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Relationship between Labour Performance and Variability in Blockwork Workflow and Labour Productivity

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Abstract
This paper examined the analysis of labour productivity data of block work activity from sixty one construction sites. The construction work composed of ongoing single story buildings in the study area Abuja metropolis. Data used for the study were obtained using daily method of data collection which has the advantage to capture both quantity and time inputs. A total of 1127 observations were made for the blockwork activity. From these data, the study variables (cumulative productivity, baseline productivity, coefficient of variation and project waste index which is the performance) were computed. The result showed that the coefficient of correlation between coefficient of labour productivity variability and performance index was formed to be 0.630** which is significant at 0.01 confidence level. The coefficient of determination (R) was calculated to be 0.44. This showed that 44% variation in crew performance is accounted for by variability in labour productivity. It was recommended that construction project managers should reduce variability by adjusting labour inputs on site.
Key Words; Variability, Labour, Workflow, Performance, Productivity, Blockwork.

1.0 INTRODUCTION

Productivity is an index that measures output (goods and services) relative to the input (capital, labour material, energy, and their resources) used to produce them (Ofori-Kuragu *et al.,* 2010). Labour productivity has been identified as an index for measuring efficiency because labour is acknowledged as the most important factor of production since it is one of the major factors that creates value and sets the general level of productivity (Ameh and Odusami, 2002). Enshassi, *et al.,* 2007, identified labour productivity as the key factor contributing to the inability of many indigenous construction contractors to achieve their project goals which include most importantly, the profit margin amongst others. They suggested the need to investigate and understand the key variables of labour productivity and to keep accurate records of productivity levels across projects.

1.1 Reduce Variability in Labour Productivity

Thomas *et al.* (2002) stated that different strategies for managing construction variability emerge from lean thinking. Some focus on reducing work flow variability with the intention of improving project performance by increasing throughput, while others employ the strategy of capacity management that is, using flexibility in responding to variability which has the capacity to improve operation by permitting rapid changes as needed.

Thomas and Zavrski (1999b) concluded in their study that the variability in daily labour productivity is highly correlated to project performance. They also stated that variability in productivity appears to be a good determinant of good and poorly performing project. Thus the goal of lean construction as stated by Thomas and Zavrski should be to improve performance by reducing variability in labour productivity. This variability in the daily labour productivity should be computed using the developed mathematical equations by Thomas and Zavrski 1999a presented in note 1.

1.2 Variability in Construction

All construction works experienced variability or changeability at varying degrees. It is common even to a well managed construction project. It is universally believed by researchers as an inhibitor of performance. “Variability can induce fluctuating and unexpected condition making objectives unstable and obscuring the means to achieve them” (Thomas *et al.*, 2002).

Variability in the management of construction work can be caused due to ineffective site supervision and other factors affecting site productivity (Abdel Razek *et al.,* 2007). It is also believed that the nature of a project, shortcoming of management to predict and establish effective defensive actions could induce various degrees of variability on a construction project.

Managing changeability on a construction project is a significant aspect of lean production management. Thomas *et al.* (2002) believed in flexible capacity management as a tool to manage variability because of its essential capability and receptiveness under varying situations.

Productive variability in construction project is majorly of two types, namely work flow variability and labour productivity variability. Both are seen by researchers as impeding system performance Horman and Kenley 1998 asserted that the ability to reduce cycle time by the application of capacity management will improve flow reliability eliminate waste and simplify operations which is the flexible approach to labour and resource management. In their research work of reducing variability in concrete activity labour productivity to improve labour performance, Idiake *et al.,* 2013, measured the effects of variability on performance to be 37% which confirmed the outcomes of previous works. Therefore this paper is aimed at determining the relationship existing between labour performance and variability in blockwork workflow and labour productivity.

2.0 RESEARCH METHODS

2.1 Collection of Data

The data collection for on-site productivity study was conducted on blockwork activity, using ten trained research assistants, who were instructed on how to observe the workmen and record observations in terms of input and output . Data collection covers concreting work in 61 live projects from building contractors within the study area (Abuja). Daily visit method of observation of labour productivity was adopted. This involved personal observation of labour activities on the selected work on live projects. The strategy here was to visit the site daily and interact with the foreman and workers in order to record the dates, number of workers, starting time, closing time and measurement of length/breadth of work done (quantities) of each worker. Entries were made on research instrument collection sheet designed for this purpose. The figures collected were analysed using lean benchmarking approach of calculating performance using Thomas *et al* (1990) mathematical model.

