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The Appraisal of Construction Sites Productivity: In Kendall's Concordance

Abdulkadir Abu Lawal

Abstract**—**For the dearth of reliable cardinal numerical data, the linked phenomena in productivity indices such as operational costs and company turnovers, etc. could not be investigated. This would not give us insight to the root of productivity problems at unique sites. So, ordinal ranking by professionals who were most directly involved with construction sites was applied for Kendall's concordance. Responses gathered from independent architects, builders/engineers, and quantity surveyors were herein analyzed. They were responses based on factors that affect sites productivity, and these factors were categorized as head office factors, resource management effectiveness factors, motivational factors, and training/skill development factors. It was found that productivity is low and has to be improved in order to facilitate Nigerian efforts in bridging its infrastructure deficit. The significance of this work is underlined with the Kendall's coefficient of concordance of 0.78, while remedial measures must be emphasized to stimulate better productivity. Further detailed study can be undertaken by using Fuzzy logic analysis on wider Delphi survey.

Keywords**—**Factors, Kendall's coefficient of concordance, magnitude of agreement, percentage magnitude of dichotomy, ranking variables.

I. Introduction

THE construction industry which is essentially labour intensive uses productivity as an index of construction success, because it is the most crucial and flexible resource used in such assessments. The International Labour Organization [1], the construction sector is seen as a means of improving social conditions and social integration through productivity as tangible reality, which generally is referred to as the relative efficiency of an economic activity in a production sector. Productivity also gives the relationship between generated outputs and the input made for the created output [2]. Essentially, it is the efficient use of resources, labor, capital, land, materials, energy, and know-how.

This boils down to the management prowess and erudition, and so, the top management must be braced and committed enhancing productivity. Productivity has eluded clearly a method of measurement and definition due to interaction of the factors affecting it, especially where the study data recording is very poor. In the general context, [3]-[5] went at length defining the concept of productivity as the degree to which the power, to make or provide goods and services having exchange value, is utilized and this is measured by the output from the resources expended. Reference [6] looked at productivity as the ratio between the values of a unit output and the cost of all the input. Furthermore, [7] improved the definition in general context, as the number of goods and services produced by a productive factor in a unit time.

The dimensions of productivity however must transcend the boarders of physical outputs and inputs, to the realm of broader perspectives as to include critically invisible service factors. Therefore, in construction, productivity can be seen in the concept conducive framework as:

- Production efforts (per unit factor) at sites.
- The effectiveness of the production effort at sites, measurable where there are cardinal numerical values as data or subjectively when not amenable to measurement. For example, detailed amount of construction company remunerations and its turnover in the span of 10 years for instance or group dynamics of labour force.

By analyzing the ordinal responses of professionals most directly involved in site production, productivity is appraised in context of the factors affecting it. Agreements and disagreements to these dimensions, as linguistic variables are recorded, and analyzed by using the Kendall's concordance in chi-squared distribution. The factors were categorized as:

- Head office factors
- Resource management effectiveness factors
- Education, training and skill development factors
- Motivational factors

II. The Kendall's Concordance

Reference [8] first used the concordance to measure the agreement and dichotomy between judges for an ordinary observation. It provided a descriptive measure of agreement or concordance for the data comprised of M sets of rank ordering, such that M > 2.0.

For a symbolic artificial rank structure, variable X consists of values X_i = (1, 2, 3, … N) and variable Y consisting of values Y_j (j = 1, 2 . . . M). R_i is the rank total ordering for values X_i of the variable X. So, assuming a perfect agreement were observed between j values of the ranking order variable, then the ranking would be thus M, and one variable of the X = 1.0. While another value of X – variable, would be 2.0 by all j – values of the ranking variable. For M – values, of the ranking variable, the rank totals are then, M, 2M, 3M … MN.

