Proceedings of the
International Conference on Mechanical Engineering 2003
(ICME2003) 26- 28 December 2003, Dhaka, Bangladesh

ICME03-AM-06

A NOVEL APPROACH IN THE DETERMINATION OF WORK STANDARDS FOR A MANUFACTURING PLANT

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ABSTRACT

The workstudy literature contains latest advances in design, analysis, modelling and optimisation of the overall work system and its components. With several published works over the last two decades, significant new insights have been provided into the various aspects of workstudy. There is at present a need to provide direction for work standards research in which the various product characteristics would be incorporated into a model that serves as a common basis for investigations. The paper presents a mathematical model that determines the standard output achievable in a manufacturing operation. The model developed was tested using data from a roll-forming manufacturing plant. The motivation for the study is the dearth of research investigations of commercial value in the area of work system. Most work standards decisions are intuitively made. Numerical experimentation was conducted by using data obtained from an Aluminium roofing sheets manufacturing company operating in a developing country in Africa. It is expected that this paper should stimulate research activities in an emerging area of work standards and encourage a proliferation of studies in other industries in the manufacturing sector.

Keywords: workstandards, workstudy, manufacturing industry, rolling forming operation

1. INTRODUCTION

The recent worldwide economic depression in nations has serious consequences on the survival of manufacturing organizations, particularly in developing countries of the world. This is reflected in the frequent management efforts at controlling costs using some management concepts such as downsizing of the labour force, reduction in company overheads, and extended production hours. As a result of this serious threat on manufacturing concerns, an unprecedented level of "labour down tooling" is observed. The agitation by the workforce poses serious challenges to the management of organisations. The justification for down-tooling ranges from late payment of salaries, wages, and benefits to unfair compensation in reward systems.

The literature is replete with studies that scientifically proffer solutions to this complex organisational problem. One of the widely accepted techniques in solving labour disputes is the use of workstudy principles for a scientific evaluation of the problem. The workstudy literature has diverse research documentations and naturally invites both academic and industrial viewpoints on the emerging issues of fundamental theory, computational paradigms, system design, and applications. Unfortunately, the workstudy literature that one expects to find help in respect of scientific inquires into work standard issues is irresponsive.

Work standards is a body of knowledge that investigate into the modelling and analysis of jobs. Jobs are broken down into elements and tasks in a scientific way that justifies “a fair day’s job for a fair day’s pay”. In this work, we present an analytical model that primarily aims at determining the standard output achievable for a crew. This is expressed in terms of weight per shift. The unit of measurement is kg. per shift. The study sprang up as a result of the strong desire to know the maximum achieved output with the set standards.

There is at present a need to provide direction for work standards research in which the various product characteristics would be incorporated into a model that serves as a common basis for investigations. All these are incorporated into the paper. The model developed was tested using data from a roll-forming manufacturing plant. Three prominent processes - bending, crimpsin, and roll forming are the focus of the study. The predictive model, labelled standard output achievable, relates to the number of bends on the product, length of sheet, width (girth) of sheet, and its thickness. Numerical experimentation was conducted by using data obtained from an Aluminium roofing sheets manufacturing company operating in a developing country in Africa.

The motivation for the study is the dearth of research investigations of commercial value in the area of work system. Most work standards decisions are intuitively made.

The data for the study were obtained through actual production observations and interviews with the concerned personnel. It is expected that this paper should stimulate research activities in emerging area of work standards and encourage a proliferation of studies applied other industries in the manufacturing sector.

2. PREVIOUS RESEARCH

Work standards may be considered the anatomy of the work study system, providing a foundation with which engineering productivity at work could be measured. Work standard is believed to affect both the productivity and the conduct of organization members at work. Perhaps, the most important and basic test in conducting scientific inquiry on work standards involves the ordering, classification, or other grouping of the object or phenomena under investigation.

The earliest significant reference to work standard could be traced to the writings of Gilbreth (see [1]), who studied motion and time with specific attention paid to the design of motion charts. For Gilbreth, production systems need to be studied in order to have precise and scientific perspective of system productivity. Although he did not specifically attempt to develop a mathematical model for the study, his works have provided the theoretical foundation for much modern day research in the field.

The strongest support for this contention derives from the work of Polk [8], Doty [3], and Zandin [9]. All the authors have offered significant testimony to the tremendous assistance and challenges that Gilbreth's work could offer. Gilbreth is most remember for developing a set of “therbligs” which is the backbone of motion and time study.