2.2 Research Technique

The population of the study was drawn from contractors handling building projects in the study area. The builders were involved in different types of construction activities such as mass housing projects of bungalow category, storey building housing projects and infrastructures. In order to meet the objectives of the study, the research samples were drawn from contractors constructing single storey buildings for the purpose of homogeneity. The research team was able to collect data from sixty one (61) construction sites, randomly drawn from the available list of builders. A total of 1127 data points were obtained for all block work activities from these sites. At the time of data gathering, it was observed that the firms were at various levels of completion.

Data Analysis and Evaluation was conducted using the following statistical tools; 1. Descriptive Statistics 2. Inferential Statistics (i) Box and Whisker analysis (ii) Regression analysis 3. Mathematical Model by Thomas *et al* (1990 and 1991)

3.0 PRESENTATION AND DISCUSSION OF RESULTS

3.1 Project Waste Index (PWI)

The PWI is a dimensionless number that is normalized about the expected baseline productivity. The PWI figures for the sixty one projects sampled are shown in the Table 1. This is presented in cumulative distribution form as shown in Figure 2. The median PWI value is about 0.332. The distribution of PWI figures gives a reliable way to differentiate good and poorly managed projects (Thomas *et al.,* 2002). Projects with low PWI values are good performing projects while projects with high PWI values had performed poorly.

3.2 The Relationship between Coefficient of Variability and Performance (PWI)

The normality test for labour productivity data was found to be slightly normally distributed as shown in Figure 1. The distribution was slightly skewed with a skewness value of 0.425 and standard deviation of 0.419. Statistical tests were further conducted to ascertain or measure the effect of construction output and labour productivity variability on performance for block laying.

3.2.1 Construction workflow Output

The values of coefficient of variation for construction output are shown in Table 1. These values and that of performance (PWI) were tested for any significant relationship. The correlation between the two variables was computed as 0.278 which was highly significant at 0.01 confidence level. The implication of this analysis with a coefficient of variation of 0.278 is that the variability in daily construction output has a weak or low correlation relationship with the project performance. Therefore the correlation coefficient obtained from this analysis confirms the earlier study that daily construction output and performance have minimal relationship. Furthermore, it appears from the test result that reducing variability in production output in order to improve performance has an insignificant or no effect on performance.

3.2.2 Labour Productivity (Input)

The figures calculated for coefficient of variation for labour productivity are shown in Table 1. The values for coefficient of variation in labour productivity range from 0.108 to 0.443. These values and the performance indexes calculated for all projects were tested for correlation analysis. The coefficient of correlation for the two variables was found to be **0.630****, which is significant at 0.01 confidence level. The implication of this test result is that the variability in daily labour productivity is more highly correlated to project performance than construction output earlier determined. Furthermore, the result of the analysis shows that reducing variability in labour productivity appears to have a critical effect on performance.

Linear analysis of the two variables showed a coefficient of determination of 0.40, which means that 40% variation in crew performance is accounted for by variability in labour productivity. The linear equation is

Pwi = 0.08424 + 0.9732x **(1.1)**

The equation has a model probability value (P-value) = **0.001**

From the linear model shown in Figure 3 the graph has an intercept of 0.08424 and for every increase of one unit of variability in labour productivity there is an increase of about **0.9732** in performance. Further analysis was carried out to ascertain the best predictive curve fit for the model and it was found out that the second order polynomial gave an improved coefficient of determination $\mathbf{R^2}$ of **0.44** with an equation model

Pwi = -0.1267 + 2.803x - 3.404$\mathbf{x^2}$ (1.2)

The equation has a model probability value (P-value) = **0.001**

From the equation model in Figure 4, the intercept on Y axis is **-0.1267** and for every increase of one unit of variability in labour productivity there is an increase of about **2.803** in performance. However it was observed that for every unit increase in variability in labour productivity raised to the power of two, there is a decrease of about **-3.404** in performance. The model revealed that most of the data points fell within the 95% prediction interval point.