Therefore, the total sum of M values of the ranking is MN $\frac{M(N+1)}{2}$ with the mean rank sum as $\frac{M(N+1)}{2}$ the degree of agreement between the values of the ranking variable reflects itself in the variation in the rank totals. When all the values of the ranking variable are in agreement, the variation is at

A. A. Lawal is a Principal Lecturer with Hassan Usman Katsina Polytechnic, Katsina, Katsina State, Nigeria, PMB 2052, College of Environmental Studies, Department of Building Technology (phone: +2348032116440, fax: +2347011534205, e-mail: aalawal3@gmail.com).

maximum. For maximum dichotomy, the rank total tends to be equal.

TABLE I
SYMBOLIC TYPICAL RANK STRUCTURE OF TWO VARIABLES: RANKS ASSIGNED TO N VALUES OF X BY M VALUES OF VARIABLE Y

Variable	Variable X				
Y	X_i ---	X_2---	X_3---	X_i ---	X_N
Y_1	R_{11} ---	R_{12}	R_{13}	R_{1i}	R_{1N}
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Y_j	R_{j1}	R_{j2}	R_{j3}	R_{ji}	R_{jN}
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Y_m	R_{m1}	R_{m2}	R_{m3}	R_{mi}	r_{Mv}
R_i---	R_1---	R_2---	R_3---	R_i---	R_N

R_i is the rank total for X_i of the variable X, then the sum of the square deviations of the rank totals from the arrange total, for N – values of variable X_i is

$$\sum_{j=1,2---M}^{M}(R,-\bar{R})^2, \quad (1)$$

$$\bar{R} = R_1(X_1) + R_2(X_2) + R_3(X_3) + R_N(X_N)/N = \frac{1}{N}\sum_{j=1}^{M} Rj = \bar{R} = \frac{1}{12}M^2N(N^2 - 1) \quad (2)$$

when perfect agreement exists between the values of the ranking variables. Rj=total rank up to M of Y – variables, $\overline{R}$ = average rank up to M of Y – variable, X_1=variable of X_i, X_3=Variable of X_i, X_N= variable of X_N, N=Number of ranks, Coefficient of concordance, θ =

$$\frac{12\sum_{j=1}^{M}(Rj-\bar{R})^2}{NM^2\ (N^2-1)} \quad (3)$$

Coefficient of concordance is defined as the totals from the coverage rank to the maximum possible value of the sum of squared deviations of rank totals form the average rank total [8].

For the nonparametric statistics, sum of the squared ranks totals can be used instead of sum of squared deviation of rank totals from the average rank total, which has the following form:

$$\theta = 12\ \frac{\sum_{j=1}^{M} Rj^2}{M^2N(N^2-1)} - 3\frac{N+1}{N-1} \quad (4)$$

R_j^2 =Squared rank total of j = 1, 2 --- M, M=Number of Y-variables up to M, N=Number of X-variables up to N, θ=Coefficient of concordance with a boundary of 0 1.0.

For N > 7 and M > 7, the critical values of the statistics are at 0.01 to 0.05 significance, and chi-squared distribution can be used [8].

$$\tau \quad =M(N-1) \quad X2(N-1)--- \quad (5)$$

τ =Approximate probability, X^2=chi-square distribution, (N-1)=Degree of freedom.

A. Analysis Responses

TABLE II
BACKGROUND OF THE RESPONDENTS

Respondents	Architects	Builders/Engineers	Quantity Surveyor
Qualification of respondents	MSc, Architecture	B. Sc, B. Eng., M. Eng., Ph. D	BSc, MSc
Years of experience	5 – 16 years	5 – 21 years	3 – 16 years
Relative percentage of respondents	27.37%	47.37%	25.26%

TABLE III
ARCHITECTS, RESPONSES TO QUESTIONNAIRE (N1 = 26) [INDEPENDENT PROFESSIONALS]

