INFERENCES ON THE RELIABILITY LEVELS OF LOST LABOUR ESTIMATING METHODS

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ABSTRACT

Recent studies conducted in the construction industry and particularly by the Association for the Advancement of Cost Engineering (AACE) recommended practice No. 25R-03 on lost labour estimation has shown that all the methods used for quantifying lost labour in construction projects have some varying degrees of accuracy occasioned by the non-unified and standardized approach of measurement. The studies have identified the limitations of the underlying measurement principle as not being an exact science. Arising from the transitory tendencies exhibited by these methods. This paper investigated the severity of the accompanying degrees of inaccuracy in the methods. This was conducted through a well structured questionnaire by mapping out the sampling frame to select the sample size of respondents. By instrument of mean score the research was able to report on the reliability levels of the estimating methods. This will alleviate the credibility and spurious doubt on any of the methods demanded by clients for the purpose of measurement and award of claims.

Key Work: *Lost labour, estimating method, reliability level, limitations, probability sampling*

Introduction

There has been standard references and literatures on this subject by *Association for the Advancement of Cost Engineering (AACE)* which I shall refer frequently to a large extent, and which formed the theoretical framework for this paper. Although, there has been a systematic bibliography on this subject by Egwanatum S.I. (2013). But foundationally, the works of Thomas, H.R & Amra A.O (1996): Fuwu Shivu, L. & Borcharging J.D (1986) are worth calling to mind. However this paper is concerned with the investigation of the reliability levels of labour estimating methods. In the early part, I shall consider more generally the approaches to lost labour estimation with their varying methodologies.

For further inquiry on the approaches, reference may be made to the works of Egwunatum S.I. (2013) that classified the approaches into project specific studies, project comparison study, specialty industry studies, general industries approach, cost basis approach and productivity impact on schedule approach. From existing literature on lost labour estimation and claims, one recurring feature subsists that these methods have their varying degrees of reliability. In the ensuring circumstance, Egwunatum S.I. (2013) had berated the incongruous manner under which claims cannot be established in a uniform parallel circumstance occasioned by non-standardization of methodologies. Branble, B.B & Callahan, M.T. (1992) noted that some of these methodologies are specifically tied to some claim circumstances, which are themselves non-repeatable to the circumstances of other projects with high degree of certainty. A validation of their reliability levels is exigent in the face of industrial and academic confrontation.

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Statement of the Problem under Investigation

The *Association for the Advancement of Cost Engineering (AACE)* opined that lost labour productivity on job sites is frequently not discretely tracked in construction projects in a speculative manner. Accordingly, unless a contractor uses a structured earned value system for tracking labour efficiency, there is no sure way of measuring productivity contemporaneously. Fuwu Shivu, L. & Borcharging J.D (1986) noted that labour loses are very difficult to identify and prove with the degree of certainty demanded by clients. The observation is in tandem with the remarks of Thomas, H.R & Amra A.O (1996) that measurement of labour cost can be difficult to substantiate. In Unison, Egwunatum S.I. (2013) agreed that lost productivity is often delayed to be computed till the end of a project specifically at the preparation of claims or request or equitable adjustment. This becomes complicated for lack of historical data that often leads to gross approximation. According to Branble, B.B & Callahan, M.T. (1992) and Halligan they lamented the limitations of empiricism associated with the measurement or estimation of lost labour in view that there is no unified standard agreement amongst cost experts as to the preferred methodology and how such man hour losses should be calculated except on the basis of unimpacted work, or on the basis of data evidence.

Hanna, A.S. Russel, J.S., Gotzion, T.W and Notheim V.E., (1999) a caveat that lost labour estimation or measurement needs not be an exact science. There are numerous ways to calculate lost labour, but again the quality of some of the methods are open to influx of challenges with respect to validity and reliability. A flood gate of criticism was opened that some of the methods are not always repeatable without seeming wide difference in value of their result. This has created spurious doubts in terms of the significance and confidence level of the methods, which has led this paper to respond to the frequently asked industrial and academic question of: what are the reliability levels of lost labour estimating methods?

