Factors Affecting Productivity of Flat Slab Rebar Installation Labors in Egypt

Hossam El-deen H. Mohamed, Ahmed H. Ibrahim, Ahmed M. Morsy

Abstract— **Estimating the construction labor productivity has a significant importance for construction planning, scheduling and cost estimating. It is very important to maximize labor productivity and accurately forecast activity durations to achieve lower labor cost and shorter project duration. A company may lose money in the execution of the project if the labor cost was wrongly estimated. On the other hand, if the estimate is high, the company may lose the contract due to overpricing.**

So this paper aims to identify the factors affecting the productivity of flat slab rebar installation labors in Egypt. Thirty factors were selected and classified into four main categories from the literature review. In addition using a questionnaire survey filled by 120 engineer and contractor in the construction sector in Egypt to get the most important factors affecting productivity of flat slab rebar installation labors, these important factors are seventeen according to using two measure scales, the first is the frequency measure which means how much the productivity of flat slab rebar installation labors is selected according to each factor and the second is the importance of each factor when occurred in the projects on the productivity of flat slab rebar installation labors. Data were gathered from 120 building projects residential in Egypt and analysis them to know the effect of each factor on the productivity of flat slab rebar installation labors in Egypt.

Index Terms— **Construction Project, Flat Slab, Labors Productivity, Rebar Installation**

I. INTRODUCTION

Construction productivity is a very important aspect and mostly analyzed by researchers because it is one of the main indicator of the performance of the construction industry. It is regarded as a true reflection of the efficiency and economic success of the operations. Construction labor productivity is influenced by several factors that vary from project to project and from task to task within the same project. Standard values of production rates are the most essential information used to analyze the performance of construction labor productivity. The accuracy of estimating and scheduling of a project is mainly dependent on the validity and reliability of the production rates data available. The accurate estimation of construction labor productivity could be challenging when effects of multiple factors are considered simultaneously.

In 1950, the Organization for European Economic Cooperation (OEEC) presented a formal definition of productivity: "productivity is the quotient obtained by dividing output by one of the factors of production. In this way it is possible to speak of the productivity of capital, investment or raw materials according to whether output is being considered in relation to capital, investment or raw materials, etc" (Sumanth 1985).

Flat slabs are widely used in the housing projects in Egypt. Even though building flat slabs can be an expensive affair but they are considered suitable for most of the construction and for asymmetrical column layouts like floors with curved shapes and ramps etc. The advantages of applying flat slabs are many like depth solution, flat soffit and flexibility in design layout.

Fat slabs allows architect to introduce partition walls anywhere required, this allows owner to change the size of room layout. Use of flat slab allows choice of omitting false ceiling and finish soffit of slab with skim coating. Flat slab construction can deeply reduce floor-to-floor height especially in the absence of false ceiling as flat slab construction does act as limiting factor on the placement of horizontal services and partitions. This can prove gainful in case of lower building height, decreased cladding expense and pre-fabricated services. All mechanical & electrical services can be mounted directly on the underside of the slab instead of bending them to avoid the beams. Use of flat slabs requires less time for construction by the use of big table formwork but it requires more time for steel work.

Flat slab reinforcement commonly consists of a double layer grid of reinforcing bars, i.e. bottom and top, placed at ninety degree and tied at selected intersections in each layer. The Bottom Layer reinforcement grid is fixed first, followed by the required electro-mechanical services. Upon the inspection of the bottom layer reinforcement and other services, top layer supporting chairs are evenly distributed and securely fixed in positions. At this stage, the top layer reinforcement grid is fixed. Rebar installation in flat slab involves cutting, bending, placing and tying bars in positions. The most common method of tying reinforcing steel is to use soft iron binding wires at selected intersections of bars in slabs. Rebar installation is a labor intensive operation, which requires a high degree of strength and skill. Firm fixing and holding reinforcing bars in position is essential during concreting.

The objective of this paper is to identify the most important factors affecting productivity of flat slab rebar installation

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labors in Egypt based on a comprehensive survey among a selected sample of construction experts.

II. LITERATURE REVIEW

The following is a summary of the milestones researches and studies in the field of construction productivity.

Abd-Elshakour (1994) applied a controller-function chart to analyze and improve construction productivity of the Egyptian construction projects. He classified the factors affecting productivity to four groups including: industry related factors, project related factors, management and labor related factors.

Abdel-Samad (2006) developed an artificial neural network model to predict the production rates of pouring ready mix concrete, the most effective factors that effect production rate of pouring process, were identified and considered as potential input variables for neural net work model. Twenty -seven factors were categorized under five groups including: project related factors, management related factors, labor related factors, industry related factors and other factors. These factors are shown in Table (1).

