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LABOR PRODUCTIVITY MEASUREMENT IN BUILDING PROJECTS

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Abstract: The aim of this paper is to report on measuring labor productivity for block works on building projects in the Gaza Strip by using activity sampling for block works. The labor productivity measurement on construction sites was based on studying block work in the Gaza Strip. In this research activity sampling technique has been chosen. Data for this study was collected from construction sites of sheikh Zayed township project through observations. This township project includes 70 five-story buildings, 5 twelve-story buildings, a mosque, a school, shops, offices, and two water reservoirs. It includes also the construction of infrastructure works. The results indicate that the average productivity rate of skilled labor in laying blocks 20 is 38.40 blocks per hour (3.07 m2/h), while average productivity rate of skilled labor in laying block 10 is 40.50 blocks per hour (3.24m2/h). The research looked at the distributions of skilled labor time and unskilled labor time in working day. The finding also indicate that productive time of skilled labor was 77% of his working time, while productive time of unskilled labor was 9.34% of his working time. It is hoped that this research will lead to an improvement of the construction productivity in Palestine and other developing countries..

KEYWORDS: labor productivity, block work, work measurement, activity sampling

قياس إنتاجية العمال في مشاريع البناء

الملخص: تهدف هذه الورقة لقياس إنتاجية البناء بالطوب للعاملين في مشاريع البناء في قطاع غزة باستخدام طريقة أخذ العينات لأعمال البناء بالطوب، إن عملية قياس إنتاجية العمال في مواقع البناء اعتمدت على دراسة أعمال البناء بالطوب في قطاع غزة، تم اختيار طريقة أخذ العينات لأعمال البناء بالطوب لأغراض هذا البحث، حيث تم جمع البيانات لهذه الدراسة من مشروع إنشاء مدينة الشيخ زايد من خلال المراقبة، ويشمل مشروع إنشاء مدينة الشيخ زايد 70 عمارة سكنية بارتفاع خمس أدوار وخمس مباني بارتفاع 11 دور بالإضافة إلى مسجد ومدرسة ومحلات تجارية ومكاتب وخزانين للمياه ، كما يشمل المشروع إنشاء أعمال البنية التحتية. أشارت النتائج أن معدل إنتاجية العمال المدربين (المهرة) في تنفيذ أعمال البناء بطوب سمك 20 سم تبلغ 38.4 طوبة/ ساعة (3.07م^2 / ساعة) بينما بلغ متوسط الإنتاجية للبناء بالطوب سمك 10 سم 40.5 طوبة/ ساعة (3.24م^2 / ساعة) ، وقد اهتم هذا البحث بدراسة توزيع الوقت للعمالة المدربة (الماهرة) وكذلك الغير مدربة خلال يوم العمل، حيث أشارت النتائج أن إنتاجية الوقت للعمال المدربين بلغت 77%

من وقت العمل بينما إنتاجية الوقت للعمال غير المدربين بلغت 9.34% فقط من وقت العمل . يؤمل أن يؤدي هذا البحث إلى تحسين وتطوير الإنتاجية في مجال الإنشاءات في فلسطين وغيرهـــا مـــن الدول النامية .

INTRODUCTION

Productivity measurement at project and crew levels has both immediate and long-term objectives. Schedule control, cost control, target setting, and motivating the work force are some of the short term objectives. Employees need productivity data as a feedback on their performance and may be used for pay bargaining. The same actions will lead to the provision of a performance database for planning and evaluating performance at this level. Performance at this level provides management with information that can influence their strategic actions [1].

There are two different techniques of generating labor productivity standards, accountancy-based, and engineering- based techniques. Accountancy-based standard rely on the analysis of historical accounting data to establish work hour requirements for specific type of work whilst engineering-based standards involve breaking down complex work processes into small manageable parts and analyzing these parts for the length of time required to complete these processes [2].