An Overview of Lost Labour Estimating Methods

Listed below in outline are the various subsisting methods within the industry and academia for estimating lost labour productivity. Jenkins, J.L. & Daryl, L.O., (2004) Emphasized in its recommended practice that the listing is consistent with their corresponding accuracy levels upon the weight of professional acceptance, case law and construction claims literature from most to least, in retrospect of Canadian and U.S. case laws. The approaches and their related methods include;

Project specific studies

- Measured mile study
- Earned value analysis
- Craftsmen questionnaire sampling method

Project comparison studies

- Comparable work study
- Comparable project study

Specialty industry studies

- Acceleration
- Changes, cumulative impact and rework
- Learning curve
- Overtime and shift work
- Project characteristics
- Project management
- Weather

General industry studies

- U.S Army corps of engineers modification impact evaluation guide
- National electrical contractors

Association
- Estimating guides

Cost basis
- Total unit cost method
- Modified total labour cost method
- Total labour cost method

Productivity Impact on Schedule
- Schedule impact analysis

These methods of estimating lost labour were midwifed by the long standing specialized field studies and experimentation conducted at one time or the other and brought together as a body of knowledge by Egwunatum S.I. (2013) forensic assessment. Reference may be made to the limited citations searched for the works of Thomas H.R. (1992) on studies mad on labour productivity measurement related to learning curve. The works of Brfunies, R., & Emir Z. (2001) & Haniello, J.B & Henry (1991) can be referred to in specialized studies related to overtime and time shift framework for measurement of lost labour. Specialized studies relating to project characteristics as a basis of lost labour estimation can be found in the works of Zeitoun, A.A., & Oberlander G.D., (1993). Those studies made in connection with changes, cumulative impact and rework towards estimating lost labour can be found in works of: Thomas H.R. & Carmen (1994) . Studies made in reference to whether parameters are seen in the works of Leonard C.A., (1987). Finally, specialized studies made with respect to project management factor inexhaustibly include those by Myers, C. W. & Shangraw (1986). These studies heralded the assemblage of lost labour estimating techniques which have been respectively found by *Association for the Advancement of Cost Engineering (AACE) to be* characterized by varying degree of reliability.

Investigation Method

This research, on the basis of two probabilistic sampling methods (stratified and systematic techniques) identified a population of clients in-building professionals, consultants, management and staff of construction contracting companies. The stratified method was used to classify the study population into strata with tolerable differences within the sample space from which the desired sample size was selected for the research. The science behind this method has been shown in the statistical works of Koehn, E. & Brown (1985) that it reduces the variability of the estimates produced from the sample: and the estimator of the population mean (μ) based on the stratified sample is

In consonance with Bienahyme's theorem, the associated variance of the mean's estimator reduces to ;

$$V(\bar{X}) = \sum_i \left(\frac{M_i}{M}\right)^2 s_{xi}^2 (N_i^{-1} - M_i^{-1}) \text{ with } \sum M_i = M \qquad Eq \quad [2]$$

M = Population size
M_i = Sizes of a population strata (i = 1, 2……….k)
M_i = Sizes of simple random sample
Ni = Size of a sample random samples
$(\bar{x})$ = Weighted mean
$V(\bar{x})$ = The variance of $\bar{x}$
Xij = The value of x for the j^{th} item in the sample from the i^{th} stratum.

On the hand, the selection of respondents according to Koehn, E. & Brown (1985) in the sampling frame by the systematic sampling method presupposes that the population under inquiry consists of elements $E_1, E_2 \ldots\ldots\ldots E_m$

arranged in some fixed order. Given that the sample consist of E_i, E_{k+I}, ………………… $E(N-1)$ K+I, elements where I takes value from 1, 2……………… k such that $Nk \leq M$. In this study, for a sample of size N, k was chosen so that Nk approximate M as possible in selecting the construction professionals for this study. Under this circumstance according to Koehn, E. & Brown (1985) (ibid) if X_α is the variate measure on the α^{th} element, the sample mean for the i^{th} systematic becomes;

$$m_i = \frac{X_i + X_{k+i} + \ldots\ldots\ldots + X_{(N-1)k+i}}{N} \qquad Eq \quad [3]$$

With k values of *i*, all equally likely,

$$E(M_i) = \sum_i \frac{M_i}{k} = \frac{1}{Nk}\sum_{\alpha=1}^{Nk} X_\alpha \text{ where } E(M_i) = \mu \qquad Eq \quad [4]$$

This approximates to the population mean (μ) when Nk = M as adopted, with an associate mean variance of

$$E(M_i) = \frac{1}{k}\sum_i (M_i - \mu)^2 = \frac{1}{N^2 k}\sum_i (NM_i - N\mu)^2 \qquad \mathbf{Eq} \quad [5]$$

Greatly due to the serial correlation of the variance.

