓	✓	×	✓	✓	
15	✓	✓	✓	✓	✓	✓	✓	
16	✓	✓	✓	✓	✓	✓	✓	
17	✓	✓	×	✓	×	✓	×	
18	✓	×	×	✓	✓	×	×	"
19	✓	×	×	×	×	✓	×	
20	✓	✓	×	✓	×	×	×	
21	✓	✓	✓	✓	×	×	×	
22	✓	✓	✓	✓	×	✓	×	"
23	×	×	✓	✓	✓	✓	✓	
24	✓	✓	✓	✓	✓	×	✓	
25	✓	✓	✓	✓	×	×	×	
26	✓	✓	✓	✓	✓	×	✓	
27	✓	✓	✓	✓	×	×	×	"
28	✓	✓	✓	✓	×	×	×	
29	✓	×	×	×	×	×	×	
30	×	×	×	×	×	×	×	
LUNCH								
Total	19	15	16	20	8	12	7	Effective unit totals

Total units: 168

Total effective units: 97

Effectiveness 58 %

**Table 12. 5 Minute Rating - Sheet No: 3.**

**Activity:** BRICKLAYING

**Date:** 13-08-87

**Weather:** FINE

**Plant:** -

BRICKLAYER

1. 2. 3. 4.

LABOUR

1. 2. 3.

Time	1.	2.	3.	4.	1.	2.	3.	Notes on Activity
15h01	X	X	✓	✓	✓	✓	✓	
02	✓	✓	X	✓	✓	✓	✓	Setting- up windows - Delay.
03	X	X	X	✓	✓	✓	✓	Mortar Delay.
04	✓	✓	✓	✓	✓	✓	✓	
05	✓	✓	✓	✓	✓	X	✓	
06	✓	X	X	✓	X	X	✓	Talking to foreman.
07	✓	X	X	X	✓	X	✓	" "
08	✓	✓	X	✓	✓	✓	✓	
09	✓	✓	✓	✓	✓	✓	X	
10	✓	✓	✓	✓	✓	X	X	
11	X	✓	✓	✓	X	X	✓	Labour 1 idle.
12	X	✓	✓	✓	X	X	✓	
13	✓	✓	✓	✓	X	✓	✓	
14	✓	✓	✓	✓	X	✓	✓	
15	X	X	X	✓	X	✓	✓	
<b>Total</b>	10	10	9	14	9	9	13	<b>Effective unit totals</b>

**Total units:** 105

**Total effective units:** 74

**Effectiveness** 70 %



**Table 14. 5 Minute Rating - Sheet No: 5.**

**Activity:** BRICKLAYING;

**Date:** 13-08-87.

**Weather:** FINE

**Plant:** -

Bricklayer 1. 2. 3. 1. 2.  
Labour

Time	1.	2.	3.	1.	2.	Notes on Activity
16h22	✓	✗	✓	✗	✗	Waiting Idle - waiting for mortar
23	✓	✗	✓	✗	✗	
24	✓	✗	✓	✓	✓	
25	✓	✓	✓	✓	✓	
26	✓	✓	✓	✓	✓	
27	✓	✓	✓	✓	✓	
28	✓	✓	✓	✓	✗	
29	✓	✓	✓	✗	✗	
30	✓	✓	✓	✓	✗	
31	✓	✗	✓	✓	✗	
32	✓	✓	✓	✓	✓	
33	✓	✓	✓	✓	✓	
34	✓	✓	✓	✓	✓	
35	✓	✓	✓	✓	✓	
<b>Total</b>	14	10	14	11	8	<b>Effective unit totals</b>

**Total units:** 70

**Total effective units:** 57

**Effectiveness** 81%

- Foreman's instructions
- Setting up of a window frame
- Labourers idle where sufficient bricks and mortar had been stacked and prepared for the bricklayers.

In rating 2 one labourer was observed to be slacking off excessively (17 minutes out of 24).

The observer found little difficulty with completing the ratings for Activity 2 for the following reasons:

- Marking of inefficient time blocks as opposed to effective ones.
- Identification of workers was easier as they were split into two groups bricklayers and labourers.
- Increased familiarity with the workers and with the rating method.

### Activity 3 - Pouring of concrete using Readymixed concrete placed by a JCB shovel

During the study period a JCB was used to transport concrete from the Readymixed truck mixer to three different locations within the same general area of the site. The concrete was to be used as filling to foundation walls, (Pan 1 & Pan 2), and for a surface bed (slab) to a housing unit. Two crews of three labourers each were responsible for placing the concrete. Both crews were on standby at the start of the study period.

Table 15 shows the Rating sheet on which is described the basic pattern followed by the two vehicles.

The most significant delay is that of the three workers responsible for placing the concrete at the surface bed. The Readymixed truck mixer was positioned wrongly so as to

Table 15. 5 Minute Rating - Sheet No: 1.

**Activity:** Pouring of concrete with  
**Date:** Readimix and JCB  
 14.08.87  
**Weather:** Fair  
**Plant:** JCB, Readimix Lorry,

Time	JCB		Readimix Lorry						Notes on Activity
	1.	2.	1.	2.	3.	(4.)	(5.)	(6.)	
09h46	✓	×	✓	✓	✓	✓	✓	✓	JCB, pouring + travel
47	×	✓	✓	×	×	×	×	×	
48	×	✓	✓	✓	✓	×	×	×	Pouring concrete
49	✓	×	×	×	×	×	×	×	Waiting while concrete dumped - Pan 1
50	×	×	✓	✓	✓	×	×	×	Men working and placing concrete
51	×	×	✓	✓	✓	×	×	×	" " "
52	×	×	✓	✓	✓	×	×	×	" " "
53	✓	✓	✓	✓	✓	×	×	×	JCB + RM moved to new location
54	✓	✓	✓	×	×	×	×	×	JCB collects concrete - travel to Pan 2
55	×	×	✓	✓	✓	×	×	×	Waiting for labour + traffic
56	✓	✓	✓	✓	✓	×	×	×	JCB and RM move to new location
57	✓	✓	✓	✓	✓	✓	✓	✓	JCB collects concrete - travel to slab
58	✓	×	✓	✓	✓	✓	✓	✓	JCB travel
59	✓	✓	✓	✓	✓	×	×	×	JCB collects concrete - travel to slab
10h00	✓	×	✓	✓	✓	✓	✓	✓	JCB travel + labour working
01	✓	✓	✓	✓	✓	×	×	×	JCB collects concrete - travel to slab
02	✓	×	✓	✓	✓	✓	✓	✓	JCB travel + labour working
03	✓	✓	✓	✓	✓	×	×	×	JCB collects concrete - to slab, men wait
04	✓	×	✓	✓	✓	✓	✓	✓	JCB travel + labour working
05	×	×	✓	✓	✓	✓	✓	✓	Delay - slack operator - RM
06	✓	×	✓	✓	✓	×	×	×	JCB collects concrete - travel to slab - men wait
<b>Total</b>	14	9	20	17	17	7	7	7	<b>Effective unit totals</b>