Productivity improvement in the construction industry may have a significant impact on improving GDP. Since economic progress depends upon the investment of the capital for future production, the rate of construction activity has a significant effect upon the economic health of a nation and its future growth. This implies that when the economy booms the construction industry also flourishes. The objective of this paper is to report on measuring labor productivity on building projects in the Gaza Strip by using activity sampling for block works.

PRODUCTIVITY MEASUREMENT METHODS

There are four productivity measurement methods often used for measuring labor productivity in construction projects. These methods are time study, activity sampling, craftsman questionnaire, and for man delay survey.

Time study

Time study was the fundamental approach to productivity improvement introduced by Taylor and Gilbreth in the late 19th and early 20th centuries, and it

is the principle technique of work measurement even today [3]. Time study is used to determine the time required by a qualified and well-trained persons working at normal pace to do a specified task [5]. Time study therefore involves: familiarization with the work to be studied; timing to discover how long various operations are taking; rating to assess the worker being observed against a norm; and building up of time standards by allowing for appropriate relaxation and contingency allowances [6,4]. Time study provides an analytical basis for budgeting and controlling human resource costs. It can be an important aid to increasing productivity by providing standards against which performance can be planned, monitored and improved [7]. The main difficulty in using time study techniques for labor productivity studies in developing countries is the lack of work-study experience not only in construction but also in manufacturing [7].

Activity sampling

Activity sample can be defined as a technique in which a large number of instantaneous observations are made over a period of time of workers, machines, or processes, or workers. Each observation records what is happening at that instant and the percentage of observations recorded for a particular activity or delay is a measure of the percentage of time during which that activity or delay occurs [8,9]. Activity sampling study provides the necessary information to help determine how time is being employed by the workforce, identify the problem area that cause the work delay, and set up a base line measure for productivity improvement. The main advantage of using activity sampling is that it allows a larger number of machines or men to be studied at one time that can be managed using a continuous time study. This leads to a broader picture of the efficiency of a particular operation that obtained from a more concentrated but continuous study on a smaller group [6]. Activity sampling concept is based on two facts; first fact is a working day can be subdivided into three major parts: productive, contributory, and unproductive time [10, 11]. Productive time means that time spend in elements directly involved in the actual process of putting together or adding to a unit being constructed. Contributory time means that time spend in elements not directly adding but essential to finishing the unit. Unproductive time means idle time or time spends in not useful or all other elements. Second fact on which activity sampling is based is small number of chance occurrences tends to form

the same distribution pattern as the whole operation. Thus it is a mathematical technique closely associated with statistics and the theory of probability [5].

Craftsman questionnaire

Craftsman questionnaire used to investigate the problems that adversely affect workers productivity and motivation. The questionnaire usually requires craftsmen to estimate loss of time due to various causes, ranking the severity of the problems and provide potential solutions to productivity problems [3]. The questions that are usually asked in this questionnaire are specific for each job site and each crafts. Another approach to craftsmen questionnaire has been called craftsman questionnaire sampling, whereby a sample of workers selected and interviewers question them about an activity in which they were engaged.

Forman delay surveys

Foreman delay survey is one such method whereby production problems are exposed by foremen through the identification of causes and quantification of delays in the daily routine of their workforce [3]. The primary purpose of this technique is to highlight problems that are outside the responsibility and control of individual foreman [11,12].

RESEARCH METHOD

The labor productivity measurement on construction sites was based on studying block work in the Gaza Strip. The main reasons for block work productivity studies on construction sites were:

- The significance of the cost contribution of block work in relation to other building activities;
- Block work would provide an opportunity to study a variety of factors;
- Its inputs and outputs are easily quantifiable;
- It is a relatively easy activity to observe and quantify because of its intensity.

