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Measuring Infrastructure Skills Productivity

Rex Asibuodu Ugulu, Stephen Allen and Andrew Arewa

Abstract

This chapter presents the concept and meaning of construction productivity and the techniques used in measuring workforce skills productivity in the construction industry. There are three major methods highlighted for monitoring and measuring productivity in the construction industry. The first relates to visual recording that requires taught watchers to be available on location to monitor and record work by specialists. The second is the physical recording technique which involves a direct surveillance technique that includes a qualified observer observing the site for the full duration of the working day operation using the work study method or work measurement. This method was typically illustrated with the application of regression model and learning curve theory to improve labour productivity. The third measuring technique discussed is the use of questionnaires and interview survey which involves information gathering through an interview with supervisors and workers working in the construction industry. Finally, the chapter discussed how infrastructure productivity can be improved through effective supervision, material management and supply chain management, project front-end planning (loading) and work face planning, training and certification of workforce and labour management and relations.

Keywords: construction, measurement, productivity, method study, skills, work measurement, work study

1. Introduction

Productivity in its broader sense is the association between a given output and the resources used to produce it; this relationship represents the global productivity factors, expressed as a fraction, of which the numerator is a measure of output and the denominator a measure of all factors combined. The combination of the factors of production (capital, labour, raw materials and power) is always heterogeneous, and values must be introduced to find an expression for it [1]. It is easier to relate output to a single factor than to a combination of factors. Labour is the factor considered in most cases, but it may be capital or a given raw material, for example.

Productivity is defined by the *Concise Oxford English Dictionary* “as the effective power of production and the proportion which goods are produced”. In this definition, it can be deliberated that the main resource in productivity is the workforce.

Construction operatives are the most productive resource; therefore, productivity in the construction industry is dependent primarily on human performance and effort [2]. Construction labour productivity is an important productivity index due to the numerous human labour required to carry out and complete

a task. Researchers in the field of economists will agree on the significant of productivity to an industry, an individual enterprise or the national economy; however, there has not been any agreement on the actual measurement techniques of productivity.

The Bureau of Labor Statistics (BLS) updated the productivity measures for four infrastructure construction industries in 2017. These industries were only recently published due to difficulties in measuring worked hours and output [3]. The US construction sector in 2017 contributed a large portion to the economy with 4.3% of GDP and 6.1% of all industry employment which was attributable to the sector. Recently, the BLS noted that the infrastructure industries comprise about 10.5% of the entire industry sector's employment.

1.1 Productivity concepts

There have been several construction labour productivity (CLP) definitions that point towards the various perception of the productivity in the construction industry. The European Association of National Productivity Centres [4] defined productivity "as how resourcefully and efficiently goods and services are being formed, efficiently in this setting be doing things right or utilizing resources to achieve anticipated results". Productivity is also defined by the American Association of Cost Engineers [5] "as a labour efficiency of relative measure, either bad or good when related to a recognised base or norm." "The comparative nature of construction productivity generate most challenges in tracing it as a complete significant over time, it is feasible to gather information on the arrangement of the recognised base, or yardstick" [6]. However, the professionals in the construction industry and project managers defined labour productivity as a proportion of expected over actual productivity; this is mathematically expressed as

$$\text{Performance Ratio (PR)} = \frac{\text{Actual Productivity}}{\text{Expected Productivity}} \quad (1)$$

When a PR is higher than the unity, it means that the daily-based quantities require more work hours than the normal average day baseline; also, it implied that the productivity of that day was worse than the baseline productivity [6]. The importance of this method is that progress is based on the constructed work and not the hour work utilised and productivity can be measured despite the type of work done. The Bureau of Labor Statistics [7] well defined labour productivity as productivity per real worked hours, and these hours refer to the really worked hours, and this quantity discounts holidays, trip and sick leave; nevertheless, it comprises salaried and voluntary overtime.

Productivity measures how capitals are hired efficiently; it is defined "as the quantity of a specific amount of input per unit of labour to a specific measure of output and usually measured as total output divided by the numbers of units of labour employed to produce that output" [8]. Labour productivity in the construction industry can be described as the man-hour output per day, which is often reduced by poor provision of inadequate tools and equipment; delayed, unclear or inadequate instructions; unbalanced work gangs; wrong working method; inadequate incentives; and non-delegation of authority from senior supervisors to lower supervisors.

Productivity definitions seem to be dependent on the context and the researcher's opinion on the study. Previous studies on engineering, technology and economics classified productivity into three broad industry groups; these various groups defined productivity from their various viewpoints [9].

Definitions of productivity are aimed at explaining the meaning of the term, while measured descriptions in the previous case are used as a base of measurement; the main objective is to increase and productivity [10].