M_i = Sample mean of a systematic sampling

$E(m_i) = \mu$ = Population mean

N = Size of a simple random sample

M = Population size

K = a unit in a strata

X_α = Variate under measurement

$V(M_i)$ = Variance of a sample mean.

Accordingly, the research design was centered on the collection of data from two sources. These include the primary source from archival materials. Data were collected through the administration of questionnaire to respondents identified in the study area of Nine States in Nigeria. A total of 261 copies of questionnaire were distributed with 192 retrieved from the multinational contracting companies, consulting firms, and corporate clients/organizations (public and private). The questionnaire was designed in multiple choice formats with different tables and checkboxes.

As a result of the content design and the analyzing instrument, questions were responded to on a five points Likert Scale. This study analyzed its data with the weighted mean score which involves assigning numerical value to respondents, rating of factors with respect to their severity for example very High (5 points) High (4 points), moderate (3 points), low (2 points) and very low (1 point). Assessment was carried out from the factors which have been weighted on five point Likert Scale to adduce the level of importance attached to each factor. The weighed mean was computed by means of SPSS ver. 19.0 from:

$$Weighted\ mean = \frac{W_1x_1 + W_2x_2 + \ldots\ldots\ldots + W_nx_n}{W_1 + W_2 + \ldots\ldots\ldots + W_n} \quad Eq\ [6]$$

X_1, X_2 ……………… x_n Represents the factors under evaluation

W_1W_2, ……………..W_n Represents the weightings of the factor that translate to:

W_1 = Number of respondents who answered very low

W_2 = Number of respondents who answered low

W_3 = Number of respondents who answered moderate

W_4 = Number of respondents who answered high

W_5 = Number of respondents who answered very high

The expectations associated with weighted mean are evaluated by

$$E(X) = \sum_{i=1}^{i=n} X_i p(X_i) \quad Eq\ [7]$$

Again this depends on the nature of the variables under test as either discrete or continuous. Data under review showed signs of discrete association so that if g(x) represent the function of the randomness of a variable (x), then the associated expectations of the weighted mean was deduced by;

$$E\{g(x)\} = \int g(x)f(x)dx \quad Eq\ [8]$$

The values often obtained from the mean score are further subjected to power test of significance. This is because data obtained from the field have the tendency not to be error free.

Accordingly to Roy, S.C (1998), for a fixed probability of type I error, the power of a test is given as.

$$p(u) = 1 - (Type\ 11) \quad Eq\ [9]$$

E{g(x)} =Expectations o r mean value of a random variate; X

f(x) = Probability of density function of a variate, X

p(u) = Power of a test administered on a mean

RESULTS

This section is dedicated to the presentation of the field results and the analysis of the data obtained through the questionnaire administered.

Table 1: Summary of demographic information of respondents

Categories	Classification	No.	%
Academic Qualification	ND	60	31.30
	HND		
	B.Sc		
	M.Sc		
	Ph.d		
Professional Qualification	NSE	70	36.56
	NIQS	60	31.30
	NIOB	35	18.20
	NIA	27	14.10
Type of Organization	Contracting	67	34.90
	Consulting	55	28.60
	Government Office	50	26.00
	Corporate Client	20	10.00
Number of projects executed over the last 10 years	0-5	53	27.60
	6-10	47	24.50
	11-15	34	17.70
	16-20	31	16.10
	Above – 20	27	14.60
Construction Experience of respondents	0-5	50	26.00
	6-10	45	23.40
	11-16	35	18.20
	16-20	34	17.70
	Above – 20	28	14.60
Age of Establishment	5-15	153	79.70
	16-20	18	9.40
	21-25	9	4.70
	26-30	7	3.60
		5	2.60

Source: Field Survey 2012

NSE =	Nigerian Society of Engineers	NIOB =	Nigerian Institute of Builders
NIQS =	Nigerian Institute of Quantity Surveyors	NIA =	Nigeria Institute of Architect