**Total units:** 168

**Total effective units:** 98

**Effectiveness** 58%

prevent access by the JCB to the surface bed as well as the second foundation wall location (Pan 2). Thus the necessary movement to new locations in minute 8 and 11 of the study by both vehicles to give access first to Pan 2 and then to the surface bed. A central positioning on the site would have allowed access to all 3 distribution points and would have had the effect of shortening the delay time for the waiting labourers.

Taken in isolation this change would not seem to make significant improvement. However, where large quantities of concrete are being poured and there is more than one truck involved, optimum positioning of vehicles is of prime importance. The Five Minute Rating allows a manager or foreman to make a quick appraisal and to make changes before the situation becomes critical and costly.

The observer finds the Five Minute Rating easily applicable to South African construction sites and recommends its use especially where decisions for change in method or procedure should be made quickly in order to prevent delay and to cut costs.

#### 7.5 Craftsman Questionnaire Sampling (CQS)

Before commencing with the case study the observer suspected that problems would be encountered with the application of CQS to a South African Construction site because of the problem of illiteracy amongst a number of the workmen. This would have made it impossible to carry out the study in the manner previously prescribed (Section 3.6). The observer therefore attempted to complete the study by means of oral questioning of crews as to their activities and by marking down their replies on a sheet containing all of the categories used on the questionnaires. Unfortunately this too proved to be unsuccessful due to the inability of the observer to speak any of the African languages spoken by

most workmen on site, and the inability of most African workers to speak or understand enough English to answer the questions put to them.

The observer then embarked on a second course of action whereby a tour of the site was made and each artisan (nearly all English or Afrikaans speaking) was questioned as to the nature of any delays he had experienced during the course of the day. This technique has an advantage over the CQS in that the delay caused to workmen in the execution of the study could be minimized. Furthermore, if a number of tours were made throughout the day, any delays which were still occurring at the time of questioning or which needed immediate action could be rectified by management immediately.

#### 7.5.1 Analysis of Results

The findings of the "Artisan Delay Survey" for the tour made of the site showed the following delays to have occurred:

- Bricklayers

Minor delays due to the insufficient supply of bricks and mortar by the crew labour

- Glaziers

A delay of half an hour was experienced while waiting for the arrival of window beadings.

- Screeding of Floors

A minor delay while scaffolding was removed from a corridor that was to be screeded.

- Brick Paving

A delay of approximately half an hour while waiting for the removal by jack hammer of a hardened heap

of mortar which had been left on the stoep of a house.

The observer finds the "Artisan Delay Survey" to be more applicable to a South African construction site than the use of CQS for the reasons mentioned above, unless the person carrying out the study is fluent in English, Afrikaans and the locally spoken African languages. The observer recommends that the "Artisan Delay Survey" need not be carried out by management but by another person who could make regular report backs to management.

#### 7.6 Work Sampling to determine Time Standards

The observer attempted to establish a standard time for brickwork. A study was made of seven bricklayers all laying straight one brick walling. Only the activity of the bricklayers was observed and the summary of their activity is shown on Table 16. The categories of Direct work, Delay and Personal were used for the purposes of this study.

**Table 16                      Summary sheet for Time Standard Sampling**

Date: 14-08-87                      Quantity of work completed: 16m <sup>2</sup>	
Weather: Fine	
Start Time: 14h45	
Finish Time: 16h20	
Bricklayer No.	1    2    3    4    5    6    7
Estimated Rating	90   90   90   110   90   105   110
Direct Work (Ave. 79.5-%)	52   45   49   53   39   41   55
Delay (Ave. 6.9%)	3    3    5    3    8    6    1
Personal (Ave. 13.5%)	5   12   6    4   13   13   4
Totals	60   60   60   60   60   60   60

The estimated rating for each bricklayer was obtained from the bricklayer foreman on site. These estimates were obtained in the form of a subjective assessment and then converted into estimations on the 0 - 100 Rating scale. (A rating of 100 describes an average, motivated, qualified worker.)

Calculation of the standard time is as follows:

$$\text{Normal time} = \frac{\left[ \text{Tot time of study in minutes} \right] \cdot \left[ \text{Direct time in decimals} \right] \cdot \left[ \text{Ave Performance Rating} \right]}{\text{Total quantity produced}}$$

$$\begin{aligned} \text{Normal time} &= \frac{(7 \times 95) \times (0.795) \times (0.98)}{16\text{m}^2} \\ &= \underline{32.38 \text{ min/m}^2 \text{ (one brick wall)}} \end{aligned}$$

Allowances: Delay 6.9% = 45.9 min + 16 = 2.87 min/m<sup>2</sup>

Personal 13.5% = 89.8 min + 16 = 5.61 min/m<sup>2</sup>

Standard time = Normal time + Delay + Personal time  
 = 32.38 + 2.87 + 5.61  
 = 40.86 min/m<sup>2</sup> (one brick wall)

Expressing this as a rate per day:

Number of bricks [ 220(l) X 90(b) X 110(d) mm ] per m<sup>2</sup>  
 of one brick wall = +/- 36 X 2 = 72

8hrs = 480 minutes + 40.86 minutes = 11.75 m<sup>2</sup>/day

11.75 X 72 = 846 Bricks per bricklayer per day.

Note: Delays and Personal time are already included in the Standard Time.