From the above background, productivity can be defined as the volume correlation relating to work hour utilisation and production. It is also the correlation relating to amounts of input hours used by an organisation to produce output:

$$\text{Labour productivity} = \frac{\text{output produced}}{\text{input work - hour}} \quad (2)$$

From Eq. 2, output can be described as any process of the outcome, either a product or service, whereas input work hour consists of the hours utilised in a process. However, the relationship between a variety of output components and work hour is very complex. Measurement of construction skills productivity presents practitioners and academics with a variety of challenges.

Several challenges have been recognised by diverse researchers for declining labour productivity under the classifications of incomplete documentation, design changes, supply chain fragmentation and inefficient project management as the most important drivers affecting productivity in the mid-rise private development in Australia [11]. Ugulu and Allen [12] carried out an experimental examination on the importance of on-site craft gangs' learning productivity and found an average improvement of learning rate of 94.21% gains as illustrated in **Table 3**. The study additionally discovered that on-site learning is a huge factor influencing productivity of construction craft gangs. In a related study, Tanko et al. [13] developed a framework for value management (VM) implementation, exploring the current construction practice factors that will improve construction productivity, the study found that people, environment, government and information are important factors that can be used by construction stakeholders to improve construction productivity practices in the Nigerian construction industry.

An investigation on productivity of panelised and long span timber construction using time lapse photography on five active case study construction sites to measure installation productivity was conducted by Forsythe, Brisland [14], using net crane time as the basis for measuring productivity, being the time dedicated purely to crane cycles involved directly in installing prefabricated timber panels; 521 cycles were measured relating to the installation of 5592 m² of panels. The study found that panelised prefabricated timber construction offers a fast and productive site installation process [14].

2. Measuring construction productivity

Labour productivity measurement in the construction industry is a difficult task; in most cases labour productivity is usually taken to mean productivity. This stems from the fact that projects in the construction industry are labour-intensive using basic equipment [15]. Productivity described the quantification of how well operatives use available resources to produce outputs from inputs [15]. The American Association of Cost Engineers [5] described productivity as when associated with standard or to a recognised base as the relative measure of labour efficiency is either good or bad.

The BLS [3] opined that the increase in labour productivity during the 2000–2005 period was primarily driven by a large rise in output. Beginning in 2005, output fell through 2009 at a speedy rate than the worked hours, leading to a sharp reduction in productivity of labour during that period. The productivity of labour

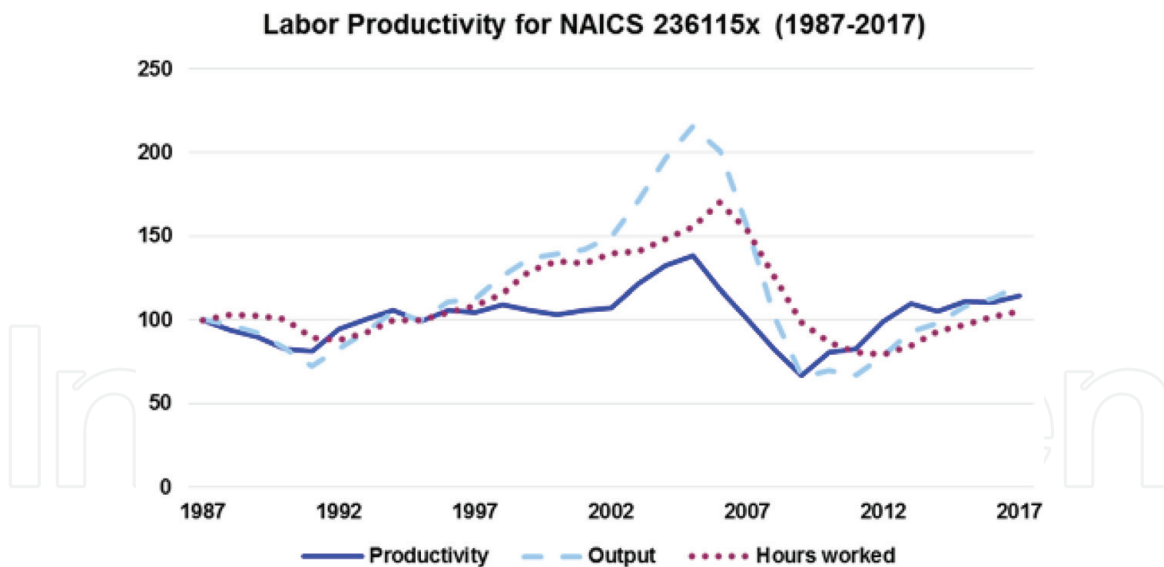


Figure 1.
Productivity of labour for single-family residential infrastructure [1].

increased since 2009; however, in 2017 it is far below its 2005 topmost as presented in **Figure 1**. productivity of labour for single-family residential infrastructure (NAICS 236115x). The report further stated that infrastructure industry experienced a decrease in productivity output and a slight fall in worked hours, resulting to decreasing productivity of labour until 2010. In 2010, the productivity output returns to normal until 2017, when output slightly declined [3].