Table 2: Familiarity with methods of Estimating Lost Labour

Lost Labour Estimating Methods	Client Mean	Rank	Consultant Mean	Rank	Contractor Mean	Rank	Overall Mean	Rank
Project Specific studies, comprising								
a) Measured mile study	3.89	1	3.80	2	3.81	1	3.8333	1
b) Earned value analysis	3.65	2	3.82	1	3.21	3	3.5600	2
c) Craftsman question sampling method	3.64	3	3.01	3	3.71	2	3.4533	3
Project comparison studies								
a) Comparable work study	3.79	1	4.01	2	3.81	1	3.8700	2
b) Comparative project study	3.63	2	5.00	1	3.59	2	4.0733	1
Specialty Industry Studies, Comprising								
a) Work Acceleration	3.76	3	3.81	1	3.82	4	3.7967	2
b) Changes, Cumulative Impact and Remark	3.86	1	3.79	2	3.86	3	3.8367	1
c) Learning Curve	3.56	6	3.43	3	3.24	5	3.4100	5
d) Overtime and Shift Work	3.68	4	3.24	5	3.12	6	3.3467	7
e) Project Characteristics	3.55	7	3.11	6	3.94	2	3.5333	3
f) Project Management	3.62	5	3.01	7	3.95	1	3.5267	4
g) Weather	3.78	2	3.25	4	3.02	7	3.3500	6
Cost Basis, Comprising								
a) Total unit cost method	3.84	1	3.94	1	3.44	3	3.7400	1
b) Modified total labour cost method	3.56	3	3.45	3	3.56	2	3.5233	3
c) Total labour cost method	3.64	2	3.55	2	3.57	1	3.5867	2

Productivity impact on schedule	4.65	1	3.49	1	3.18	1	3.77	1
a) Schedule impact analysis								
General industry studies, comprising								
a) Estimating guides U.S. Army corps of Engineers modification impact	3.67	1	4.05	1	3.49	3	3.7367	1
b) Evaluation guide	3.65	3	3.09	4	3.50	2	3.4133	4
c) National electrical conductors association guide	3.60	4	3.54	3	3.69	1	3.6100	2
d) Mechanical contractors association guide	3.66	2	2	2	4	2	3.6067	3

Source: Field survey from respondents. 2012

Table 3: Reliability Level of Lost Labour Estimating Method

Lost Labour Estimating Methods	Contractor Mean	Rank	Overall Mean	Rank
Project Specific studies, comprising				
a) Measured mile study	3.51	3	3.78	3
b) Earned value analysis	3.81	2		
c) Craftsman question sampling method	4.01	1		
Project comparison studies				
a) Comparable work study	3.91	1	3.87	2
b) Comparative project study	3.82	2		
Specialty Industry Studies, Comprising				
a) Work Acceleration				
b) Changes, Cumulative Impact and Remark	3.46	5	4.60	1
c) Learning Curve	3.81	4		
d) Overtime and Shift Work	3.45	6		
e) Project Characteristics	4.01	3		
f) Project Management	4.82	1		
g) Weather	4.71	2		

Cost Basis, Comprising				
a) Total unit cost method	3.76	1	3.68	5
b) Modified total labour cost method	3.71	2		
c) Total labour cost method	3.58	3		
Productivity impact on schedule	3.69		3.69	4
a) Schedule impact analysis				
General industry studies, comprising				
a) Estimating guides U.S. Army corps of	4.30	1	3.63	6
Engineers modification impact	3.54	2		
b) Evaluation guide	3.38	3		
c) National electrical conductors association guide	3.30	4		
d) Mechanical contractors association guide				

Source: Field survey from respondents. 2012

Preliminary Comments

In the overview of the study, various approaches, method for estimating lost labour were enumerated with their relative merits. Also limitations associated with lost labour estimation were also highlighted, noting that the process of the estimation need not be an exert science. Each of the methods applies according to the situation at hand. The situation has been acknowledged by Board of Contract Appeals and Legal Systems. Table 3 shows the result of a survey carried out to determine the reliability level of the various methods of estimating lost labour in terms of giving repeatable value when applied to different circumstances. In earlier enumerations, it was reported that some of the methods are generally classified and given the nomenclature by way of their derivation or place of application. The end users of these methods are principally; the client who is often contesting the legality of the methods, the consultants who evaluates the situation and determine the suitability of the method to be used, and the contractor who is interested in wealth maximation and thereby gets skeptical about the method in use. Their relative merits are quite alien to stakeholders in construction project, hence this study attempted to demystify the reliability levels to avoid the options of legal contest, and suitability associated with lost labour claim and award.

The first assessment that was carried out is shown in Table 2. The table gives at a glance, the level of familiarity of these methods amongst the end users. On Likert scale of 5, familiarity was measured at very high, moderate, low and very low. From the project specific studies approach, clients are most familiar with the measured mile method, consultants are most familiar with the earned value analysis method while contractors are best soothed with the measured mile. Comparatively, from the ranking and frequency of occurrence, the measured mile method is the most familiar with an over all mean of 3.8333. In the project comparison studies approach, the comparable project study method has an overall Mean of 4.0733. From the respondents view point, this method is the most familiar of all the methods.