3.2.3 Multiple variables effect of work flow and labour productivity

The independent variables (work flow and labour productivity) were entered against the dependent variable to determine the effect of the two variables on performance. The coefficient of determination ($\mathbf{R^2}$) was calculated to be **0.401,** which was significant at 0.001 with an equation model of,

Pwi = 0.99 – 0.64covquant + 1.034covlp **(1.3)**

Where: covquant = Coefficient of Variability for construction output

Covlp = Coefficient of Variability for labour productivity

The observation here is that the value of the coefficient of determination obtained from the multiple regression is the same with that of linear regression analysis conducted earlier for the two variables. The implication of this is that either of the two equation models could be used to predict the behaviour of crew performance. But a polynomial best curve fit analysis conducted showed a higher relationship with a coefficient of determination of **0.44.** The multiple regression analysis was found to have a lower significant effect on performance compared to the single variable, polynomial best curve fit analysis, of labour productivity variability thus single polynomial variable effect is proposed for the assessment of variability effect on performance.

3.3 Variation in Average Daily Quantities for All Projects

Figure 5 shows the average daily output for each project investigated. It reveals the different levels of variability in cumulative daily construction output for all the projects examined, which is another source of variability in project management. Projects 36 and 60 have the highest and lowest average daily quantities of $140m^2$ and $18m^2$ respectively.

The level of variability shown in the above graph is a measure of work flow variability which is measured in this study by daily construction output. Variations in construction output provide a measure of levels of work flow variability. From the analysis the following important observation are hence noteworthy.

(1) Correlation between project waste index (performance) and coefficient of variability for construction output for the tested building activity; block work = 0.278*;

(2) Correlation between project waste index (performance) and coefficient of variability for labour productivity for the tested trade; block work = 0.630**; Therefore, the independent variable is thus found to be significant predictor of performance of site labour crew for the block work activity investigated.

(3) The coefficient of determination computed for block work activity showed that the effect of variability in labour productivity on performance is 44% which is the level of variation in crew performance for concrete work accounted for by variability in labour productivity.

4.0 CONCLUSION

It has been discovered in this research work that variability exist in daily labour productivity of cement based works on site in Nigeria to such a magnitude that is consistent with that of other developing countries. This research work investigated the effects of workflow variability and labour productivity variability on the job site performance. Using labour productivity data from block laying on multiple projects, two parameters of output and input variability were tested against construction performance. The labour workflow productivity data analyzed were found to be slightly skewed. The value of skewness was greater than zero but less than one. This showed the level of reliability of data used in the analysis.

The correlation relationship between work flow variability and performance was found to be low for block laying. Similarly, the correlation between labour productivity and performance was discovered to be highly significant for all selected site activities. Therefore, it is suggested that, in measuring the impacts of variability on performance, emphasis should be placed on labour productivity variability instead of work flow or construction output variability. The values of variability in labour productivity were compared with the project performance (PWI) it was found out that the higher the values of labour productivity variability the poorer the performance. Also the baseline productivities computed for all selected activities were compared with the mean labour productivities.

It was discovered that performance gap exist for blockwork activity. This is an indication of opportunity for performance improvement in labour utilization for the site activity investigated. The effect of variability on jobsite performance was determined using regression analysis. The level of effect was established for the block laying activity to be 44%. This suggests that reducing variability will bring about improvement in labour performance.

5.0 RECOMMENDATIONS

1 The correlation relationship between work flow variability and performance was found to be low for block laying therefore it is recommended that in measuring the impacts of variability on performance, emphasis

should be placed on labour productivity variability instead of work flow or construction output variability and that labour productivity variability be used to measure the impacts of variability on performance.

2 The variations in crew performance in all activities investigated were found to be as a result of variations in labour productivity therefore it is suggested that, where there is growth and the output increases faster than input; the increase in input should be fairly proportionately less than the increase in output throughout the period of operation.

3 Multiple variables effect of work flow and labour productivity variability on labour performance was found to have no significant effect on performance compared to the single variable effect of labour productivity variability thus single variable effect is proposed for the assessment of variability effect on performance.

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Note 1

Determination of Research Variables

Thomas and Zavrski (1999a), 1999b) expressed the projects attributes in the following forms.

$$\textit{Total work hours} = \sum \textit{Daily work hours} \qquad (1.1)$$

$$\textit{Total quantities} = \sum \textit{Daily quantities} \qquad (1.2)$$

$$\textit{Cumulative Productivity} = \frac{\textit{Total work done (wh)}}{\textit{Total quantity } (m^2)} \qquad (1.3)$$

Baseline Productivity: This is defined as the paramount performance a contractor can get from a particular model or design. To compute the baseline productivity values certain laid down steps were applied to the daily productivity figures for each project (Abel Hamid *et al.*, 2004 and Enshassi *et al.*, 2007).