It was not until three decades ago that the next major scientific effect made its appearance. Karger and Bayha [5] provided a scientific base framework that has helped thousands to profitably use traditional time and motions study and the predetermined time system, MTM-1.

In the paragraphs that follow, we add a review of some prominent research in the area of workstudy. These studies provide a rich fund of knowledge for future investigations.

Workstudy has been a recurring theme over the past 40 years, having achieved prominence in improving productivity in organizations. As such, workstudy has become the focal point in performance improvement efforts and researchers are becoming increasingly interested in the field. The increase of interest in work study is illustrated as much by the increasing number of paper which have been published in journals devoted to scientific management and by the great number of communications given on them in scientific meetings. Several international working groups also meet on a regular basis to examine this subject.

The work study literature is distinguished into two parts (i) Method Study and (ii) Work Measurement. Investigations into method study are diverse and broad. It has been applied in diverse areas and several industrial and service setups. More recently, method study is finding its place in outpatient pharmacy as reported by Hartley and associates [4]. The case studied is a multidimensional work sampling performed at a hospital based outpatient pharmacy.

Data were collected from nine full-time and five part-time pharmacists over 45-day baseline period. Pharmacists were silent, random-signal generators that permitted continuous work sampling. In the work, Hartley et al. [4] introduced the concept of quick ideas to allow pharmacists to record their work using a single letter for repetitive activities. Pharmacists record 4,687 observations, 90 per cent using quick codes. The most common activity was checking prescriptions (36.2 per cent).

Detection and correction of prescribing errors was the most common reason for their word (39.4 per cent). Most related activities were performed along (80 per cent) with little time in contact with patients or physicians. These baseline measurements should be compared with future measures to assess the effect of the implementation of computerized prospective drug utilization review and clinical treatment guideline on pharmacists' work. It is expected that these technological and process changes will increase opportunities for pharmacists to educate patients and consult with physicians.

Other research on workstudy has primarily addressed several areas. For example, various works have been reviewed on work measurement techniques involved in establishing what pharmacists do and how they perform these various duties. In a particular search, seven methods of work measurement were used in pharmacy research. Such methods are explained and its applicability to pharmacy research evaluated.

Work measurement studies have proved to be of value in analyzing individual jobs and quantifying institutional staffing levels. By understanding the advantages and disadvantages of each method, researchers in this area should be able to choose the most appropriate method for investigations.

Aft [1] presented the concept of work measurement and enhancing working conditions as a way of improving productivity. It is presented as an outgrowth of Frederick Taylor’s time and motion studies that began in the early 1900’s. Nearly 100 years later, business and industry have begun the traditional concept of work measurement. The work offers concise coverage of the concepts and application of work measurement to boost cooperative productivity.

Barnes [2] demonstrated an application of motion and time study to the design and measurement of work and industrial problem solving. The author showed how motion and time study can increase productivity, improve equipment utilization, conserve materials and energy, reduce human effort and advance organizational goals. Barnes also discussed on computer-aided time study, human factors, and wage incentives.

Zadin’s work [9] is a revolutionary tool designed to simplify and speed up the process of setting engineered time standards. He presented a predetermined motion time system that can be used across all industries.

3. METHODOLOGY

Consider a manufacturing system under the following assumptions:

(1) an effective production system is in place, such that the efforts put into system is directly reflected to the output of the production team;
(2) the right number of production personnel with the skills and training necessary for implementing day to day activities are used;
(3) there is a defined responsibility for individual production worker. Hence, production target is in place and monitored;
(4) the machines are always in a healthy state. Once broken down they can be always be repaired and restored in a negligible time frame; and
(5) there is a clear definition and measurement of output. Hence, unit of measurement of production output are known and specified.

If all these assumptions are valid then we can en-vision a new host of variable to which work standard could relate. Obviously this modelling effort is a natural extension of the traditional way of calculating work standard of various jobs.

The traditional perspective of work standard calculation hinges on determination of standard time through actual observation. However, our model builds on this to incorporate a predictive element in order to allow for the calculation of the standard time needed to carry out certain activities based on historical data.

The model developed in this work is as stated below:

if "y_{ij}" represents the standard time of activity "i" in period "j" and x_j denotes the parameter of interest for the measurement period,

then we may have a predictive model of the form

$$y_{ij} = f(x_i) \qquad (1)$$

Since we are investigating a case for a roofing sheet industry, it means that this simple model applies to each of the three processes of bending, rolling, and crimpsin.