Construction skills productivity measurement is complex and challenging when comparing productivity in the construction industry between nations [16]. Productivity indices are utilised to adjust input and output information with the goal that efficiency measurement can be differentiated after some time and among industry divisions, and countries found that these lists vary among nations [17]. For instance, output in the construction industry is complicated when compared and quantified within a nation due to complexity in comparing single-family households to transportations, colleges to bridges or clothes centres to workplace buildings.

The National Research Council [18] noted that worldwide productivity evaluations have similar encounters, such as the heterogeneity of inputs and outputs. The loss of valued information on the nature of heterogeneous building construction output is as a result of combining data to an organisational level [17]. In addition, [18] noted that “an industry productivity analyst varies on whether productivity in the construction industry is decreasing or improving.” Productivity has been declining for over 30 years. However, some construction projects and construction tasks studies document investigated improved in their productivity in the US industry productivity analysis [18].

Contractor’s labour performance measure is degraded by variability in building processes when the presence of variation with process of construction time can no longer be determined [19]. Construction variability inflates the construction duration and decreases the processes and the ability of the production network [20]. Rework flow in construction project is a significant cause of variability that causes procedures to be unpredictable [6]. However, in building projects, rework can be arising due to errors in construction exposed through official stage examinations or casual on-site observations. Additionally, another kind of rework is client-related rework, which is instigated by variations in project design, plan and scope by the client [21].

Construction on-site is environmental dynamic and subjected to a high level of unpredictability and outside volatility that can be caused by constraints outside the project location, such as extreme conditions of weather, while internal variability

can be caused by various sources of unstable motivation, workflows and quality issues causing rework [22]. Construction variability presence influences the possible increase in the production rate by improving bottleneck processes [19].

Previous literatures in engineering management studies have revealed that the two major noteworthy instruments for controlling changeability work process are unpredictability caused by rework which can be limited using effective observing and quality review [23, 24]. Walsh and Sawhney [25] saw that workflow process levelling approaches deliver steady outstanding burdens for exchange of temporary workers and workflow process levelling in construction productivity can be connected in different courses.

Bashford and Sawhney [26] carried out an investigation and observed that in the activity-based model, an equally spaced schedule is upheld for all activities. In order to tackle these problems of unnecessary rework and ineffective time, certain management techniques have been evolving which is known as “time and motion study” but are now termed work study [27].

Shirowzhana [28] investigated the use of a Wi-Fi-based positioning and communicating system for indoor positioning with radio communication systems called the Voice Communication and Locating System (VCLS). The VCLS was integrated with BIM and GIS for enhancing labour productivity in the construction industry. The GIS and the BIM were used for displaying the positions of mobile devices for tracking the position of a worker in a proposed site. The study revealed that VCLS has the ability of tracking the estimated locations of workers in 3D environment and GIS and VCLS are valuable software that could improve the communication efficiency and quality of interaction on the infrastructure site.

2.1 Techniques used for measuring time and motion study

There are three major methods used in the measurement of time and motion study (work study) in construction productivity [29]:

1. Visual recording method
2. Physical recording method
3. Interview and questionnaire method

2.1.1 Visual recording method

Visual account is a strategy utilised in observing the execution of specialists on destinations persistently, and it may be considered as a pioneer in the use of visual chronicle method for efficiency checking determinations [29]. Parker and Oglesby [30] saw that this procedure includes the utilisation of photography time-slip with the application of a camera concentrated on a work territory and a photo is taken at precise time interims extending from 2 to 8 minutes. This strategy has a few advantages over others giving right, enduring and unquestionable records that can be valuable to teach determination of construction claims and contract contradictions, assessing workforce skills performance and evaluating the productivity of construction methods. This technique is related with a few burdens, for example, creating distress between the labourers being continually watched, lacking inadequate coverage area and the prerequisite for various cameras on huge destinations.

Another kind of visual recording approach is the utilisation of tape recording framework in estimating workforce abilities execution. It has related elements of a task yet catches all or most concurrent exercises considering less eyewitnesses

nearby. One of the burdens of this strategy is discovered that the procedure is a costly technique; it requires taught watchers to be available on location to monitor and record the work finished by specialists. The rudimentary methodologies utilised in this execution are activity sampling, visiting the site every day and consistent observation. Sampling activity strategy is otherwise called sampling work [30].

Activity sampling technique can be portrayed as a sporadic recognition methodology that incorporates seeing a little degree of assignment events that is adequately tremendous to have a numerical consequence. Regardless, it includes an eyewitness who may stroll around the project site and record workforces' events, it is used to pass on a gadget for describing how the pros commit their time on attempted site, and it is occasionally expected that work accomplished, or yield is identified with the measure of period spent on direct work [30]. Activity sampling technique has been used widely and tested by several researchers, and important results were presented in many technical articles; one of the main importance of the method is that several workers can be concurrently observed by an observer on site, while the main drawback accompanying this method is the assumption that the amount of direct time spent is related to the outputs [31].