S/N	Variable factors	Responses			
		Ya	Na	PA (%)	PDa (%)
	Head office factors				
1	There is delegation of responsibility	26	0	100	0.00
2	Integration of project information	20	6	76.92	23.08
3	Project planning	26	0	100	0.00
4	Scheduling of project activities	2.6	0	100	0.00
5	Lead of authority	21	5	80.77	19.23
6	Effective supervision of sub-contractor	15	11	57.69	42.31
7	Communication between head office and site is effective	23	3	88.46	11.54
8	There is involvement of site managers in contract meetings	5	21	19.23	80.77
9	Accepted characteristic of site personnel is seen.	16	10	61.54	38.46
10	Effective decision making process	16	10	61.54	38.46
	Resource management effectiveness				
11	Procurement of materials is organized	10	16	38.46	61.54
12	Effective site programme	15	11	57.59	42.31
13	There is accuracy of technical information	26	0	100	0.00
14	Appropriate tools are used for tasks.	16	10	61.54	38.46
15	There is clear knowledge of projects technology	26	0	100	0.00
16	No management interference on workmanship	26	0	100	0.00
17	Site layout is excellent and properly layyed out	26	0	100	0.00
	Motivational factors				
18	There is promotion of employee	`26	0	100	0.00
19	No resentment regarding company policies	10	16	38.46	61.54
20	There is incentive scheme for rewarding good performance	10	16	38.46	61.54
21	Opportunities to exercise skill/knowledge on sites	26	0	100	0.00
22	Management responses to settle employee's grievances	0	26	0.00	100
23	Workers are uncertain about their career prospects	0	26	0.00	100
24	Conducive work environment and teamwork	10	16	38.46	61.54
	Education and training				
25	Experience employee is recognized	20	6	76.12	23.08
26	Contract administration skill	26	0	100	0.00
27	Knowledge of scientific techniques	26	0	100	0.00
28	Training on new technology	10	16	38.46	61.54
29	Availability of multi skilled project personnel is maintained	26	0	100	0.00
30	Application of computer technology	26	0	100	0.00

Note: Y_a=Agreement by Architects, N_a=Disagreement by Architects, P_A=Percentage agreement by Architects, PD_a=Percentage disagreement by Architects, N_T=Total respondents (Architects).

TABLE IV
BUILDERS/ENGINEERS RESPONDENTS QUESTIONNAIRE (NT = 45)
(INDEPENDENT PROFESSIONALS)

S/N	Variable Factors	Responses			
		$Y_{b/e}$	$M_{b/e}$	$PA_{b/e}$	$PD_{b/e}$
	Head Office Factor				
1	There is delegation of responsibility	33	12	73.33	26.67
2	Integration of project information	20	25	44.44	55.56
3	Project planning	20	25	44.44	55.56
4	Scheduling of project activities	20	25	44.44	55.56
5	Level of authority	20	25	44.44	55.56
6	Effective supervision of sub-contractor	25	20	55.56	44.44
7	Communication between head office on sites is effective	25	20	55.56	44.44
8	There is involvement of site managers in contract meetings	0	45	0.00	100
9	Accepted characteristic of site personnel exists	25	20	55.56	44.44
10	Effective decision making process	30	15	66.67	33.33
	Resources management effectiveness				
11	Procurement of materials is organized	15	30	33.33	66.67
12	Effective site programme	20	25	44.44	55.56
13	There is accuracy of technical information	25	20	55.56	44.44
14	Appropriate tools are used for tasks	45	0	100	0.00
15	There is clear knowledge of projects technology	30	45	66.67	33.33
16	No management interference on workmanship	36	0	80.00	20.00
17	Site layout is excellent and properly laid out	36	9	80.00	20.00
	Motivational factors				
18	There is promotion of employee	25	20	55.56	44.44
19	No resentment regarding company policies	15	30	33.33	66.67
20	There is incentive scheme for rewarding good performance	20	25	44.44	55.56
21	Opportunities to exercise skill and knowledge on sites	36	9	80.00	20.00
22	Management responses to settle employee's grievances	15	30	33.33	66.67
23	Workers are uncertain about their career prospects	36	9	80.00	20.00
24	Conducive work environment and teamwork	20	25	44.44	55.56
	Education and training				
25	Experience of employees recognized	36	9	80.00	20.00
26	Contract administration skill	34	11	75.56	24.44
27	Knowledge of scientific techniques	36	15	66.67	33.33
28	Training on new technology	20	25	44.44	55.56
29	Availability of multiskilled projects personnel is maintained	20	25	44.44	55.56
30	Application of computer technology	36	9	80.00	20.00

Note: $Y_{b/c}$=Agreement by Builders and Eengineers, $N_{b/c}$=Disagreement by Builders and Engineers, $PA_{b/c}$=Percentage Agreement by Builders and Engineers, N_T=Total respondents (Builders and Engineers).