Depending on the function behaviour of the parameter of interest the function may assume any mathematical expression of linear and non-linear functions. For a clear understanding of our model we limit ourselves to the bending process for he purpose of this explanation.

If we take a close look at the basic variables that serve as the components of the bending process, then the following may be mentioned:

(i) number of bend that would appear on the flat sheet when finished;
(ii) the length of the sheet measured in meters;
(iii) the width if the sheet measured in millimetres;
(iv) the thickness of the sheet measured in millimetres but convertible to meters.

If our model is to be fine-tuned to the bending process then each of these four expressions forms the basic variables of the model.

Let the variables represented with notations x_1,x_2,x_3,and x_4. Then we have a linear model of the form:

$$y_i = b_o + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 \qquad (2)$$

where b_0,b_1,b_2,b_3 and b_4 are constants of the model.

This model is a first order linear expression. Higher others could be obtained by varying the powers of x_i's.

By the same argument, a non-linear expression for the model could be stated as

$$y_i = (b_o)(b_1x_1)(b_2x_2)(b_3x_3)(b_4x_4) \qquad (3)$$

Based on all these variables, the standard time could be determined in seconds or minutes. Arising from our calculation could be the standard time per bend. We could also calculate the running meter per shift as well as the weight per shift.

For the rolling process, modelling the system is slightly different from that of the bending. In general, the following elements also influence our calculation:

(i) the number of observations considered;
(ii) total number of observed time;
(iii) average observe time;
(iv) performance rating;
(v) basic time; and
(vi) allowance.

In developing the model work standards data from actual production operations were collected. The historical work standard data and the model results for the various processes are shown below starting with the bending process.

Table 1: Work standards database (Performance Rating = 95%)

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
3	1	6	6.00	5.70	0.97	6.67
4	15	133	8.87	8.42	1.43	9.86
6	3	45	15.00	14.25	2.42	16.67
4	3	28	9.33	8.87	1.51	10.37
3	5	55	11.00	10.45	1.78	12.23
7	4	50	12.50	11.88	2.02	13.89
7	1	7	7.00	6.65	1.13	7.78
3	1	18	18.00	17.10	2.91	20.01
3	5	37	7.40	7.03	1.20	8.23

Key:
Col. 1: Number of Bends (x_1)
Col. 2: Number of Observations (x_2)
Col. 3: Total Observed Time
Col. 4: Average Observed Time
Col. 5: Basic Time
Col. 6: Allowance
Col.7: Standard Time

The linear model suggested above was applied o the data. Thus, resulting in six set of equation for he bending process (table 2). It should be noted that table 1 produces only the first element of table 2 (i.e. place sheet in machine).

Table 2: Bending Process

Equation	Description of activities
$Y = 21.849 + 0.1269(x_1) – 0.158(x_2)$	Place sheet on machine
$Y = 82.76 + 32.895(x_1) + 713(x_2)$	Bend sheet
$Y = 0.921 + 10.72(x_1) – 0.0979(x_2)$	Measure length to bend
$Y = 12.23 + 0.034(x_1) + 0.029(x_2)$	Pick sheet to machine
$Y = 465.7 + 3.01(x_1) + 150.7(x_2)$	Carry sheet to store
$Y = 1.801 + 0.203(x_1) + 0.051(x_2)$	Stocking of sheet by side.

Therefore, in order to develop the linear model for the other five activities we obtained similar data to table 1 for experimentation.

An interesting dimension of the model is varying the order of the equations. A second order work standards model for the bending operation could thus be formulated such that if "y" is differentiated with respect to the component variables, we may establish different sets of equations. For example in the case of "place sheet on machine" the relationship between x_1 and x_2 is represented as

$$y = 0.2538(x_1)^2 – 0.158(x_2) \quad (4)$$

If this equation is differentiated with respect to x_1, then we have:

$$x_1 = 0.7890\sqrt{x_2} \quad (5)$$

This means that in order to find the number of bends that a set standard time could permit, you only need to know the number of observations involved. For instance in the case of 15 observations the number of bends for the optimal level of performance will be

$$0.7890(\sqrt{15}) = 3 \text{ bends.}$$

A variance of these could be obtained if factored. If we consider the making a factor of x_2, then we have