An investigation carried out on the US plant construction using an extensive analysis of the data collected by activity sampling established there was no relationship among the direct working time spent and the outputs. The investigation found that work sampling technique does not differ between actual and busy work and decided that direct labour cannot be used to estimate productivity [31].

Another type of activity sampling technique is the daily visit technique which is also known as intermittent observation method that encompasses the observer collecting data from site visit on a day-to-day basis [32]. According to Naoum and Hackman [32], finished site work or construction is visually checked by the observer and, if appropriate, marked on drawings; this technique has numerous importance, and if building sites are in near closeness to one another, the viewer can screen numerous sites throughout the same day.

Significance of this strategy is that it evades the turmoil joined by workforces being watched and checked and underpins in maintaining a decent relationship among the watcher and site labourers. The information assembled by this procedure relies upon the exactness and precision of the information given by the site specialists; the steady perception strategy can be isolated into perception by direct technique and work study technique.

2.1.2 Physical recording technique

Direct observation technique can also be described as a physical method of observation that consists of a researcher physically observing the site for the total duration of the operational day and the observer concentrating his devotion on a gang of skilled craft members and recording direct and contributory time spent on the work and the period that is not consumed at work such as late starts and early quits, attending to personal needs and breaks [33].

This technique offers a correct data and is very advantageous in determining the time input distribution used to accomplish certain outputs. The major disadvantage of this method comprises dissatisfaction and mistrust between the workers or group being constantly monitored, which might cause incorrect or inflated productivity, and also, on big project sites, it might necessitate more than one observer to efficiently observe the tasks rendering this method expensive [34]. There are three parallel approaches to physical recording technique, namely, work study, method study and work measurement.

- Work study

The term “work study” considers the parallel strategies of method study and work measurement, which by an efficient method of examination and enhancement try to get the most ideal utilisation of human and materials assets [27].

The work study strategy is another related procedure like the immediate perception technique; notwithstanding, it shifts in the season of checking by the watcher on location; this technique, perception identifies with the work grouping of the undertaking analysed (British standard glossary, BS 3138). Work study can be all around characterised as an association benefit dependent on those techniques; particularly work measurement and method study strategy contemplate what is utilised when exploring human work in all background, and this can prompt the precise examination of the considerable number of capitals and variables which aggravate the viability and economy of the condition being inspected, so as to impact improvement [32].

Work study bolsters the parallel method study and work measurement strategies, which is a methodical technique for acquiring the most ideal utilisation of material and HR. It is a standout among the most possibly helpful apparatuses of the management. Conventional men can accomplish extraordinary outcomes by limiting squandered exertion and time and setting an appropriate standard of execution.

- Method study

Method study measures the adequacy of the strategy and work technique procured to convey frameworks of examination designed for the headway of efficiency measures and surroundings of working [35]. The aim of method study is to evaluate the best method of doing work in order to recommend the best efficient technique of production. Although the detailed analysis may become more complex, the basic procedure is summarised in **Figure 2**.

The initial approach to this method is to first select the type of work that will impact the overall productivity of the skills workforce. The factors to be considered during the selection are economic, technical or human. Economic factors can include “bottlenecks” that can influence other activities. For example, form working on reinforced concrete-framed buildings, the operations can involve lots of labour/plant or the transportation of materials through a long distance like excavation of long hauls and repetitive work like building. There are always technical issues, but these issues must be resolved by a consultant specialist [27].

- Work measurement

A work measurement complements method study in order to derive the maximum benefits from a systematic study of work activities. While method study is related to the approach in which work is performed, work measurement is interested with the human resources involved in the job. Although work measurement and method study are interdependent, they cannot be separated from each other.

The mental approach of work study is primarily the application of common sense, and assessment of the expected time needed to carry out a specific task by work measurement, because of the special technique employed, is mainly the field of the trained and experienced expert. Nevertheless, a project manager must have an adequate understanding of the principle involved if he is to employ work study successfully. Since work measurement seeks to reveal the shortcomings of management and to show up the behaviour of workers, it is often met with resistance so that an understanding of human factors involved is important. It is worth noting