1. Establish the figures for workdays that consist 10% of the workdays studied.
2. The number established in one above should be rounded off to the next highest odd number which should not be less than (5) five. This number, n, explains the size of the baseline division.
3. The contents of the baseline division are the n workdays that have the highest daily production or output.
4. The next step is to compute the summation of the work hours and quantities for these n workdays
5. The baseline productivity can now be expressed as the ratio of work hours and the quantities contained in the baseline division.

Project Management index (PMI) or Project Waste Index (PWI) According to Abdel-Hamid

et al. (2004); Thomas and Zavrski, (1999a), 1999b) it is expressed as follows:

$$\textit{Project Waste Index (PWI)} = \frac{\textit{Cumulative Productivity} - \textit{Baseline Productivity}}{\textit{Expected Baseline Productivity}} \qquad (1.4)$$

Project Waste Index (PWI) has been identified in previous studies as a useful tool to measure performance (Thomas and Zavrski 1998, 1999).

$$\textit{Coefficient of productivity variation } (CPV)_j = \frac{PV_j \times 100}{(\textit{Baseline Productivity}_j)} \qquad (1.5)$$

Where CPV_j = coefficient of productivity variation for project_j. Alternatively it can be computed as a ratio of the standard deviation to the mean.

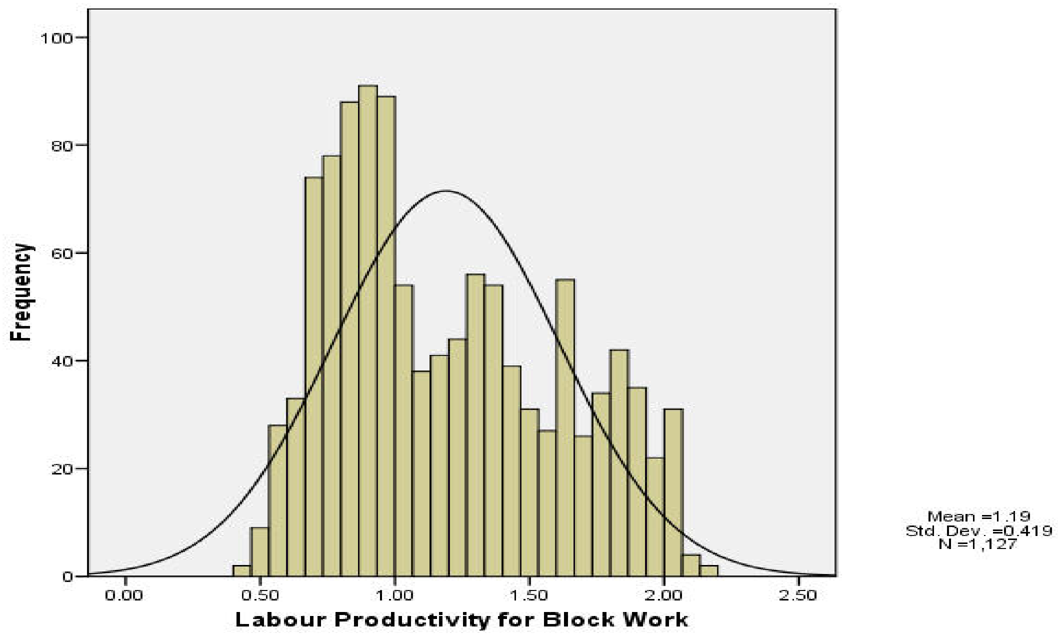

Figure 1 Normal Distribution Curve of Labour Productivity Data for Block work Activity