Block work productivity observations and productivity factors were evaluated as follows:

Activity sampling along with the physical measurement of output per hour was used. An evaluation of productivity factors during the process was also performed. Specialized teams performed all block work operations in construction sites. They are also responsible for hiring all equipment for the project's task. These comprised hammer, trowel, bucket, axe, hatchet and spirit level. Contractor provided all materials. Block work would normally start daily

at 8 A.M and finish at 5 P.M. There is one hour break for lunch from 12 o'clock to 1 o'clock therefore day working hours of block work gang are 8 hours. There are two types of blocks mainly used for block work. First type is block 20 and second type is block 10. The size of block 20 is (20cm * 40cm * 20cm). The size of block 10 is (10cm * 40cm * 20cm).
Four techniques for measuring labor productivity have been briefly discussed, these are: time study, activity sampling, craftsman questionnaire, and foreman questionnaire. In this research activity sampling technique has been chosen for the following reason: observation skills required in this technique are not as demanding as those required to accomplish similar objectives using other techniques such as time study; it provides information on the extent of labor utilization on construction sites; it is possible to identify in detail the sub-activities involved in the production process; It is possible to attach statistically quantifiable inferences to the results of the study [8,12,3,1].

Data for this study was collected from construction sites of sheikh Zayed township project through observations. This township project includes 70 five-story buildings, 5 twelve-story buildings, a mosque, a school, shops, offices, and two water reservoirs. It includes also the construction of infrastructure works. This project was funded by Abu Dhabi fund for development and owned by the Ministry of Housing in Gaza. The consultant for this project was DIWI International consultant, and the main contractor was Consolidated Contractors Company, who has subcontracted the project to Al-Zafer group for investment and development. The budget for the project was 55345000 US$, and the duration was 24 calendar months. There were 14 block laying gangs working in the project.

Number of observations required to determine the proportions of productive, contributory and unproductive times of block work gang were calculated from following formula [1, 13, 3].

$$N = \frac{Z^2 \times P \times (1 - P)}{L^2}$$

Where
N = sample size
Z= value obtained from statistical tables depending on the confidence level. This research used 95 % confidence level (Z = 2)
L = limit of accuracy which will be ± 5 %

P = percentage of activity observed

For maximum N, $\frac{dN}{dP} = \frac{Z^2}{L^2}(1 - 2P) = 0$

P = 0.5

Substituting P = 0.5, L = 0.05 and Z = 2 into the equation gives:

$$N = \frac{2^2 \times 0.5 \times (1 - 0.5)}{0.05^2} = 400$$

Thus if N = 400 is used, all possible proportions of P would meet the accuracy criteria. Further to activity sampling, quantification of skilled labor productivity per hour was recorded through actual physical measurement. The number of observations required for quantification of skilled labor productivity per hour is obtained by plotting the cumulative average productivity per hour against the number of observations. Observations stopped when the line stabilized [3].

The following procedure was adopted for conducting the field study to meet the research objectives [11]:

1. Construction sites were visited and ongoing activities were identified in consultation with site staff;
2. Individuals to be included in the sample were identified ;
3. The block work operation was broken down into three groups of elements, namely productive, contributory, and unproductive activities;

- Productive elements: elements directly involved in the actual process of putting together or adding to a unit being constructed
- Contributory elements: elements not directly adding to but essential to finishing the unit;
- Unproductive elements: not useful or idle or all other elements;

4. An appropriate study sheet with random observation intervals equal 5 minutes was designed [14, 1, 13, 6, 3].
5. Before starting the actual observation, the following was ensured:

- All persons involved in the activity were clearly identified and their specific roles were defined; and
- Work completed prior to the start of the study was noted as accurately as possible. This enabled an accurate assessment of work accomplished during the observation interval;

6. Observations were made at pre-identified times. At any instantaneous observation, a record was made of the sub-activity being performed by each of the workers;
7. An accurate physical measure of the work accomplished per hour was recorded;
8. Additional information such as labor age, labor experience, method of payment, general level of supervision, tools and equipment used, gang sizes, and general site conditions were recorded;
9. The data were summarized in a separate sheet at the end of each observation period

RESULTS

Distributions of Block work working time

The researchers divided block work operation into three groups of activities. First group, productive activities which included "spreading mortar on the wall in preparation for laying blocks", "cutting blocks to required size", "positioning and pressing the block on the course, and checking verticality and horizontality of blocks", and "placing mortar into vertical gaps between blocks and removing excess mortar". Second group, contributory activities which included "mixing mortar and filling it in buckets", "ancillary work such as fixing angles and setting scaffolding, checking distances in line with drawings, taking instruction from supervisors", "distribution of mortar and blocks to spots close to skilled labor", and "cleaning working site". Third group is unproductive activities which included "idle time", and "removing and replacing already completed work due to operator fault or management fault".