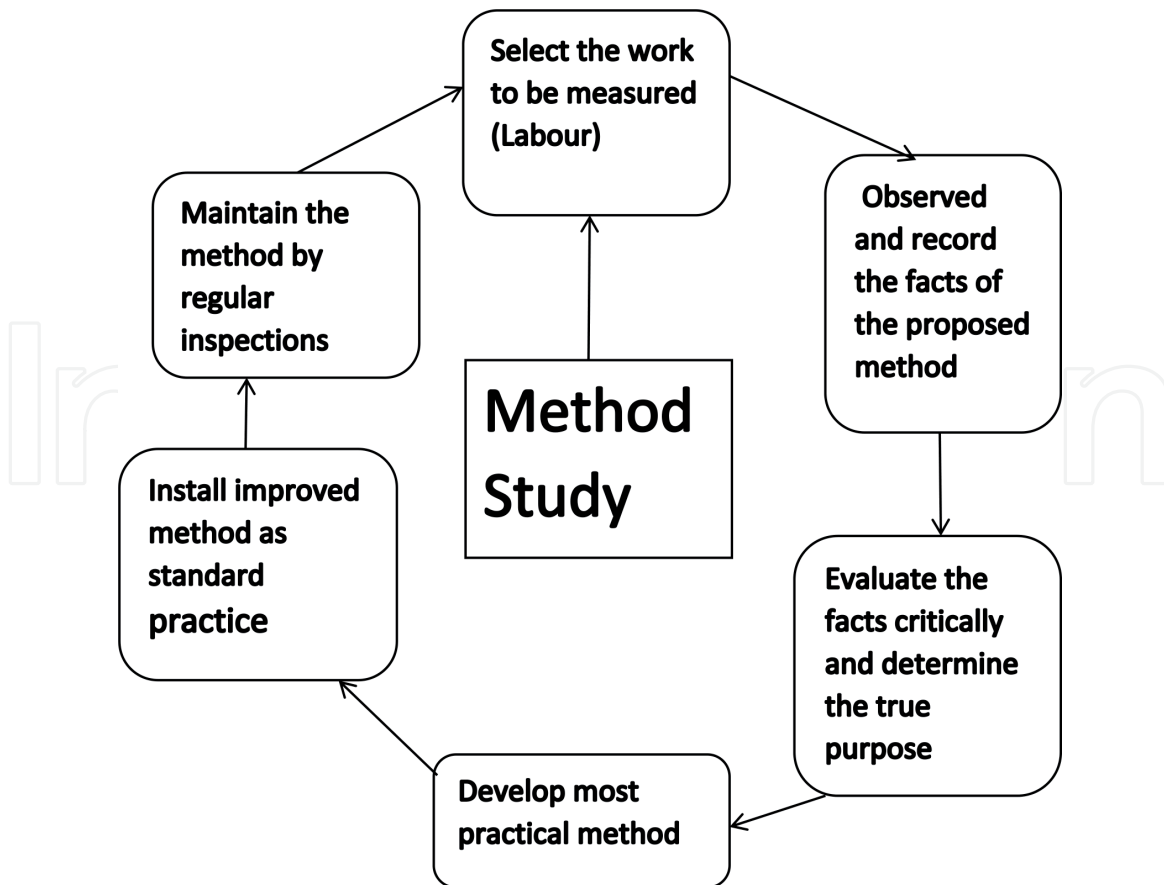


Figure 2.
Method study procedure.

that time study provides a record of a particular operation, and not a check on an individual's performance [27]. The general procedure for work measurement is presented in **Figure 3**.

Work measurement can be carried out by the advanced method. Time study is the basic technique: Timing is usually performed with a watch unless the extremely accurate measurement is required, when devices such as the cine camera or portable tape machine may be used. The watch can be a good wrist or pocket type with a second hand, but a stopwatch is better and more convenient. The purpose of work study is to optimise productivity from the manpower and materials available, and since it is management's responsibility to see that the best use is made of organisation resources, it is, therefore, building managers who must be convinced of the value of work measurement application on building operations [27].

- Work measurement procedure

Work measurement includes structuring a progression of perception structures to incorporate pertinent undertaking data. Site information data is incorporated into the perception shape. Precedent: venture type, perception number, compelling beginning date, space limitation, assuming any, ordinary day by day working hours, and the site management level. Furthermore, a short depiction of the watched task, for example, the technique, divider type, adds up to floor zone, and the quantity of stories will likewise be incorporated into the form. At long last, the qualities of each watched exchange are featured as presented in **Table 1**: work measurement form. The fundamental motivation behind these structures is to reliably record the basic efficiency parameters of data sources and their related yields for the different aptitudes or exchanges and to reflect, to an expansive degree, the genuine conditions on destinations.