III. KENDALL'S CONCORDANCE IN PRODUCTIVITY LINKED PHENOMENA

The study on the ranking for productivity factors yielded a concordance of 0.78. This is essentially an intragroup affair thus within the given rank structure.

If conversely we want to investigate a concordance in two typically ranked structures of same dimension, it is then essentially an intergroup analysis of Kendall concordance, while the former is a case for in depth investigation of two phenomena linked to productivity, such as operational costs, versus company turnover in several-year time frame. For this purpose, assume typical rank structures, A and B, as in Table I rank structure A, with variables X and Y, second rank structure, with analogous variables W and Z.

TABLE V
QUANTITY SURVEYORS RESPONSES TO QUESTIONNAIRE (NT = 24),
[INDEPENDENT PROFESSIONALS]

S/N	Variable factors	Responses			
		Yqs	Nqs (%)	PDqs (%)	PDqs (%)
	Head office factors				
1	There is delegation of responsibility	0	24	0.00	100.00
2	Integration of project information	0	24	0.00	100.00
3	Project planning	10	14	41.67	58.33
4	Scheduling of project activities	10	14	41.67	58.33
5	Level of authority	10	14	41.67	58.33
6	Effective supervision of sub-contractor	0	24	0.00	100
7	Communication between head office and site is effective	10	14	41.67	58.33
8	There is involvement of site managers in contract meetings	0	24	0.00	100
9	Accepted characteristic of site personnel is seen	0	24	0.00	100
10	Effective decision making process	10	14	41.67	58.33
	Resource management effectiveness factors				
11	Procurement of materials is organized	10	14	41.67	58.33
12	Effective site programme	24	0	100	0.00
13	There is accuracy of technical information	24	0	100	0.00
14	Appropriate tools are used for tasks	24	0	100	0.00
15	There is clear knowledge of prospects technology	20	4	83.33	16.67
16	No management interference on workmanship	4	20	16.67	83.33
17	Site layout is excellent and properly laid out	21	3	87.5	12.50
	Motivational factors				
18	There is promotion of employee	0	24	0.00	100
19	No resentment regarding company policies	0	24	0.00	100
20	There is incentive scheme	10	14	41.67	58.33
21	Opportunities to exercise skill and knowledge on site	0	24	0.00	100
22	Management responses to settle employees' grievances	10	04	41.17	58.33
23	Workers are uncertain about their career prospects	24	0	100	0.00
24	Conducive work environment and teamwork	0	24	0.00	100
	Education, and training factors				
25	Experience of employee is recognized	12	12	50.00	50.00
26	Contract administration skill	20	4	83.33	16.67
27	Knowledge of scientific techniques	0	24	0.00	100
28	Training on new technology	0	24	0.00	100
29	Availability of multi skilled project personnel is maintained	0	24	0.00	100
30	Application of computer technology	24	0	100	0.00

Note: Y_{qs}=Agreement by Quantity Surveyors, N_{qs}=disagreement by Quantity Surveyors, PA_{qs} = Percentage agreement of Quantity Surveyors, PD_{qs} = Percentage disagreement by Quantity Surveyors, N_T=Total respondents (Quantity Surveyors).