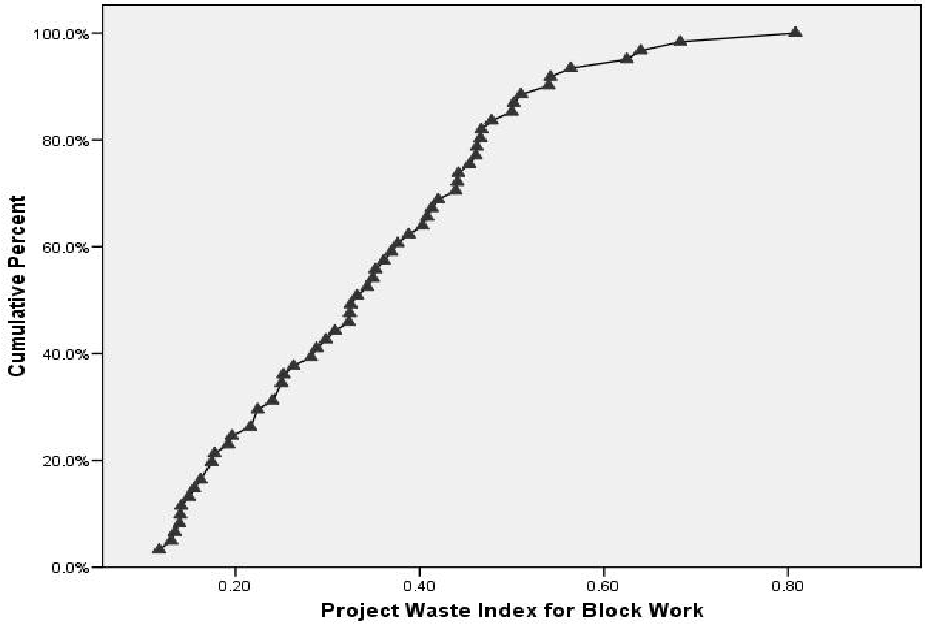

Figure 2 Cumulative Distribution of Project Waste Index (PWI)