#### 7.6.1 Problems encountered by the observer

The observer did not find great difficulty in carrying out the study. However, it is felt that the Standard Time obtained from the study is inaccurate for the following reasons:

- The lack of experience of the observer, and the unfamiliarity of the bricklayer foreman with the rating system.
- In order to obtain a greater statistical reliability a study of some days would be necessary to obtain a higher Confidence limit and Limit of error. The 420 observations made for this study provide 95% confidence and a 5% limit of error.

- The observer anticipates that difficulty will be found when trying to establish time standards for activities that are neither repetitive nor of long duration since sufficient observation must be obtained for the same activity under the same conditions to ensure statistical validity and a properly defined time standard.

## 8. AN INVESTIGATION INTO THE USE OF CONSTRUCTION WORK SAMPLING IN SOUTH AFRICA

### 8.1 Introduction

In order to establish the extent to which Work Sampling methods are already in use in South Africa as well as other related information, a questionnaire was sent to 60 construction companies. The companies chosen were based in Johannesburg, Cape Town, Port Elizabeth and Durban. In selecting the companies, mainly medium to large sized companies were chosen. The researcher felt that these companies would be more likely to use, or be aware of the existence of Work Sampling than would the smaller companies.

The return on the questionnaire was 28% (17/60). Two of the companies who returned the questionnaire were no longer trading. This low return does not allow for any of the results shown to be assumed for the whole industry. However, an indication of the extent and awareness of the use of Work Sampling is obtained.

Appendix IV and V are specimens of the covering letter and the questionnaire sent to the companies.

A question by question analysis of the returned questionnaires is followed by an overall discussion of the results.

### 8.2 Questionnaire analysis

Question 1      Name of Company

The researcher does not deem it necessary to disclose the names of the companies.

**Question 2** Details of company size

The lowest, average and highest number of personnel employed in each category as well as the standard deviation for the sample under each category is given on Table 17.

**Table 17** Details of Company size

Category	L	Ave.	H	SD
Artisans	0(sc)	56	182	54
Skilled labour	6	62	+/-500	123
Semi-skilled labour	0	110	+/-1000	252
Unskilled labour	35	353	+/-2500	605
Foremen	2	19	150	37
Site management	1	11	80	20

(sc = All sub-contracted)

The purpose of requesting this information was to show the size of company which responded to the questionnaire and to relate this to the percentage of companies actually using Construction Work Sampling (See question 5). From the table it can be seen that the standard deviation for each category is large. This is because of the considerable range of numbers employed by the companies and the small sample size.

**Question 3** What type of work is the company primarily involved in?

The 15 companies were involved in a wide range of construction work as shown on Table 18.



## Comments:

"Work sampling has been used in isolated instances, although it has not been implemented formally."

Question 7 If rejected please state in brief the reasons for rejection.

## Comments:

"Accuracy of figures generated; Perception that it is finger-pointing i.e. there has been a lack of commitment and /or participation."

"After having used this technique a few times we found that the results were more or less constant."

Question 8 Were you aware of the existence of Work Sampling techniques before receiving this questionnaire?

YES: 11

NO: 4

Question 9 If your answer is yes from which of the following sources were you made aware?

The National Productivity Institute	4
Literature e.g. Journals	6
Other (not clarified)	6

**Question 10** Which of the following methods of Work Sampling are in use/have been used?

Part 1

**Table 19 Methods of Work Sampling**

Methods	NO.of Co's using method
Field ratings	3
Activity Sampling	0
Productivity ratings	2
Five Minute ratings	3
Work Sampling to determine time standards	1
Craftsmen Questionnaire Sampling	0
Other	0

Part 2

Please give details as to any of the above methods in use:

Comments:

"We do not use clock cards; Black checkers monitor the labour forces' presence on site (comment is necessary to understand how we operate). Site checkers have carried out head counts to determine numbers involved in certain activities over a certain time period (figures generally lack accuracy). Length of study period has been 1 week to a number of months depending on requirements. Site engineers/foreman have conducted random studies."

"Foreman/contracts manager/directors are involved in sampling on a continual basis.

Observations are made on a visual basis during informal site visits by directors and continual evaluation by foreman.

No sample sheets are used. However productivity is assessed on historical information based on work of a similar nature previously undertaken ."

- Sampling is carried out by time keepers or trainees.
- Observations are made using the tour approach.
- Ticksheets are used to record observations.
- The length of study varies with the method being used.

Question 11 Have you been able to make significant improvements using any of the above methods?

Comments:

"Yes, productivity and quality evaluation has a bearing on cost effectiveness and ultimately profitability."

"No, however awareness has been/was created for the necessity to improve. Improvement was generally short term due to lack of follow up and the changing nature of a job from day to day."

Question 12 What problems have you encountered with the use of Work Sampling?

Comments:

"Work sampling is ideal for a repetitive job. It is difficult to apply it to an environment that is constantly

changing e.g. foundations, columns, slabs, brickwork, trenches all in small quantities or changing dimensions and conducted randomly."

"Evaluating conditions on site while a person is undertaking a study is not a true reflection of what normally occurs. Productivity/quality improves if staff are aware that they are being assessed."

Question 13 Have Work Sampling studies been carried out by the National Productivity Institute for you company? (Please give details.)

YES: 1

NO: 14

Comments:

"Yes, the NPI analysed our work on the construction of the Turbine house concrete structure at Lethabo Power Station (500m long, 22m high, slabs at 3 levels). Their recommendations made a lot of sense but the implementation was not practical for the following reasons.

1. Number of input activities fell outside our control i.e. issue of drawings, changing client requirements.
2. The lack of taking a holistic approach to the complete process.
3. Lack of commitment from senior management to implement certain changes (costly).

The bottom line was that improvements were made mainly as a result of improving communication."

Question 14 What other productivity measurement techniques are in use in your company?