TABLE VI
TOTAL NUMBER OF INDEPENDENT PROFESSIONALS AGREEING ON THE VARIABLE FACTORS (Y_T), MAGNITUDES OF AGREEMENT, AND PERCENTAGE MAGNITUDE OF AGREEMENT (Y_M & P_{YM}), STANDARD DEVIATION (S) AND SQUARED DEVIATIONS(S^2)

S/N	Variable factors	Architect's agreement Y_a	Builders/ engineers agreement $Y_{b/c}$	Quantity surveyor agreement Y_{qs}	Total Y_T	Magnitude of agreement Y_m	Percentage magnitude of disagreement P_{ym}(%)	Standard deviation S	Square of standard deviation S^2
1	There is delegation of authority	26	33	0	59	1.97	30.39	27.81	773.40
2	Integration of project information	20	20	0	40	1.33	53.00	18.86	355.70
3	Project planning	26	20	10	46	1.53	45.94	21.68	470.02
4	Scheduling of project activities	26	20	10	46	1.53	45.94	21.68	740.02
5	Level of authority	21	20	10	41	1.37	51.59	19.33	373.65
6	Effective supervision of subcontractor	15	25	0	40	1.33	53.00	18.86	355.70
7	Communication between head office and site is effective	23	25	10	48	1.60	43.46	22.63	512.12
8	There is involvement of site manager in contract meetings	5	0	0	5	0.17	94.00	7.86	61.78
9	Accepted characteristic of site personnel is seen	16	25	0	41	1.37	51.59	19.33	373.65
10	Effective decision making process	16	30	10	46	1.53	45.94	21.68	470.02
11	Procurement of material is organized	10	15	10	45	1.50	47.00	21.21	449.86
12	Effective site programme	15	20	24	59	1.97	86.00	27.81	773.40
13	There is accuracy of technical information	26	25	24	75	2.50	33.00	35.36	1250.33
14	Appropriate tools are used for tasks	16	45	24	85	2.83	0.00	40.10	1608.01
15	There is clear knowledge of project technology	26	30	20	76	2.53	10.60	35.83	1283.79
16	No management interference on workmanship26	36	36	4	66	2.20	22.26	31.11	967.83
17	Site layout is excellent and properly layed out	26	36	21	73	2.40	15.19	34.41	1184.05
18	There is promotion of employee	26	25	0	51	1.70	39.92	24.04	577.92
19	No resentment regarding company policies	10	15	0	25	0.83	70.67	11.79	1390.00
20	There is incentive scheme for rewarding good performance	10	20	10	40	1.33	53.00	18.86	355.70
21	Opportunities to exercise skill/knowledge on site	26	36	0	62	2.07	26.06	29.23	854.40
22	Management responses to settle employee's grievances	0	15	10	25	0.83	70.67	11.79	139.00
23	Workers are uncertain about their career prospect	0	36	24	60	2.00	29.33	28.28	719.76
24	Conducive environment and teamwork	10	20	0	30	1.0	64.66	14.14	199.94
25	Experience of employee is recognized	20	36	12	68	2.27	56.00	32.10	1030.41
26	Contract administration skill	26	34	20	80	2.67	5.65	23.57	555.54
27	Knowledge of science techniques	26	30	0	56	1.87	33.92	26.40	696.96
28	Training on new technology	10	20	0	30	1.00	64.66	14.14	199.76
29	Availability of multi skilled project personnel is maintained	26	20	0	46	1.53	45.94	21.68	470.02
30	Application of computer technology	26	36	24	62	2.07	26.86	29.23	854.40

Note: Y_a=Agreement for Architects, $Y_{b/c}$=Agreement for Builders/Engineers, Y_{qs}=Agreement for Quantity Surveyors, Y_T=Ya + Yb/c + Yqs, Y_m=Magnitude of agreement, P_{ym}=Percentage magnitude of agreement, S=Standard deviation, S^2=Squared deviation.

Assuming a marginal difference between the two rank structures, then for rank structure A,

$$R_{j1} < r_{j2} < r_{j3} < \ldots r_{ji} < \ldots r_{jN} \ldots \quad (6)$$

and for rank structure B;

$$r_{j1}^{B} > r_{j2}^{B} > r_{j3}^{B} < \ldots.. r_{ji}^{B} > \ldots r_{jN}^{B} \quad (7)$$

For the differences in absolute terms between the ranks of the two structures A, and B,

$$\sum_{i=1}^{N}\sum_{j=1}^{M} \left| r_{ji}^{A} - r_{ji}^{B} \right| \quad (8)$$

r_{ji}^{A}=rank in the rank structure A of the value Xi of the variable X, assigned by the value Yi of the ranking variable Y.

r_{ji}^{B}=rank in the rank structure of the value Wi of the variable W, assigned by the value Zj of the ranking variable Z.