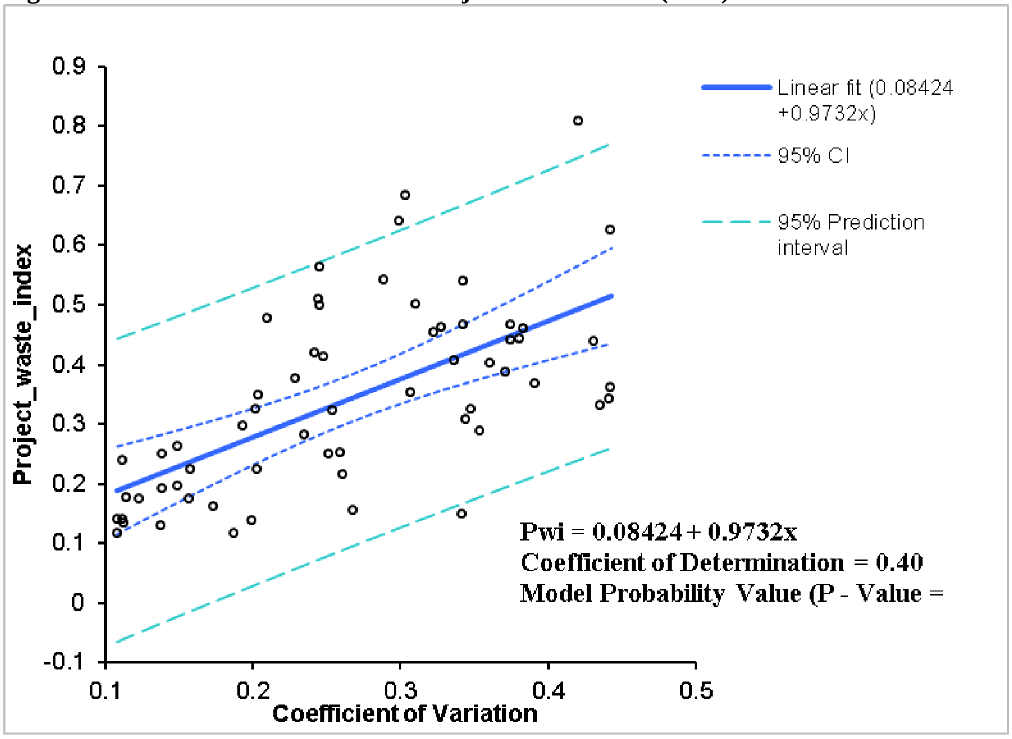

Figure 3 Linear Regression Model for Block Laying

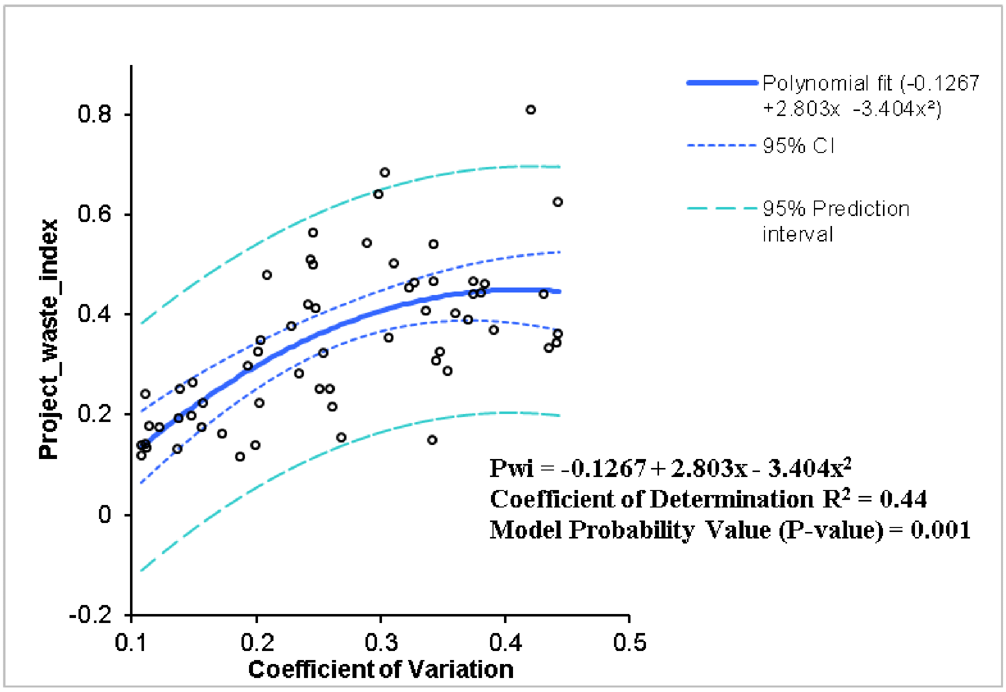

Figure 4 Best Curve Fit Polynomial Regression Model for Block Work Trade

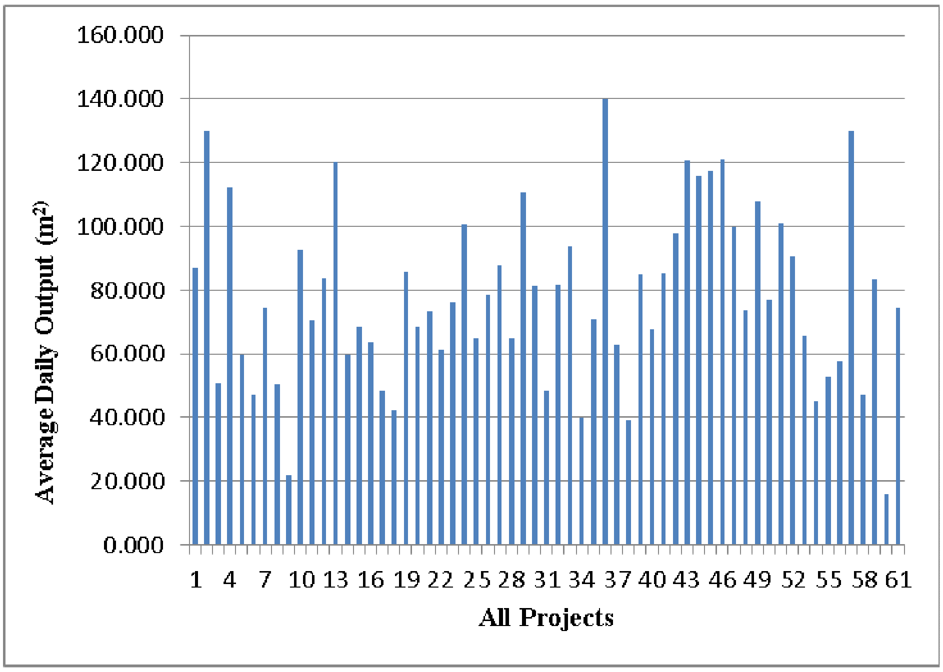

Figure 5 Variation in Average Daily Quantities for all Projects for Block work Activity