**Table 20 Other productivity measurement techniques**

Techniques	Companies using them
Unit costs	12
Questionnaires/Interviews	4
Foreman Delay Surveys	3
Other	5

Details of other methods being used

"Historical comparisons based on similar work in similar conditions."

"Our labour costing is mainly historical although forecasting is used."

"A costing system consisting of daily production cost is maintained on our larger contracts. Costs are compared with tender allowances and corrections made where possible."

"Weekly cost vs Allowable."

"Spot checks."

"Recording of productivity and outputs on specific items for comparison with budgeted costs, i.e. labour costing (either daily or weekly depending on requirements)."

Question 15 Would you be interested in finding out further information on Construction Work Sampling?

YES: 12

NO: 3

### 8.3 Discussion of the results

The researcher is of the opinion that companies employing large numbers of personnel and involved in large projects are more likely to be aware of Work Sampling or to have used these methods than smaller companies. This is because the need for control over productivity is likely to increase the more complex and numerous site activities become, thus emphasising the need for awareness of methods available for assessing and improving productivity.

When considering the average numbers employed under each category (question 2), the wide range of construction work (question 3), and the average length of operation in the industry (38 years), of those companies that returned the questionnaire, the researcher feels that the 20% use of Work Sampling might be a reasonable if not inflated estimate of the situation over the whole construction industry.

The three companies that have made use of Work Sampling methods would appear to have used the methods in isolated cases or in an informal way. This might account for the problems of suspicion by the workers and the lack of commitment and participation shown for one company, and the constant (unhelpful) results obtained by another (See question 6,7 & 10).

The most commonly used methods would appear to be the Field Rating and Five Minute Rating (See question 10). In the experience of the researcher these methods are both relatively easy to use and understand, and would be likely choices for an inexperienced user. Information obtained from the Field Rating is however not suited to isolated use and is best incorporated into a trend analysis over time.

The improvements made by the use of work sampling would appear to have been in terms of productivity and quality, or to have created an increased awareness of the necessity to make improvements. (See question 11)

The problems encountered with the use of work sampling, (See question 12) include the reaction to the presence of an observer and the problems associated with the continually changing nature of the work. The researcher noted similar difficulty while engaged in the case study. These problems can be overcome to an extent by the continued use of Work Sampling which will make workmen less suspicious of its objectives; and at the same time a data base for a number of different activities and conditions can be established.

The results of questions 8 and 9 suggest that knowledge of the existence of Work Sampling was obtained mainly through literature and other (unfortunately not clarified) sources. Twelve out of the fifteen companies expressed their interest in obtaining further information on Construction Work Sampling (See question 15).

The National Productivity Institute at present carries out productivity analysis for companies requesting it. This productivity analysis makes use of Work Sampling methods as well as other techniques, for example the Foreman Delay Survey. Analysis was done for one of the companies who returned the questionnaire (See question 13), and the recommendations made were reported to be worthwhile but not practical for the reasons given. The researcher would recommend that the National Productivity Institute further advertise the availability of their service to construction companies.

The results of question 14 show that the majority of the companies make use of either a unit or historical costing system which compares reported costs with the allowable costs as described in section 6.1 of this report. This

system has its disadvantages (See section 6.1) and should be supplemented with a form of productivity analysis which allows action to be taken while work is still in progress, for example Work Sampling.

One of the companies undertook a comprehensive productivity investigation on a large project incorporating some Work Sampling techniques as well as questionnaires answered by foremen and section engineers.

Appendix VI gives a detailed report on the productivity investigation undertaken.

To conclude, the small sample size and the small proportion of companies which supplied positive information has prevented a detailed analysis of this questionnaire. Nevertheless it has served to provide an indication of the extent of use and awareness of Construction Work Sampling amongst South African construction companies. Eleven out of fifteen companies were aware of the existence of these methods and only three of those companies have actually implemented them.

## 9. CONCLUSIONS

### 9.1 The Field Rating

The Field Rating represents Work Sampling in its simplest form and provides limited information as to the nature of the activities which are observed, or the reasons behind activities observed as "not-working". Field ratings may be used for the study of crafts, crews or for activity over the whole or part of a site. The results will be best utilized if incorporated in a trend analysis to highlight any significant changes in activity levels.

During the case study little difficulty was found in applying the Field Rating to a South African construction site.

The results of the questionnaire showed that Field Ratings were used by all three companies using Work Sampling methods.

### 9.2 Activity Sampling

Activity Sampling is able to provide more detailed and useful information than the Field Rating. The categories chosen for the study can be suited to an overall site study or may give the detail required for a particular craft or crew. Analysis of the percentages obtained under each category may highlight inefficiencies in the methods being used, or of the organization as a whole.

During the case study the observer found difficulty with the selection of categories because of the diversity of activities in progress. Selection of the categories necessitated a few preliminary tours. Furthermore the categories of "Travel empty-handed" and "Idle/Unexplained"

do not provide sufficient explanation for the cause of these activities and would necessitate questioning of a workman by the observer to obtain this information. This may present difficulty on a South African construction site if the observer cannot speak the required languages.

The results of the questionnaire showed that no companies make use of Activity Sampling.

### **9.3 The Productivity Rating**

The Productivity Rating provides a more detailed breakdown of activity into Direct, Indirect and Delay category divisions. The percentages of activity obtained can be compared with the quantity of work produced during the study period. However, Productivity Ratings may be misleading if the exact methods and working conditions are not accurately recorded with the results of sampling. This is because disorganization of the work as well as differing methods may result in different percentages of productive work content. This is especially the case when comparing different sites.

The case study highlighted the difficulty of selecting categories and the inadequacy of the delay categories in explaining the causes for delay. A slightly extended observation was found helpful to establish the nature of an observed delay.

The questionnaire showed that two companies make use of the Productivity Rating.

### **9.4 The Five Minute Rating**

The Five Minute Rating provides a quick appraisal of an activity and creates awareness of delays that affect the progress and the cost of a job.

The case study showed that the Five Minute Rating was easily applicable to South African Construction sites once the observer was familiar with the use of this method.