Table 1 show that productive time of skilled labor is 77.01% of working time whilst productive time of unskilled labor is 9.34% of working time. Also productive time of block work gang is 48.28% of working time. Contributory time of skilled labor is 9.76 % of working time. On the other hand, Contributory time of unskilled labor is 54.66% of working time. Contributory time of block work gang is 28.72% of working time. Finally unproductive time of skilled labor is 13.23% of working time, unproductive time of unskilled labor is 36% of working time, and unproductive time of block work gang is 23% of working time.

Table 1. Block work working hour's basic statistics

Mean parameter	Statistics	Skilled labor	Unskilled labor	Gang
Productive time	Mean	77.01%	9.34%	48.28%
	Std. Deviation	9.00%	8.23%	8.58%
Contributory time	Mean	9.76 %	54.66%	28.72%
	Std. Deviation	6.6 %	18.62%	9.2%
Unproductive time	Mean	13.23%	36.00%	23.00%
	Std. Deviation	6.67%	14.00%	7.1%

Table 2 indicates that spreading mortar on the wall take 21.17% of skilled labor working time, 0.55 % of unskilled labor working time and 12.25 % of block work gang working time. Cutting blocks to required size take 5.69% of skilled labor working time, 5.58 % of unskilled labor working time and 5.55 % of block work gang working time. Positioning and pressing the block on the course, and checking verticality and horizontality of blocks take 38.87% of skilled labor working time, 2.25 % of unskilled labor working time and 23.76 % of block work gang working time. Placing mortar into vertical gaps between blocks and removing excess mortar take 11.28% of skilled labor working time, 0.96 % of unskilled labor working time and 6.72 % of block work gang working time. Mixing mortar and filling it in bucket take 0.20% of skilled labor working time, 22.55 % of unskilled labor working time and 9.47 % of block work gang working time.

Distribution of mortar and blocks to spots close to operators take 0.52% of skilled labor working time, 23.59 % of unskilled labor working time and 10.61% of block work gang working time. Work relevant to block work such as (fixing angles, setting scaffolding, checking distances in line with drawings, and taking instruction from supervisors) takes 6.68% of skilled labor working time, 6.81 % of unskilled labor working time and 6.40% of block work gang working time. Cleaning working site takes 2.36% of skilled labor working time, 1.71 % of unskilled labor working time and 2.24% of block work gang working time. 12.74% of skilled labor working time is idle whilst 36 % of unskilled

labor working time is idle. Removing and replacing already completed work due to operator fault or management fault take 0.49 % of skilled labor working time and 0.25% of block work gang working time.

Table 2. Distributions of block work activities

Type of work	Activities	Skilled labor	Unskilled labor	Gang
Productive activities	Spreading mortar	21.17%	0.55%	12.25%
	Cutting blocks	5.69%	5.58%	5.55%
	Laying blocks	38.87%	2.25%	23.76%
	Raking and pointing	11.28%	0.96%	6.72%
Contributory activities	Making mortar	0.20%	22.55%	9.47%
	Ancillary work	6.68%	6.81%	6.40%
	Distributing blocks or mortar	0.52%	23.59%	10.61%
	Cleaning	2.36%	1.71%	2.24%
Unproductive activities	Idle	12.74%	36.00%	22.75%
	Rework	0.49%	0.00%	0.25%

Findings show that skilled labor spent more than three-fourth (77.01%) of his working time in productive work. On the other hand, skilled labor spent only 9.76% of his working time in contributory work. This indicates that skilled labor work mainly in productive activities. Findings also show that unskilled labor spent only 9.34% of his working time in productive work. On the other hand unskilled labor spent more than half (54.66%) of his working time in contributory work. This indicated that unskilled labor work mainly in contributory activities. Unproductive time of skilled labor was 13.23% of his

working time whilst unproductive time of unskilled labor was 36% of his working time.