The measure of Kendall's concordance between two rank structures, representing two linked phenomena of productivity (for instance), θ is defined as the ratio of sum of responses in absolute terms between the ranks of the two rank structures, to the maximum possible sum of differences in absolute terms between the ranks of the two rank structures.

In case of ranks structure an odd number of ranks,

$$\theta = \frac{2}{M(N^2-1)} \sum_{i=1}^{N} \sum_{j=1}^{M} \left| r_{ji}^{A} - r_{ji}^{B} \right| \quad (9)$$

While in case of ranks structure with an even number of ranks,

$$\theta = \frac{2}{MN^2} \sum_{i=1}^{N} \sum_{j=1}^{M} \left| r_{ji}^{A} - r_{ji}^{B} \right| \quad (10)$$

Kendall's concordance = 1.0, for perfect agreement, but we assume marginal disagreement. Therefore, for odd number of ranks is equal to

$$1 - \frac{2}{M(N^2 - 1)} \sum_{i=1}^{N} \sum_{j=1}^{M} \left| r_{ji}^{A} - r_{ji}^{B} \right| \quad (11)$$

In case of ranks structure with an even number of ranks,

$$\theta = 1 - \frac{2}{MN^2} \sum_{i=1}^{N} \sum_{j=1}^{M} \left| r_{ji}^{A} - r_{ji}^{B} \right| \quad (12)$$

where, M=number of the variables j = 1, 2, 3, … M, N=number of the variable in group of the variable Xi, i = 1, 2, 3, … N, r_{ji}^{A} =ranks in rank structure A of the variable Yi in rank structure A, r_{ji}^{B} =Ranks in rank structure B of the variable Wi in the rank structure B, =Summations, θ=Intergroup structural concordance in Kendall's concordance of two ranked productivity linked phenomena, such as operational costs, and company turn over in a given time frame. Say 10 – 20 years (phenomena).

IV. Discussion

Table VI summarized all the other Tables III-V in the analysis of the responses obtained. The highest magnitude of dichotomy of 86 is observed in respect of the variable factor 12, for effective site programme, which is neglected with only 1.97 magnitude of agreement aggregated. The use of appropriate tools has the highest magnitudes of agreement amongst all the professionals, with almost zero magnitude of dichotomy. It should be noticed that there is growing resentment from employees concerning company policies, a negative attribute to improved productivity, no matter what the investment is. Ym = 0.83 while 70.67% attested to this. Generally, it can be seen that a lot has to be done to improve productivity, which now is low ebbed on the construction sites, a negative contribution to the national economy. The Kendall's coefficient of concordance of 0.78 indicates that this research has considerable significance, as the standard deviation to the observed responses is low. This shows that all the professionals involved have the same opinions that productivity must be improved to boast national economy to facilitate improving collective social conditions and social integration.

V. Conclusion

With availability of reliable cardinal numerical data, an analysis of linked phenomena would be more tangible in depicting the consequences of low ebbed productivity on sites for our national development. However, with scarcity of reliable data and bad record keeping attitude, factor analysis in this context is the last option to get to the gnosis of productivity problem. Nigeria infrastructure action plan is already in serious jeopardy if the problems of productivity herein identified, are not critically considered. A more implicating research work is possible by considering the unbiased opinions of experts in wider perspectives, by using Fuzzy logic, wherein their opinions could be aggregated to indicate the imperativeness of productivity problems in Nigeria. This will certainly spur the government to brace against the more impending infrastructure deficit. However, the conducted research in respect of the factors affecting productivity herein, has thrown more light on the problems at hand from its root causes, and the possible ways out for facilitating improvement.

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