The questionnaire showed that all three of the companies using Work Sampling were using the Five Minute Rating.

#### **9.5 Setting Time Standards using Work Sampling**

The use of Work Sampling to determine Time Standards has a number of advantages over Time Study. The case study showed that a Time Standard was easily calculated, but the accuracy of the result was dependent on the experience of the observer in rating the observed workmen, and the necessity for sufficient observations to be taken of similar activity for a long duration to obtain the necessary accuracy of result.

The results of the questionnaire showed that one company was using this method.

#### **9.6 Craftsman Questionnaire Sampling**

Using Craftsman Questionnaire Sampling more information as to the nature of craftsmen's activities is obtained than with the other Work Sampling methods. However, an interruption in the work is necessary to obtain this information.

The case study showed that this method was not easily applicable to South African construction sites due to the high degree of illiteracy amongst many workmen which prevented the satisfactory completion of the questionnaires.

An alternate "Artisan Delay Survey" was used by the observer and was useful in determining the nature of the delays that occurred on site.

The questionnaire showed that no companies were using Craftsman Questionnaire Sampling.

#### 9.7 Comparison of Work Sampling with other methods of measuring productivity

The effectiveness of Work Sampling as compared with the other methods described differs with the objective to be achieved and no generalization can be made as to the best method to use. Nevertheless, Work Sampling performs well in the following areas:

- Providing information for positive action from foreman level upwards.
- Identifying problem sources from foreman level upwards.
- Identifying problems with methods as well as administrative or support problems.

## 10. RECOMMENDATIONS

The general impression gained while writing this report, conducting the case study, and analysing the questionnaire is that there is no half-measure if Work Sampling is to be used.

Work Sampling will only be successfully implemented if a company totally commits itself to the use of these methods. This will involve a detailed statement of objectives and participation at all levels of the organization (especially with regard to action taken on the results of studies made), studies of long duration will be necessary to obtain relativity for the data produced, and finally, open communication at all levels with regards the objectives of Work Sampling.

Work Sampling should be supplemented by other methods for measuring productivity to back up the data obtained, and to be sure that any changes to be made are justified.

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**APPENDIX I**

**DETAILED BREAKDOWN OF CATEGORIES**

## A. Direct Activity

The performance of necessary elements of a task in a work area that advances the physical completion of the project.

### Examples:

- (1) All manual productive work.
- (2) Picking up or laying down any tool while performing productive work.
- (3) Making measurements directly on material or equipment immediately prior to performing manual work on that material or equipment.
- (4) Necessary holding of parts or tools.
- (5) Walking within close confinements of work area (normally within 10 feet of object of work).
- (6) Inspection for proper fit or operation of work or equipment.
- (7) Putting on or taking off gloves, goggles, or other apparel in preparation for completion of a job.
- (8) Cleaning tools upon completion of job.
- (9) Cleaning goggles or safety equipment.
- (10) Necessary clean-up of job site during or after completion of job.
- (11) The attendance upon, or actual operation of, pieces of equipment performing physical work.
- (12) The necessary supervision or direction of work of other crew members (e.g. iron worker directing crane operator; electrician supervising labour's backfilling of conduit trench).
- (13) Assigned general clean-up.
- (14) Procuring or handling materials and equipment when it is a crew assigned task.

### Examples:

- (a) Iron-workers off-loading iron at rail siding.
- (b) Iron-workers rigging a crane.

- (15) Where complexity of work requires the reading of prints or instructions immediately prior to performing physical activity.

Examples:

Electrician reading wiring diagram in front of panel.

B. Support Activity - (Indirect Labour)

Activity, although necessary, that indirectly advances the progress of a project.

- (1) Getting Equipment - Getting tools or equipment away from the immediate work area.

Examples:

- (a) Getting or putting away of tools or equipment when not in immediate work area.  
 (b) Getting or returning tools at the tool room.

- (2) Equipment Travel - Travelling to or from the immediate work area with or for tools or equipment.

Examples:

- (a) Travelling to obtain or return equipment to storage area.  
 (b) Travelling with material in order to use equipment not in work area.

Examples:

Electrician carrying conduit to a threading machine not located in his work area.

- (c) Travelling to see supervisor to obtain location or permission to use equipment.

- (3) Getting Material - Getting materials at a location away from immediate work area.
- (4) Material Travel - Travelling to or from work area with or for additional usable materials.

Examples:

- (a) Travelling to or from material storage areas.
  - (b) Travelling to a foreman's office to obtain location of, or permission to use, additional materials.
  - (c) Carrying materials to job except to start job.
- (5) Planning - The development of instructions prior to performing a task, or the interpretation of existing instructions prior to performing a task.

Examples:

- (a) Talking with fellow workers concerning a job at hand.
  - (b) Planning to determine what materials or equipment are required for job.
  - (c) Making sketches.
  - (d) Reading drawings, sketches, or instructions.
  - (e) Checking to determine where and how to begin a job.
  - (f) Talking with a foreman or other member of supervision concerning job.
- (6) Travel - Travelling out of immediate job area, when not concerned with getting additional tools, equipment or materials. Travelling for personal reasons is not included in this category.

Examples

- (a) Travelling to see foreman for instructions
- (b) Travelling to begin a new job, either empty handed or with tools or materials.
- (c) Travelling to dispose of scrap material.

- (d) Travelling when purpose of travel has not been determined by Activity Analysis observer.

### C. Delays

Any time that a worker is available for and ready to work but is not performing Direct Activity or Support Activity.

#### (1) Equipment Delay

Examples:

- (a) Waiting in line at tool room
- (b) Waiting for crew member while he is getting tools or equipment.
- (c) Waiting for another crew member to finish using a tool or piece of equipment.
- (d) Searching for equipment or tools that have been misplaced.
- (e) Waiting for equipment required to obtain materials.

#### (2) Material Delay

A delay concerned with procuring material.

Examples:

- (a) Waiting for crew member while he is getting materials.
- (b) Waiting at work area for material to be delivered by another crew.
- (c) Waiting in line at material storage areas.
- (d) Searching for specific piece(s) of material.