Results illustrate that the most important activity done by skilled labor was laying blocks which had taken 38.87% of skilled labor working time. Second important activity done by skilled labor was spreading mortar on wall which had taken 21.17% of skilled labor working time. On the other hand, the most important activity done by unskilled labor was distribution blocks and mortar which had taken 23.59% of unskilled labor working time. Second important activity done by unskilled labor was making mortar which had taken 22.55% of unskilled labor working time. This result is acceptable as the main job of skilled labor is laying blocks while the main job of unskilled labor is providing materials required for skilled labor to perform his work. Results also indicate that skilled labor and unskilled labor spent approximately equal time in cutting blocks. Also skilled labor and unskilled labor spent approximately equal time in ancillary work. This is because some gangs depend on skilled labor for cutting blocks and ancillary work and other gangs depend on unskilled labor to perform these two activities.

As mentioned in results, idle time of unskilled labor (36%) is higher than idle time of skilled labor (12.74%). This indicates that the work is not well distributed between skilled and unskilled labor. Findings also indicated that skilled labor lost only 0.49 % of his working time in rework. This result might be interpreted as block work in all buildings of Sheikh Zayed Township project is typical from ground storey to last storey therefore block work is repeated from storey to storey and from building to building. This repetition of work helped skilled labor to understand drawing and specification requirements and consequently reduce rework. Findings illustrate that block work gangs spent more than three-fourth (77%) of their working time in working activities. This percentage is acceptable but it could be improved by effective distribution of work between skilled and unskilled labor.

Block work skilled labor productivity

Table 3 indicates that skilled laborer average productivity per hour in laying blocks 20 is 38.40 blocks. On the other hand, skilled laborer average productivity per hour in laying blocks 10 is 40.5 blocks. Skilled laborer productivity in laying blocks 10 greater than skilled laborer productivity in laying blocks 20 because blocks 10 is lighter than blocks 20 thus blocks 10 is easier than blocks 20 in handling and fixing .

Table 3. Block work skilled labor productivity statistics

Block type	Mean (blocks/Hour)	Std. Deviation
Blocks 20	38.40	11.86
Blocks 10	40.50	12.52

Frequency histograms were drawn for skilled labor productivity in blocks 20 and blocks 10 to provide a visual illustration of the frequency distributions of skilled labor productivity in both types of blocks. These have been presented in figure 1 and 2. Both figures show a high variation of skilled labor productivity in both blocks 20 and blocks10.