The specialty industry studies approach has a long list of variants which in spite of its numerous methods, a very high frequency by way of responses from respondents, revealed that the change, cumulative impact and remark, method with an overall mean of 3.8367 showing a very high significance as the most familiar method of all the variant. The cost basis method with three variants has the total unit cost method with an over all meant of 3.7400 showing that is it is highly significant and concord amongst respondents as the most familiar method amongst the variants. The schedule impact analysis of the productivity impact on schedule approach was agree to be highly familiar with a mean score of 3.77. The general industry studies approach with four (4) variants has the estimating guide of the U.S. Army corps of engineers' Modification Impact method as the most familiar method with an overall Mean of 3.7367. The cross analysis between client, consultancy and contractor showed a trend of concordance amongst respondents. In all of these methods, the project comparison studies approach with comparable project study method was agreed to be the most familiar method amongst them with the highest overall mean of 4.0733. In reality, this method in existing literature seems to be most welcomed by professionals because of its scientific basis which compares impacted period of labour output disruption to unimpacted period when labour output is not disrupted. This will give a basis for evaluating the difference between labour output baseline and labour output actual. The difference is considered as the lost labour.

Inferences on the Reliability Levels

The previous table 2 was used to assess the familiarity of estimating methods. It was quick to point that comparable project study method is the most familiar method amongst stakeholders. The problem now is that, as the most familiar method is it the most reliable in terms of giving repeatable value when applied to different situations? Naturally there is suppose to be concordance between familiarity and reliability since the popularity amongst end users might be a function of simplicity not necessarily efficiency.

Listed in outline in Table 3 are the responses of respondents for their mean score among clients, consultants and contractors to show a cross assessment of the level of the most reliable estimating method. Accordingly, the project specific studied approach with all its variants has the craftsman questionnaire sampling method as the most reliable of the estimating methods with a group mean of 4.01, followed by the earned value analysis method with a group mean of 3.81 and lastly the measured mile study method with a group mean of 3.51. The project comparison studies approach has the comparable work study method which has a group mean of 3.82. The specialty industry studies approach has the project characteristics method with a mean of 4.82 as the most reliable of the variants. The cost basis approach has the total unit cost method as the most reliable method with the highest ranking mean of the group as 3.76. The only method of the productivity impact on schedule approach of schedule impact analysis has an acceptable value of 3.69 indicating high response amongst the respondents.

The general industry studies approach was investigated having the estimating guides of U.S. Army corps of engineer's modification impact method as the highest rank with a group mean of 4.30. From the foregoing, it is important to examine the cross reliability of the group means to show their optimality and sense of acceptance amongst cost experts. A careful observation of these group means showed some variance, with respect to the respondent's familiarity of the methods. However, the loop moving average of the group is an index of each of the methods. In the light of the above, the specialty industry studies approach not limited to the highest ranking approach is shown to be most reliable of the approaches with loop (overall) mean of 4. Closely following is the project comparison studies method with a loop mean of 3.87. The project specific studies method had a loop (overall) mean of 3.78.

The productivity impact on schedule approach has an overall mean of 3.69, while the cost basis approach has an overall mean of 3.68. The least reliable approach is the general industries studies approach with an overall mean of 3.63. From the foregoing, it is pertinent to note that the acceptability of the specialty industry studies methods amongst the construction professionals shows some signs of uniqueness in spite of its invariant familiarity against the project specific studies methods. The obvious reason is shown to be related with its numerous methods with the project characteristics methods shown to be most reliable. Inspite of its less scientific nature, the reason that every project has its own peculiarity should accommodate its acceptability to the highest level of reliability is a clear factor that the popularity of any of the group methods must have arisen from convenience against expertness. The issue of their cross significance presupposes that all the methods are not in question, but it is pertinent to note that lost labour should be measured by specialty industry studies approach of which the project characteristics should be most desirable.

Conclusion

This study delved into assessment of the reliability level of lost labour estimating methods as popularly used in construction projects. It identifies the main methods of estimation project specific studies with its variants, project comparison studies with its variants, specialty industry studies with its variants, cost basis method with its variants, productivity impact on schedule method and general industry studies method with its variants. In view of the various end users assessment in the construction industry, a cross assessment was made on the clients, consultants and contractors. In all of these, the study found out that the specialty industry studies method with its variant of changes, cumulative impact and remark method as the most reliable irrespective of the circumstance that caused the lost labour.

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