#### (3) Crew Delay Same

A delay caused by one or more men having to wait while their fellow crew members are working. The workers must be at the work area and ready for work.

**Examples:**

- (a) A delay inherent in type of work, such as: A helper waiting while a welder welds a flange to a piece of pipe: an iron worker up on the steel waiting for crew member on ground to put a choker on a beam.
- (b) Too many men assigned to a task, such as three labourers assigned to dig a ditch large enough to hold only two men.

**(4) Crew Delay Other**

A delay caused by one or more men having to wait for other crew members before proceeding with work. The workers must be at work areas, ready for work.

**Examples:**

- (a) Too many crews assigned to work area, such as member of labour crew B being momentarily unable to work because member of labour crew A is in way.
- (b) Crew members being held up due to another trade working.
- (c) Worker(s) held up by unfinished task of another crew, such as electricians waiting for labourers to arrive to remove dirt slide in conduit trench.

**(5) Supervision Delay**

Delay caused by supervision. For an observation to be marked supervision delay, the worker must be available and ready for work.

**Examples:**

- (a) Worker is in job area and has no work to do.
- (b) Worker is waiting for instructions or permission to complete a job.
- (c) Worker working on personal task assigned by supervision.

- (d) Workers observed in expected and prolonged delays due to another crew performing work, as in a pipe crew waiting to lay sections of pipe while a backhoe is excavating trench.
- (e) Worker is told to wait by supervision.
- (f) Prolonged delays due to lack of materials or equipment, and where workers have not been reassigned to alternate duties.

#### (6) Miscellaneous Delay

Those delays not concerned with getting equipment, tools or materials, and not covered in crew delays, supervision delays, or personal delays.

##### Examples:

- (a) Attending safety meetings, group training sessions, and department meetings.
- (b) Observation of worker in first aid shack.
- (c) Conference with supervision concerning personal matters.
- (d) Travelling when concerned with any of the above.
- (e) Idleness in work area due to proximity of quitting or lunch time making additional work impractical.
- (f) Waiting for elevator.
- (g) Talking with welding inspector, field checker, etc.
- (h) Workers idled by recent equipment breakdown.
- (i) Workers assigned as fire look-outs, safety duties, guard duties at gate, and like activities.
- (j) Carpenters attending a concrete pour.

Any situation where the presence of idle worker(s) is due to trade practices or jurisdictions.

#### (7) Personal Activity

Delays which are under the worker's control.

**Examples:**

- (a) Inactivity on assigned task.
- (b) Going to rest room.
- (c) Personal clean-up unnecessary for proper completion of job, including before lunch and at end of shift.
- (d) Talking when it does not concern job.
- (e) Travelling when concerned with personal activities.
- (f) Taking rest or lunch periods (even though authorized) at other than standard time.

**APPENDIX II****RATES OF WORKING ON THE PRINCIPAL RATING SCALES**

Scales				Description	Comparable walking speed <sup>1</sup>	
60-80	75-100	100-133	0-100 Standard		(mi/h)	(km/h)
0	0	0	0	No activity.		
40	50	67	50	Very slow; clumsy, fumbling movements; operative appears half asleep, with no interest in the job.	2	3.2
60	75	100	75	Steady, deliberate, unhurried performance, as of a worker not on piecework but under proper supervision; looks slow, but time is not being intentionally wasted while under observation.	3	4.8
80	100	133	100 (Standard Rating)	Brisk, business-like performance, as of an average qualified worker on piecework; necessary standard of quality and accuracy achieved with confidence.	4	6.4
100	125	167	125	Very fast; operative exhibits a high degree of assurance, dexterity and co-ordination of movement, well above that of an average trained worker.	5	8.0
120	150	200	150	Exceptionally fast; requires intense effort and concentration, and is unlikely to be kept up for long periods; a "virtuoso" performance achieved only by a few outstanding workers.	6	9.6

<sup>1</sup> Assuming an operative of average height and physique, unladen, walking in a straight line on a smooth level surface without obstructions.  
Source: Freely adapted from a table issued by the Engineering and Allied Employers (West of England) Association, Department of Work Study.

**APPENDIX III****ALLOWANCES FOR VARIOUS CLASSES OF WORK**

**Rest allowances (in percentage) for various classes of work**

1. Constant allowances:	
a. Personal allowance.....	5
b. Basic fatigue allowance.....	4
2. Variable allowances:	
A. Standing allowance.....	2
B. Abnormal position allowance:	
a. Slightly awkward.....	0
b. Awkward (bending).....	2
c. Very awkward (lying, stretching).....	7
C. Use of force, or muscular energy (lifting, pulling, or pushing):	
Weight lifted (pounds):	
5.....	0
10.....	1
15.....	2
20.....	3
25.....	4
30.....	5
35.....	7
40.....	9
45.....	11
50.....	13
60.....	17
70.....	22
D. Bad light:	
a. Slightly below recommended.....	0
b. Well below.....	2
c. Quite inadequate.....	5
E. Atmospheric conditions (heat and humidity):	
Variable.....	0-10
F. Close attention:	
a. Fairly fine work.....	0
b. Fine or exacting.....	2
c. Very fine or very exacting.....	5
G. Noise level:	
a. Continuous.....	
b. Intermittent—loud.....	2
c. Intermittent—very loud.....	5
d. High pitched—loud.....	5
H. Mental strain:	
a. Fairly complex process.....	1
b. Complex or wide span of attention.....	4
c. Very complex.....	8
I. Monotony:	
a. Low.....	0
b. Medium.....	1
c. High.....	4
J. Tediousness:	
a. Rather tedious.....	0
b. Tedious.....	2
c. Very tedious.....	5

From Niebel, *Motion and Time Study*, p. 380.

**APPENDIX IV**

**COVER LETTER FOR QUESTIONNAIRE**



## Department of Construction Economics and Management

24 July 1987

University of Cape Town · Private Bag Rondebosch 7700  
Centlivres Building · Telephone: 650-3445  
Head - Assoc Professor A J Stevens

### TO WHOM IT MAY CONCERN

Dear Sir:

I am writing to ask for your kind assistance and co-operation in the completion of the enclosed questionnaire.