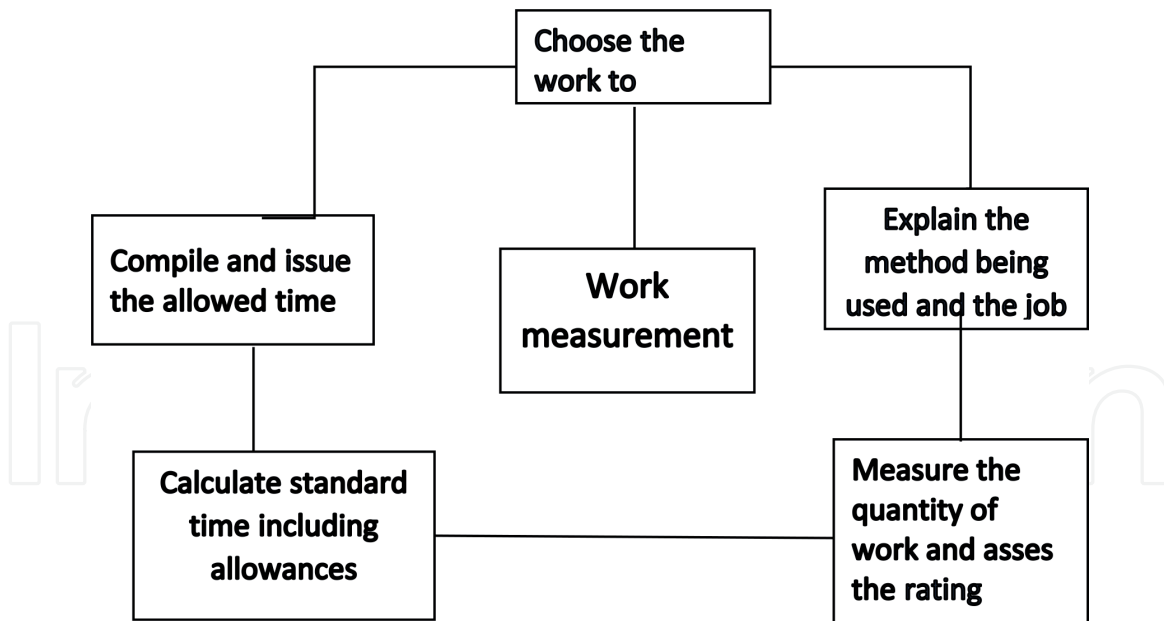


Figure 3.
 Work measurement procedure.

Table 2 presents a typical analysis of work measurement data using the simple linear regression technique to investigate the relationship between the cycle numbers of the repetitive productive work input. The dependent variable is the skills worker recorded observed time productivity. A significant level of 5% was used to determine the relationship between skills worker inputs and cycle numbers by substituting the recorded observed time into the linear regression model equation:

$$Y = \alpha + \beta X \quad (3)$$

From the regression equation, α and β indicate the intercept and the slope of the linear regression model. The slope and the intercept are estimated; thus

$$\beta = (n\sum xy - \sum x\sum y) / (n\sum x^2 - (\sum x)^2) \quad (4)$$

$$\alpha = \bar{Y} - \beta \bar{X} \quad (5)$$

where y are the man-hours and x are the cycle numbers.

In the regression equation above, α and β were used to calculate the regression model for the skills productivity as presented in **Table 2**.

As depicted in **Table 2**, the slope and the intercept were estimated; thus

$$\beta = (n\sum xy - \sum x\sum y) / (n\sum x^2 - (\sum x)^2), \text{ and } \alpha = \bar{Y} - \beta \bar{X} \quad (6)$$

In order to measure the significant of the skills (blockwork) productivity, the authors employed the application of the learning curve theory utilising the straight-line unit model as presented in **Table 3**. The mathematical model for the straight-line learning curve is

$$Y = T1 \times (x)^b \quad (7)$$

where y = cost and man-hours; $T1$ = cost, man-hours or time necessary to perform the first unit; x = cycle number of the unit; and b = slope of the learning curve, which is calculated as

$$b = \ln S / \ln 2 \quad (8)$$

Work measurement data collection form							
Firm:		Study no.:			Date:		
Gang no.:		Start time:					
No. of skilled:	No. of unskilled:	Finish time:					
No. of operators in gang:		Total observed time:					
Contract duration:		Wall thickness:		100 mm	150 mm		
Type of building:	Bungalow	225 mm		Other			
Storey building:	Other	Wall height:		0–1.5 m			
No. of floors:		1.5–2.1 m		2.1–3.0 m			
Weather condition:		Above 3.0 m					
Observer:							
Element description	R	WR	OT	BT	AL	ST	Remark
Discharge/loading of material							
Mixing of mortar							
Laying of blocks							
Pointing							
Others (specify)							

R, rating; WR, watch reading/cumulative; OT, observed time; AL, allowance; ST, standard time; BT, basic time.

Table 1.
Typical work measurement form [2].

S/N	LN man-hours Y	LN cycle no. X	C XY	D X ²	E Y ²	F nΣXY	G ΣXΣY	H nΣX ²	I (Σx) ²	J H-I	K F-G	M β = K/J	N Bx̄	O α = Ȳ-βx̄
1	6.10	—	0	—	37.2100	9579.295908	9591.644112	4209.966516	3754.35602	455.6104957	-12.348204	-0.0271	-0.063871109	6.08464
2	6.04	0.6931	4.186324	0.4804	36.4816									
3	6.03	1.1098	6.692094	1.2317	36.3609									
4	6.01	1.3862	8.331062	1.9216	36.1201									
5	6.01	1.6094	9.672494	2.5902	36.1201									
6	6.03	1.7917	10.80395	3.2102	36.3609									
7	6.12	1.9459	11.90891	3.7865	37.4544									
8	6.04	2.0794	12.55958	4.3239	36.4816									
9	6.05	2.1972	13.29306	4.8277	36.6025									
10	6.02	2.3025	13.86105	5.3015	36.2404									
11	6.04	2.3978	14.48271	5.7494	36.4816									
12	6.03	2.4849	14.98395	6.1747	36.3609									
13	6.04	2.5649	15.492	6.5787	36.4816									
14	6.04	2.6390	15.93956	6.9643	36.4816									
15	6.00	2.7080	16.248	7.3333	36.0000									
16	6.01	2.7725	16.66273	7.6868	36.1201									
17	6.04	2.8332	17.11253	8.0270	36.4816									
18	5.98	2.8903	17.28399	8.3538	35.7604									
19	6.01	2.9444	17.69584	8.6695	36.1201									
20	5.98	2.9957	17.91429	8.9742	35.7604									
21	5.98	3.0445	18.20611	9.2690	35.7604									
22	5.99	3.0918	18.51988	9.5592	35.8801									
23	5.98	3.1355	18.75029	9.8314	35.7604									
24	5.98	3.1781	19.00504	10.1003	35.7604									
25	6.01	3.2189	19.34559	10.3613	36.1201									
26	5.98	3.2581	19.48344	10.6152	35.7604									