Figure 1. Frequency histogram of skilled labor productivity in Blocks 20

Figure 2. Frequency histogram of skilled labor productivity in Blocks 10

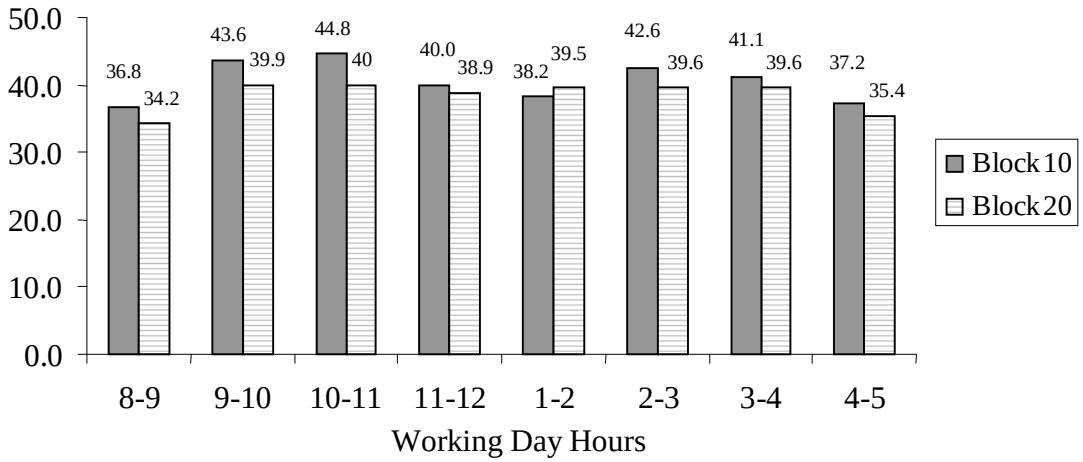

Figure 3. Histogram representing skilled labor productivity in hours of day

Results indicate that skilled labor has highest productivity from 9 o'clock to 11 o'clock and from 2 o'clock to 3 o'clock and they have lowest productivity from 8 o'clock to 9 o'clock and from 4 o'clock to 5 o'clock for both types of blocks (figure 3). But it should be noted that skilled labor productivity in morning hours higher than skilled labor productivity in afternoon hours for blocks 10 but skilled labor productivity in morning hours approximately equals skilled labor productivity in afternoon hours for blocks 20.

Results indicate that skilled labor has highest productivity on Sunday for blocks 10 (figure 4) whilst they have highest productivity on Wednesday for blocks 20. On the other hand, skilled labor has lowest productivity on Thursday for both types of blocks. Also it should be noted that skilled labor productivity is high on Monday and Wednesday for both types of blocks.

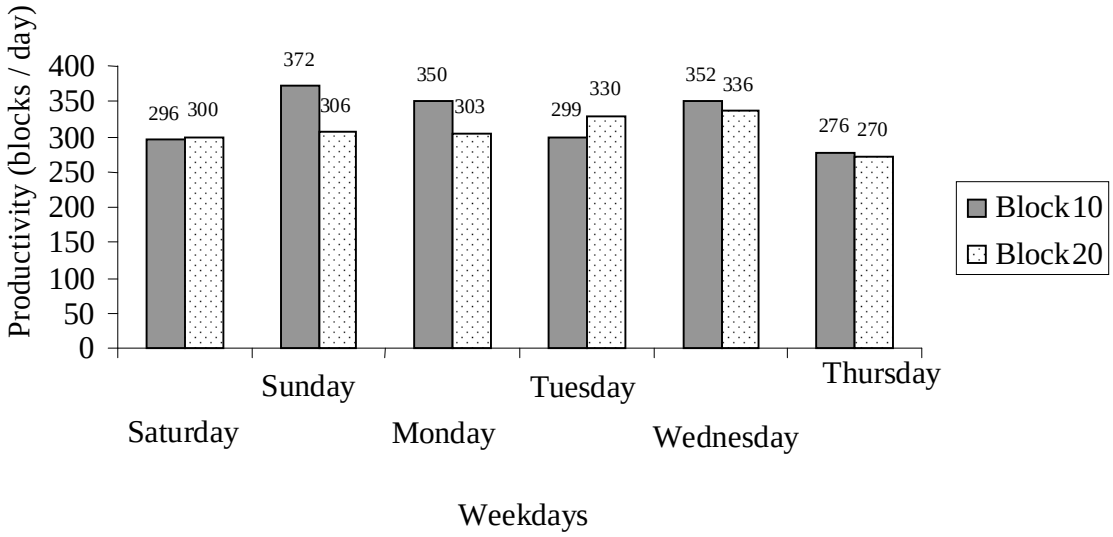

Figure 4. Histogram representing skilled labor productivity in week days

Skilled labor productivity in laying both blocks 10 and blocks 20 were high from 9 o'clock to 11 o'clock. On the other hand, skilled labor productivity in laying both blocks 10 and blocks 20 were low from 8 o'clock to 9 o'clock and from 4 o'clock to 5 o'clock. High productivity from 9 o'clock to 11 o'clock because these hours are first hours of working day thus skilled labor in these hours is vital and have more power and ability for production. The Low productivity from 8 o'clock to 9 o'clock because skilled labor spent approximately 10 minutes of first hour preparing mortar required to start block laying and Low productivity from 4 o'clock to 5 o'clock because skilled labor was tired by that hour.