I am a final year student at the University of Cape Town studying for a B.Sc in Building Management. As part of the course curriculum we are required to complete a Technical Report. I have chosen as my subject Construction Work Sampling.

Work sampling is already widely used in the United States and Europe. The basic theory on which work sampling is based takes the form of observations taken of men and machines on site at random times during the day, enabling a small percentage of total activity to be classified. By statistical analysis of the results the activity as a whole may be estimated in terms of percentage working time and non-working time.

Work sampling is especially beneficial to management as an analytical tool which helps to identify areas of unnecessary delay and of poor productivity.

The attached questionnaire will enable me to ascertain the extent to which work sampling methods are already in use in South Africa. The extent of awareness of work samplings' existence as well as reasons for its non-use are also questioned.

I am aware that companies such as yours are often plagued with questionnaires of a similar nature. I would therefore appreciate your assistance in its completion, even if you do not use work sampling methods.

Due to the time limit imposed for the handing in of the Technical Report, kindly return the questionnaire by the 12 August 1987, in the envelope enclosed.

Thanking you for your co-operation.

Yours faithfully

**PETER HUND**

PH / ah

**APPENDIX V****QUESTIONNAIRE ON CONSTRUCTION WORK SAMPLING**

**QUESTIONNAIRE ON CONSTRUCTION WORK SAMPLING**

**1.Name of Company.....**

**2.Details of Company size:**

Approximately how many of the following personnel are employed by your company?

Artisans (contract/local).....

Skilled labour (contract/local).....

Semi-skilled labour (contract/local).....

Unskilled labour (contract/local).....

Foremen.....

Site management.....

**3.What work is the company primarily involved in?**

.....  
.....  
.....

**4.How long has the company been in operation?**

.....

5. Does your company make use of Work Sampling techniques on site?

YES / NO (Circle appropriate answer)

If answer is NO please complete questions 6 - 9, 14 & 15.

If answer is YES please complete questions 10 - 15.

6. Has the use of Work Sampling techniques been considered for your company and been rejected?.....

7. If rejected please state in brief the reasons for rejection.....

8. Were you aware of the existence of Work Sampling techniques before receiving this questionnaire?

YES / NO

9. If your answer is YES, from which of the following sources were you made aware?

THE NATIONAL PRODUCTIVITY INSTITUTE .....

LITERATURE eg. Journals .....

OTHER .....

10. Which of the following methods of Work Sampling are in use/have been used?

(PLEASE TICK APPROPRIATE METHODS).

-Field ratings / Activity ratings / Head counts .....  
(Working / not-working % ).

-Work Sampling .....  
(Sample size determined according to confidence limit, limits of error and category proportion).

-Productivity ratings .....  
(Activity broken down into Productive, Indirectly Productive and Non-Productive).

-Five Minute ratings .....  
(Observations of a few minutes made - indication of delays and crew effectiveness).

-Work Sampling to determine time standards for activities.  
.....

-Craftsmen Questionnaire Sampling. ....  
(Questioning of craftsmen on a random selection basis as to recent activity on site).

-Other. ....



11. Have you been able to make significant improvements using any of the above methods?.....

.....  
.....

12. What problems have you encountered with their use?.....

.....  
.....  
.....  
.....  
.....  
.....  
.....

13. Have Work Sampling studies been carried out by the National Productivity Institute for your company? (Please give details).....

.....  
.....  
.....  
.....  
.....

14. What other productivity measurement techniques are in use in your company?

UNIT COSTS .....  
QUESTIONNAIRES/INTERVIEWS .....  
FOREMAN DELAY SURVEYS .....  
OTHER (Please give details) .....

.....  
.....  
.....  
.....

15. Would you be interested in finding out further information on Construction Work Sampling?.....

.....  
.....

**APPENDIX VI****PRODUCTIVITY INVESTIGATION REPORT**



PRODUCTIVITY INVESTIGATION AT  
LETHABO DURING 1985

1. INTRODUCTION

The Lethabo investigation concentrated on the general method employed by each section. The utilization/distribution of labour and equipment, pre-planning, communication and general organization of each section were studied for a 1-2 week period. A longer study period was employed if the extracted information was considered inadequate. Data on actual formwork erection and concrete placing were also collected. Improvement in the productivity of individual employees was not considered. The systems used by the backup services (batch plant, stores and workshop) were also investigated.

2. INVESTIGATION

Before any investigations commenced all the labour costing was consolidated so that data could be timeously presented.

The study consisted of questionnaires that both foreman and engineer were asked to complete. A number of the questions to both parties were the same. Statistics were gathered from the Q.A. department and off the wage sheets.

Information concerning the foreman's use of labour, crew sizes, effectiveness, office structure, communication, material usage, attitude and goal setting was gathered during the study period on site. A report was compiled for discussion with the section engineer and foreman. Where improvements to the system were necessary, actions were recommended. The years survey encompassed fourteen foremen, the batchplant, workshops, stores and the section engineers.

Information was distributed (in three languages) to the foremen and section engineers regarding the cost of labour and various formwork materials.

Fortnightly meetings with the section engineer and his foremen were introduced from August 1985. These meetings were structured along the lines of those adopted in quality circles. Discussion at these meetings was based on 40 productivity improvement ideas that had been compiled from information presented by the foreman. A monthly newsletter was issued. It included actual production figures and any conclusions that could be drawn from the fortnightly meetings.

3. FINDINGS/ACTIONS

The survey done on the section engineers only indicated what time they spent on various activities. However it became apparent later that the recording systems for dayworks, site instructions, drawings, etc. needed improving.

Of the 14 sections investigated, resourced programmes and progress records in 11 and 9 cases respectively, were either not done or inadequately prepared. Consequently some foremen lacked satisfactory targets, their work area was spread out and continuity of work was poor. These were all verified. A few crews lacked direction because of the poor programming. Labour targets were not being given; overall crews in 7 cases were too large and there was often insufficient supervision within a crew.