S/N	LN man-hours	LN cycle no.	C	D	E	F	G	H	I	J	K	M	N	O
	Y	X	XY	X ²	Y ²	nΣXY	ΣXΣY	nΣX ²	(Σx) ²	H-I	F-G	β = K/J	Bx̄	α = Ȳ-βx̄
Σ	156.54	61.2728	368.4345	161.9218	942.5226									

Table 2.
Regression model for skills productivity.

S/N	LN man-hours	LN cycle no.	C	D	E	F	G	H	I	J	K	L	M	O	P	Q
	Y	X	XY	X ²	nΣXY	ΣXΣY	nΣX ²	(Σx) ²	E-F	G-H	β = I/J	Ŷ	Ẋ	Bẋ	α = Ŷ-Bẋ	S = 2b*100
1	6.1000	—	—	—	9579.2959	9591.6441	4209.9665	3754.3560	-12.3482	455.6105	-0.0271	6.0208	2.3566	-0.0639	6.0846	98.1389
2	6.0400	0.6931	4.1863	0.4804												
3	6.0300	1.1098	6.6921	1.2317												
4	6.0100	1.3862	8.3311	1.9216												
5	6.0100	1.6094	9.6725	2.5902												
6	6.0300	1.7917	10.8040	3.2102												
7	6.1200	1.9459	11.9089	3.7865												
8	6.0400	2.0794	12.5596	4.3239												
9	6.0500	2.1972	13.2931	4.8277												
10	6.0200	2.3025	13.8611	5.3015												
11	6.0400	2.3978	14.4827	5.7494												

S/N	LN man-hours	LN cycle no.	C	D	E	F	G	H	I	J	K	L	M	O	P	Q
	Y	X	XY	X ²	n Σ XY	Σ X Σ Y	n Σ X ²	(Σ x) ²	E-F	G-H	$\beta = I/J$	\dot{Y}	\dot{X}	B \dot{x}	$\alpha = \dot{Y}-B\dot{x}$	S = 2b*100
12	6.0300	2.4849	14.9839	6.1747												
13	6.0400	2.5649	15.4920	6.5787												
14	6.0400	2.6390	15.9396	6.9643												
15	6.0000	2.7080	16.2480	7.3333												
16	6.0100	2.7725	16.6627	7.6868												
17	6.0400	2.8332	17.1125	8.0270												
18	5.9800	2.8903	17.2840	8.3538												
19	6.0100	2.9444	17.6958	8.6695												
20	5.9800	2.9957	17.9143	8.9742												
21	5.9800	3.0445	18.2061	9.2690												
22	5.9900	3.0918	18.5199	9.5592												
23	5.9800	3.1355	18.7503	9.8314												
24	5.9800	3.1781	19.0050	10.1003												
25	6.0100	3.2189	19.3456	10.3613												
26	5.9800	3.2581	19.4834	10.6152												
Σ	156.5400	61.2728	368.4345	161.9218												

Source: Bureau of Labor Statistics [3], Ugulu and Allen [12].

Table 3.
Learning rate of skills productivity.

where S is the learning rate, which is defined as the percentage reduction in the unit input, i.e. cost, man-hours or time, as a result of doubling the number of units completed. Eq. 8 can be rewritten as

$$S = (2^b) * 100 \quad (9)$$

2.2 Questionnaires and interviews

Questionnaire and interview techniques involve collection of information through interviews from workers and supervisors in the construction industry [36]. The two types of surveys that are mainly used by observers are:

1. The craftsmen's questionnaire survey
 2. The foreman delay survey
- The craftsmen's questionnaire

The craftsmen's questionnaire survey is an intermittent perception strategy that is utilised for assessing the management productivity and to recognise difficulties impacting skilled workers' output and motivation. This procedure includes a normal premise; the labourers are asked to give a guess of the loss of time on site, rank the seriousness of the difficulties and prescribe system to these difficulties, and therefore, managers would have the capacity to distinguish difficulties activated by deferrals and their plausible administrative suggestions to these difficulties. This strategy produces work joy and inspiration between the specialists as it communicates the feeling of association in the enhancement of the job instead of being only a device for its achievement [37].