Skilled labor had high productivity in laying blocks 10 on Sunday, Monday, and Wednesday whilst they were had medium productivity on Saturday, and Tuesday. On the other hand, skilled labor had low productivity in Thursday. Skilled labor had high productivity in laying blocks 20 on Tuesday, and Wednesday whilst they were had medium productivity on Saturday, Sunday, and Monday. On the other hand, skilled labor had low productivity on Thursday. Low productivity in laying blocks in Thursday might be interpreted as this day is last working day in the week thus skilled labor were tired and

fatigued in that day. Also skilled labor was subjected to mental distraction in that day because they plan for the method of spending weekend.

Summary of labor productivity measurement

Labor productivity measurement was carried for block work operation in construction sites of Sheikh Zayed Township project. Skilled labor productivity for blocks 10 and blocks 20 was observed. Also the researchers studied the productive time, contributory time and unproductive time of skilled and unskilled labor of block work. As shown in table 4 the average productivity of skilled labor in laying blocks 20 is 38.40 blocks per hour (3.07 m2/h) while average productivity of skilled labor in laying blocks 10 is 40.50 blocks per hour (3.24 m2/h). Also table 4 indicates that productive time of skilled labor was 77.01% of his working time while productive time of unskilled labor was 9.34% of his working time. The contributory time of skilled labor was 9.76 % of his working time while contributory time of unskilled labor was 54.66% of his working time. Unproductive time of skilled labor was 13.23% of his working time while unproductive time of unskilled labor was 36% of his working time.

Table 4. Block work operation productivity basic statistics

Main parameter	**Mean**
Skilled labor Productivity rate per hour in laying blocks 10	40.50 blocks (3.24 M2)
Skilled labor Productivity rate per hour in laying blocks 20	38.40 blocks (3.07 M2)
Skilled labor productive time	77.01%
Skilled labor contributory time	9.76 %
Skilled labor unproductive time	13.23%
Unskilled labor productive time	9.34%
Unskilled labor contributory time	54.66%
Unskilled labor unproductive time	36.00%

CONCLUSION

The lack of use of available activity sampling techniques has been considered as one of the reasons for the declining trend in construction productivity. Construction productivity can be increased by improving the work efficiency of the industry's labor force and by carefully monitoring this efficiency. The research looked at the distributions of skilled labor time and unskilled labor time in working day. The findings indicate that skilled labor work mainly in productive activities as they spend 77.01% of their working time in productive activities. Also it is indicated that unskilled labor work mainly in contributory activities as they spend 54.66% of their working time in contributory activities. Also findings highlight that the work is not well distributed between skilled labor and unskilled labor as idle time of unskilled labor (36%) is higher than idle time of skilled labor (12.74%).

Productivity of skilled labor is another issue that was studied in this research. The findings confirm that average productivity of skilled labor in laying blocks 20 is 38.40 blocks per hour (3.07 m2/h) while average productivity of skilled labor in laying blocks 10 is 40.50 blocks per hour (3.24m2/h). Skilled labor productivity in laying both blocks 10 and blocks 20 were high from 9 o'clock to 11 o'clock. On the other hand, skilled labor productivity in laying both blocks 10 and blocks 20 were low from 8 o'clock to 9 o'clock and from 4 o'clock to 5 o'clock. Moreover the findings show that skilled labor has high productivity in laying blocks 10 on Sunday, Monday, and Wednesday while lowest productivity of skilled labor in laying blocks 10 on Thursday. On the other hand, skilled labor has highest productivity in laying blocks 20 on Tuesday, and Wednesday while skilled labor has lowest productivity in Thursday.

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