Appendix 3 Computation of Research Variables

S/N	Project code number	Coefficient of Variation Qty	Coefficient of Variation LP	Average daily output m^3	Cumulative Productivity whr/m^3	Baseline Productivity	Project waste index
1	Project 1	0.729	0.344	88.188	1.056	0.805	0.308
2	Project 2	0.434	0.342	129.765	0.693	0.571	0.149
3	Project 3	0.709	0.354	51.053	0.964	0.729	0.288
4	Project 4	0.903	0.375	89.625	1.031	0.671	0.441
5	Project 5	0.461	0.381	59.292	1.125	0.764	0.442
6	Project 6	0.616	0.299	60.572	1.458	0.936	0.640
7	Project 7	0.544	0.342	84.250	1.243	0.802	0.540
8	Project 8	0.267	0.304	61.200	1.452	0.896	0.683
9	Project 9	0.425	0.246	25.316	1.347	0.940	0.500
10	Project 10	0.477	0.328	99.600	1.217	0.840	0.462
11	Project 11	0.842	0.323	66.067	1.165	0.794	0.454
12	Project 12	0.472	0.204	85.053	1.084	0.799	0.349
13	Project 13	0.576	0.242	91.300	1.066	0.723	0.420
14	Project 14	0.363	0.254	59.706	1.181	0.918	0.323
15	Project 15	0.223	0.311	55.842	1.205	0.795	0.502
16	Project 16	0.845	0.371	64.857	1.067	0.750	0.388
17	Project 17	0.451	0.248	42.900	1.063	0.727	0.413
18	Project 18	0.755	0.436	41.417	0.999	0.728	0.332
19	Project 19	0.876	0.336	70.167	1.023	0.691	0.408
20	Project 20	0.973	0.235	70.412	1.276	1.046	0.282

21	Project 21	0.033	0.123	76.850	1.005	0.863	0.174
22	Project 22	0.372	0.202	66.692	1.588	1.323	0.325
23	Project 23	0.354	0.259	79.214	1.335	1.129	0.252
24	Project 24	0.482	0.442	61.350	1.055	0.775	0.343
25	Project 25	0.315	0.246	78.263	1.314	0.854	0.564
26	Project 26	0.579	0.251	78.650	1.010	0.806	0.250
27	Project 27	0.726	0.307	75.167	1.142	0.855	0.352
28	Project 28	0.418	0.149	66.421	1.566	1.352	0.263
29	Project 29	0.576	0.431	80.550	1.011	0.652	0.439
30	Project 30	0.421	0.137	81.400	0.597	0.491	0.130
31	Project 31	0.377	0.139	48.579	1.049	0.892	0.192
32	Project 32	0.303	0.112	81.895	0.999	0.884	0.141
33	Project 33	0.684	0.421	46.421	1.144	0.485	0.808
34	Project 34	0.397	0.229	42.350	1.152	0.846	0.376
35	Project 35	0.300	0.158	70.737	1.108	0.925	0.224
36	Project 36	0.341	0.342	130.905	1.220	0.839	0.467
37	Project 37	0.605	0.193	61.950	1.421	1.179	0.298
38	Project 38	0.495	0.244	49.789	1.355	0.940	0.510
39	Project 39	0.417	0.289	89.100	1.283	0.841	0.542
40	Project 40	0.401	0.203	69.571	1.098	0.915	0.224
41	Project 41	0.502	0.261	79.765	1.142	0.966	0.216

42	Project 42	0.314	0.139	98.000	1.095	0.891	0.250
43	Project 43	0.375	0.157	120.650	0.774	0.632	0.174
44	Project 44	0.404	0.112	115.952	0.844	0.735	0.134
45	Project 45	0.249	0.114	117.750	0.860	0.716	0.177
46	Project 46	0.503	0.361	96.550	1.131	0.802	0.403
47	Project 47	0.468	0.391	79.750	1.024	0.723	0.369
48	Project 48	0.474	0.443	58.350	0.972	0.678	0.361
49	Project 49	0.253	0.108	108.100	0.783	0.688	0.117
50	Project 50	0.471	0.383	55.900	1.146	0.770	0.461
51	Project 51	0.266	0.109	100.952	0.816	0.702	0.140
52	Project 52	0.554	0.375	66.895	1.122	0.742	0.466
53	Project 53	0.483	0.149	65.905	0.931	0.771	0.196
54	Project 54	0.295	0.112	45.143	1.268	1.073	0.240
55	Project 55	0.464	0.187	52.727	1.025	0.930	0.117
56	Project 56	0.488	0.210	66.400	1.298	0.908	0.478
57	Project 57	0.462	0.443	106.286	1.145	0.635	0.625
58	Project 58	0.360	0.174	98.381	0.762	0.629	0.162
59	Project 59	0.412	0.199	136.550	0.736	0.622	0.139
60	Project 60	0.540	0.348	26.389	0.958	0.694	0.324
61	Project 61	0.442	0.268	96.600	0.812	0.686	0.155