As such we have the equation

$$y = 0.2538(x_1) - 0.158(x_2)^2 \quad (6)$$

The summarised results of the second order equations for the bending process are shown in tables

Table 3: Second order equation for Bending process
(x_1 = second order)

Equation	Description
$Y = 0.2538(x_1)^2 -0.158(x_2) = 0$	Place sheet on machine
$Y = 65.7906(x_1)^2 +713(x_2) = 0$	Bend sheet
$Y = 21.44(x_1)^2 - 0.0979(x_2) = 0$	Measure length to lead
$Y = 0.068(x_1) + 0.029(x_2) = 0$	Pick sheet on machine
$Y = 6.02(x_2) +150.7 (x_2) = 0$	Carry sheet to store
$Y = 0.406(x_1) + 0.051(x_2) = 0$	Stocking of sheet by side

Table 4: Second order equation for Bending process
(x_2 = second order)

Equation	Description
$Y = 0.2538(x_1) - 0.158(x_1)^2 = 0$	Place sheet on machine
$Y = 65.7906(x_1) + 713(x_2)^2 = 0$	Bend sheet
$Y = 21.44(x_1) - 0.0979 (x_2)^2 = 0$	Measure length to lead
$Y = 0.068 (x_1) + 0.029(x_2)^2 = 0$	Pick sheet on machine
$Y = 6.02(x_1) + 150.7(x_2)^2 = 0$	Carry sheet to store
$Y = 0.406(x_1) + 0.051(x_2)^2 = 0$	Stocking of sheet by side

For the rolling process we have a set of equations for the first and second order linear equations shown below: (tables 5, 6, and 7)

Table 5: Rolling process

Equation	Description
$\hat{Y}= 950.09 +188.91(x_1) + 0.13(x_2)$	Sheet running on machine
$\hat{Y}= 63 + 0.26(x_1) – 0.06(x_2)$	Stocking sheet by side

Table 6: Second order equation for Rolling process
(x_1 = second order)

Equation	Description
$\hat{Y}= 376.82(x_1) + 0.13(x_2)=0$	Sheet running on machine
$\hat{Y}= 0.52(x_1) + 0.06(x_2)=0$	Stocking sheet by side

Table 7: Second order equation for Rolling process
(x_2 = second order)

Equation	Description
$\hat{Y}= 188.91(x_1) + 0.26(x_2) = 0$	Sheet running on machine
$\hat{Y}= 0.26(x_1) + 0.12(x_2) = 0$	Stocking sheet by side

By applying the same approach to the crimpsin process we have a new set of equations in tables 8,9,and 10.

Table 8: Crimpsin process

Equation	Description
$\hat{Y}=3.97 + 0.075(x_1) + 0.94(x_2)$	Pick sheet from flour to machine
$\hat{Y}=68.98 + 0.13(x_1) + 8.47(x_2)$	Set up sheet on machine
$\hat{Y} = 3790.4 - 10.72(x_1) – 435.40(x_2)$	Crimpsin operation
$\hat{Y}= 36.34 - 0.28(x_1) + 5.53(x_2)$	Carry sheet to store

Table 9: Second order equation for Crimpsin process
(x_1 = second order)

Equation	Description
$\hat{Y} = 0.150 (x_1)^2 + 0.94(x_2)$	Pick sheet from flour to machine
$\hat{Y} = 0.26 (x_1)^2 + 8.47(x_2)$	Set up sheet on machine
$\hat{Y} = 21.44 (x_1)^2 - 435.40(x_2)$	Crimpsin operation
$\hat{Y} = 0.56 (x_1)^2 + 5.53(x_2)$	Carry sheet to store

Table 10: Second order equation for Crimpsin process
(x_2 = second order)

Equation	Description
$\hat{Y} = 0.075(x_1) + 1.88(x_2)^2$	Pick sheet from flour to machine
$\hat{Y}= 0.13(x_1) + 16.54(x_2)^2$	Set up sheet on machine
$\hat{Y}= -10.72(x_1) - 870.80(x_2)^2$	Crimpsin operation
$\hat{Y}= -0.28(x_1) + 11.06(x_2)^2$	Carry sheet to store

3.1 Model sensitivity analysis

The usual practice in model development is to find out the responsiveness to changes of some parameters embedded in the model. As such, the robustness of the model could be tested. In addition, the reliability of the estimated values could be ascertained.