Labour and material utilization in 50% of the cases needed improvement. The labour utilization was improved, to name a few actions, by having gangs resourced to suit the work, reducing gang sizes, having the storemen perform extra duties, absorbing the compressor labourers into crews, getting the truck drivers to tip their own trucks and better planning.

Where material utilization was poor it invariably included a lot of double handling, abuse, excessive use of material, mediocre maintenance of small plant and tools, and generally a lack of management from both section engineers and foremen.

Notwithstanding the sections where improvement was required there were a number of sections operating extremely efficiently; where selective recruitment, small gang sizes and good supervision were the order of the day.

The consolidation of the labour costing figures indicated a large number of inconsistencies in the monthly claims. It was consequently difficult to present accurate figures on a monthly basis. Figures that were extracted for individual items showed that the production of those items was done at approximately 50% of the allowable, whereas the overall productivity  $\left(\frac{\text{Allowable}}{\text{Actual}}\right)\%$  was around 100%.

This shows that +50% of the labour is utilized in performing sundry activities like cleaning, patching, pre-assembling etc.

#### CONCLUSION

The productivity survey confirmed an opinion that management activities require attention before any meaningful productivity gains can be obtained from the individual. There is definitely a greater awareness of the need to change existing attitudes and operating methods.

The clearest tangible result has been the reduced number of labourers performing various duties e.g. concrete and voiding gangs.

It is clear that the more successful foremen give their labour responsibility and are more selective in their employment and promotion practices.

Further research should be undertaken before a productivity programme is implemented.



## INTRODUCTION

During 1985 Noel Fitchet was employed full time to investigate productivity at Lethabo Site. This was done by studying each section for a period of time and producing a report with recommendations which was discussed with the Section Engineer and Foreman involved, who then effected the recommendations agreed on. The more important results achieved by the investigation are summarised below.

## FOREMAN ATTITUDE

As a result of the interest shown in the labour levels required for various operations the foremen have become much more "cost concious". In a number of cases the crew size used for various activities has been reduced and the foremen are organising their labour more systematically. Appendix B shows the relative labour levels as at 19 March 1986 compared to 6 March 1985. This list only includes foremen who are currently doing the same work as they were doing in March 1985 and excludes those who have left site during the period or been re-allocated to other areas of work.

The reduction in labour levels on the Batch Plant, Q.A. Laboratory and office are in part due to a decrease in the level of activity on the site. The overall reduction in black labour levels of almost 20% is almost entirely a direct result of the Productivity investigation of last year.

## SECTION ENGINEERS

It became apparent at a very early stage of the Productivity investigation that the Section Engineer played a key role in determining the overall level of productivity. The most important areas affected by the Section Engineers are:

1. Planning the work.
2. Providing the foreman with the necessary materials, built in items etc without delay.
3. Resourcing the work
4. Measuring and monitoring the performance.

In order to achieve greater participation by the Section Engineers in the Productivity drive a competition was run for the second half of 1985.

Based on previous figures and estimates of improvements that could be achieved, a productivity target for each foreman was set. The productivity figure was defined as the allowable man-hours divided by the actual man-hours spent expressed as a percentage.

The results of this competition were particularly encouraging and are shown in Appendix A. It should be noted that discrepancies due to fluctuations in the Certificate claims have resulted in distortions of some of the figures, but these are not significant and overall the figures quoted give a fair reflection of the achievements on site.

The following steps have been taken to ensure continuous participation by the Section Engineers in productivity improvement.

1. Each month the Section Engineers produce a detailed programme of work for the following month for each of their foremen.
2. Allowables are calculated for the work programmed to be done in this period and compared with existing labour levels to predict a productivity figure. If this figure is unacceptable then either the programme or the level of resourcing is amended.
3. The Section Engineers will in future calculate the quantities for each monthly claim for their own sections of work. This has been done in an attempt to improve the accuracy of the monthly claims.

#### CONCLUSION

The greater awareness of Productivity as a result of the investigation last year has certainly resulted in an attitude of "managing for Profitability" as against managing to get the work done, in both the Section Engineers and Foremen.

I am very pleased with the results achieved by the Productivity Investigation conducted last year and believe it was very beneficial.

R.C. SHEPPARD



APPENDIX A - PRODUCTIVITY FIGURES FOR THE PERIOD  
1 JULY to 13 DECEMBER 1985

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	<u>TARGET</u>	<u>ACTUAL</u>
P. Blain. C.W. Ducts and Pumphouse.		
J. Palm	150%	175,3%
A. Rodriques	120%	129,1%
M. Kennedy. T.H. & Auxiliary Bay to zero level & T.G. Block & Drainage		
A. Van Breda	105%	125%
D. Prins	110%	132,7%
Drainage	100%	105,3%
J. Coetzee. T.H. Superstructure and T.H. to zero Units 3 & 4		
J. de Villiers	90%	48,2%
M. Viegas	115%	110,9%
R. Lamble. Boiler Basement		
F. Minnie	90%	116,7%
H. Stoop	100%	160,9%
H. Stoltz	80%	89,0%
C. Stoltz	115%	129,0%
S. Buckley. Boiler Superstructure		
J. Perestrelo	118%	146,3%
H. da Silva	118%	143,4%
J. Antunes	100%	127,3%



## APPENDIX B - COMPARATIVE LABOUR LEVELS

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FOREMAN/SECTION	6 MARCH 1986		19 MARCH 1986	
	EUROPEAN	BLACK	EUROPEAN	BLACK
H. da Silva	3	55	3	48
A. Rodriques	2	68	3	49
J. de Villiers	3	50	3	36
J. Palm	1	30	0	23
J. Antunes	5	97	6	93
D. Haasbroek	2	141	2	125
A. Van Breda	5	51	4	37
H. Stoltz	3	29	2	16
H. Stoop	3	30	3	24
M. Viegas	13	129	10	99
D. Prins	4	65	4	40
J. Perestrello	1	45	1	35
Office	1	25	0	20
Q.A. Laboratory	2	13	1	8
Batch Plant & Pre-cast Yard	0	76	0	47
Workshops (excluding Mechanics)		28		19
TOTAL	48	932	45	750