The inconvenience of this system is because information gathered together are normally founded on the labourer's memories and estimates as opposed to correct and point-by-point ongoing data.

Shortcoming originates from the measurement that workforces are not in a site to quantitatively perceive the reasons of general delays as they are not regarding the organisation, which lessens the individual technique and inclined to incorrectness, and work may likewise be irritated when workforces are named upon to fill the forms in classification for namelessness purposes; also, the methodology ends up being troublesome and dreary when every representative needs to fill a form.

The investigation conducted by Chang and Borcharding [37] recommended a new method which is related to the activity sampling method. In this method workers are selected randomly and are requested to fill the questionnaire form based on their utmost current events; this technique leads to better-quality accurateness and abridged work interruption as workforces are near to the observer at their various areas of work to complete the surveys form on the spot.

- The foreman delay survey

The basic principle of the foreman delay survey method is to assist foremen, being closer to their work in order to determine and calculate the losses due to time at the close of each day at work with acceptable correctness [38]. This technique involves the foremen being requested to fill a list for day-to-day delay account in the project site, and the obtained information is measured, and a summary of time lost is shown stipulating all the stages of site supervision, together with the foremen who contributed to the data.

This method generates job happiness and motivation for foremen and their teams as they increase in value the fact that their decisions are respected by site

management. Furthermore, the foreman delay surveys do not consider the availability of data on the efficiency of work approaches in a job and the capability of the labour force or the level of productivity attained; also, it offers a reasonably priced technique of finding input times activities.

3. How can infrastructure skills productivity be improved?

Previous researchers [12, 14, 39] on improving infrastructure productivity observed that infrastructure productivity can be improved through any of the following:

1. Effective supervision and monitoring
2. Material management and supply chain management
3. Project front-end planning (loading) and work face planning
4. Training/learning and certification of workforce
5. Labour management and relations

- Effective supervision and monitoring

In effective supervision and leadership area of improving construction productivity, professionals in the construction industry should adhere to the following:

- Ratio of labour to supervision of 1–8 to 1–20. Should not exceed 20
- Oversight with experience and authority
- More formal process to enforce company failures
- Accountability of scope, time and cost
- Availability of all materials for construction
- Material management and supply chain management

Material management and supply chain managers should ensure the following:

- Ensure that all materials are available in a timely manner.
- “Look ahead” material management and logistic plans.
- Provide more resources, for example, material availability, land surveyors, construction supervisors and contractors.
- Provide the right materials at the right time and ensure accountability.
- Build relationships with suppliers.
- Implement material management and controls in advance.

- Project front-end planning (loading) and work face planning
 - Front-end planning is the method of developing enough strategic information which the project team can address the scope of the project and requirements that allow successful execution of the project, defining long-term plan, objectives and scope rather than jumping into design and quick construction.
 - If long-term goals and planning are more concretely defined, rework can be limited. Define scope of project and reduce conflicting scopes.
 - Plan projects in detail before starting.
- Training/learning and certification of workforce
 - Training programs for both foreign and local labour help companies improve productivity in the following ways:
 - Encourage more organisational training for lower-level supervisors who are directly responsible for people on the tools.
 - Provide training and mentoring for frontline supervision.
 - Provide training for project management field/plant personnel.
 - Ensure proper training on the job to infrastructure worker to enhance experience.
 - Infrastructure trades promotion versus office/clerical alternative education.
 - If resource from other countries is used, then foreman must speak the same language.
 - Investing in apprentice training is necessary.
 - Provision of proper programs for mentorship will improve both work performance and training effectiveness.
- Labour management and relations can be improved through:
 - Better relationship with workers because when management treat workers better, they perform better.
 - Provide attractive incentives, education and skilled labourer retention.
 - Foster a productivity culture productivity with an aim to get above 65%.

4. Conclusion

This chapter featured the systems utilised in measuring productivity in the construction industry. There are three noteworthy techniques that are possible for measuring construction skills productivity. The first identifies visual recording strategy that includes the use of consistent record of the labourer execution output on sites. The second is the physical recording procedure which includes

an immediate surveillance system that incorporates a qualified onlooker really watching the site for the full length of the working day; the eyewitness or observer concentration is on a group of skilled workers who record the time spent on direct work. On enormous sites, more than one onlooker might be expected to productively watch the task of work utilising work study, method study or work measurement. The third measuring system is the utilisation of surveys and interviews which include data assembling through a meeting from supervisors and workers working in the construction industry. Finally, the chapter concluded that infrastructure productivity can be improved through effective supervision, material management and supply chain management, project front-end planning (loading) and work face planning, training and certification of workforce and labour management and relations. The above different strategies featured and talked about with illustrations are utilised in the measurement of infrastructure skills productivity.

Conflict of interest

The authors declare that there is no conflict of interest.

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