The predictive model discussed in this work was tested for sensitivity using some of the parameters in the model developed. In order to have a clear picture of the model sensitivity to changes of the parameters, we varied the parameters by some accounts, usually at 5% increase or decrease in value of input. We then noticed the corresponding changes in the output. The result of our variations is displayed in table 10 below:

Table 10a: Sensitivity Analysis of x_1 (bending process)

Input Changes (%)	Value of ŷ	Output Changes (%)
5	-6538.46	1
10	-6615.65	2
15	-6692.83	4
20	-6770.02	5
25	-6847.20	3
30	-6924.38	7
35	-7001.57	8
40	-7078.75	9
45	-7155.94	11
50	-7233.12	12
55	-7310.30	13
60	-7387.49	14
65	-7464.67	15
70	-7541.86	16
75	-7619.04	18
80	-7696.22	19
85	-7773.41	20
90	-7850.59	22
95	-7927.78	23
100	-8004.96	24

Table 10b: Sensitivity Analysis of x_2 (bending process)

Input Changes (%)	Value of ŷ	Output Changes (%)
5	-6896.68	7
10	-7332.08	13
15	-7767.48	20
20	-8202.88	26
25	-8638.28	33
30	-9073.68	40
35	-9509.08	47
40	-9944.48	54
45	-10379.88	61
50	-10815.28	67
55	-11250.68	74
60	-11686.08	81
65	-12121.48	88
70	-12556.88	94
75	-12992.28	101
80	-13427.68	107
85	-13863.08	114
90	-14298.48	121
95	-14733.88	128
100	-15604.68	142

4. CONCLUSIONS AND FUTURE RESEARCH

In the face of a continued economic depression, the world over, there is a strong and urgent need for manufacturing companies to develop scientific systems of measurement of work. This is aimed at reducing the incessant occurrences of labour down tooling in manufacturing concerns. It will also lead to an improved uptime of machines and consequently improve production performance and lower production cost. To meet these requirements, the decision-maker must have a substantial depth of work standards knowledge and experience in the application of the model presented in this paper.

This work: (i) explores the role of work standards in a manufacturing concern, (ii) reviews the relevant research that have been carried out to date, (iii) propose same top priority research questions for empirical, theoretical and conceptual scrutiny by the work measurement community; and (iv) presents on analytical model based on some sound traditional scientific basis in the work study literature.

Primarily, the bending and roll forming processes consist of three activities each coil-loading, machine running time, and unloading times. The results show that on the average coil loading time was 12 minutes; coil offloading time takes about 2 minutes, and machine running time per metre averages 3 seconds. For the roll forming crew/shift has the capacity to produce up to 14.88.8 tons of roofing sheets with a thickness and width of 0.45mm and 1,200mm respectively. For a 0.55mm x 1,200mm sheet, a crew/shift can produce up to 18.197 tons. Furthermore, for a diversion of 0.55mm x 1,000mm sheet, 15.164 tons is achievable.

For the bending process, the standard time per bend is 35.36 seconds for a thickness of 0.45mm. The achievable production capacity per shift is 0.857 tons per shifts. On the average, the standard time per bend is 34.37 seconds.

The study presents work standards as a multi disciplinary area involving professionals in personnel management, industrial engineering, mechanical engineering, and management services. Work standards have many parts: standard time, normal time and allowances. Allowances may include relaxation, breaks, rests etc. Hence, the goal of the article is to sharpen our understanding of work standards research. Certainly, this work does not attempt to replace the existing literature by any means, but rather to support it. This research is motivated by the dearth of research in the work standards domain.

Currently, the literature is saturated with the traditional approach of solving work standard problem. The work standard literature seems unchallenged. This work is therefore an effort to rethink about the way work standards are carried out. We expected this study to stimulate some research in this seemingly inactive research area. From the findings of this study, it is recommended that many areas warrant investigations. A top priority research is the development of a methodology that relates work standard with job rating and analytical hierarchy process.

Since information technology is becoming a reality among many new and old business functions, an integration of this highly rated technology with the work standards research resources and human intelligence. The outcome of an intensified effort on work standards could be the development of work standard computer software. This computer tool could be viewed from both the customers' and producers' viewpoints. However, by utilizing the work standard software, the manufacturing organization has permanent records in a database that can be manipulated to provide specific workforce performance information.

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