Table (1): Factors Affecting Production Rate of Pouring Process (Abdel-Samad, 2006)

A -Project related factors
1- Method of construction.
2- Type of project.
3- Building element.
4- Project location.
5- Pouring level.
6- Complexity due to steel bars and equipment efficiency.
7-Equipment efficiency
B - Management related factors
1- Time planning and scheduling.
2- Quality control.
3- Degree of supervision.
4- Project organization and communication.
5- Site layout.
6- Availability of materials.
C - Labor related factors
1- Worker skill-ness.
2- Motivation.
3- Crew size.
4- No. of composition in each crew.
5- Over time
D - Industry related factors
1- Application of safety and health regulation.
2- Temperature.
3- Relative humidity.
4- Stoppage due to rain or wind.
E - Other factors
1- Pouring size
2- Carpenter and form worker performance.
3- Mobile pump capacity.
4- No. of batch plant.
5- Location of patch plant (inside or outside the project).

Abdel-Azeem (2009) developed an artificial neural networks model and a two regression models to predict the production rates of Egyptian bricklayers, the most effective factors that effect production rate of Egyptian bricklayers, were identified and considered as potential input variables for neural net work model and for the two regression models. Thirty -five factors were categorized under five groups including: project related factors, management related factors, labor related factors, industry related factors and design factors. These factors are shown in Table (2). He made a comparison between the artificial neural networks model and a two regression models and the results of comparison indicated that neural network model produced better results and was the most appropriate technique because it had the lowest invalidity percent.

Table (2): Factors Affecting Production Rate of Egyptian Bricklayers (Abdel-Azeem, 2009)

A - Labor related factors
1- Crew Size.
2- Crew Composition.
3- Labor Skill.
4- Types of Labor Employment.
5- Motivation.
6- Absenteeism.
7- Daily Wage of labor
B - Project related factors
1- Project Location.
2- Project Repetitiveness.
3- Type of Contract.
4- Job Size.
5-. Work Hours Per Day
6- Work Days Per Week.
C - Management related factors
1- Project Organization& Communication.
2- Efficiency of Supervision
3- Materials Availability
4- Tools Availability
5- Information& Feedback
6- Time Planning And Scheduling
7- Interfere Between Crews And Space Congestion
8- Incomplete Drawings
9- Design Changes & Change Orders
10- Quality of Drawings And Specifications
11- Work Space Layout
12- Workers motivation system
13- Delay of payments to suppliers
14- Quality Control
D - Industry related factors
1- Safety And Health Regulations
2- Union Rules& Government Regulations
3- Supply And Demand Characteristics
4- Weather Conditions
5- Work Ethics.
E – Design related factors
1- Complexity of Design
2- Thickness of wall
3- No of Openings in Walls

Abdellateef (2010) used benchmarking model for calculating individual project metrics to compare one project

to another and presenting a regression computer program that can predict the construction brick layer productivity to identify the best and the worst performing projects. The factors he studied were advancement in technology, contestation and accessibility, environmental factors, project uniqueness, management, work method, change order, communication, region, material, rework, job planning, drawings, labor factors, crew structure and organization, and work content.

Jarkas (2010) developed a regression model to predict the production rates of rebar fixing labor of beamless slabs. He explored the buildability factors affecting its rebar fixing efficiency. These factors were rebar diameter; reinforcement quantity; slab geometry; and reinforcement layer location are determined. Buildability is amongst the most important factors affect labor productivity. Buildability, is defined by "the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building".

Hafez et al. (2014) identified and ranked the relative importance of factors perceived to affect labor productivity on Egyptian construction projects. To achieve this objective, a statistically representative sample of contractors was invited to participate in a structured questionnaire survey, comprising 27 productivity factors, classified under the following four primary groups: (a) Technological; (b) Management; (c) Human/Labor; and (d) External. Among the factors explored, the subsequent ten are discerned to be the most significant in their effects on labor productivity: (1) Payment delay; (2) Skill of labor; (3) A shortage of experienced labor; (4) Lack of labor supervision; (5) Motivation of labor; (6) Working overtime, (7) Construction managers lack of leadership, (8) High humidity, (9) Clarity of technical specification, (10) High/low temperature.

Kisi et al. (2016) introduce a two-prong strategy for estimating optimal productivity in labor-intensive construction operations and by applying this strategy to a pilot study on the replacement of electrical lighting fixtures. The first prong, or top-down approach, estimates the upper limit of optimal productivity by introducing system inefficiencies into the productivity frontier the productivity achieved under perfect conditions. They used a qualitative factor model to identify this upper limit. The second prong, or bottom-up approach, estimates the lower limit of optimal productivity by taking away operational inefficiencies from actual productivity recorded in the field. A discrete-event simulation model provides this lower-limit value. An average of the upper and lower limits yields the best estimate of optimal productivity.

El-Gohary et al. (2017), introduce an engineering concept to document, control, predict, and improve the contractor's labor productivity. A wide range of influencing factors on the micro level (project management and administration) and the micro/micro level (activity level at construction site) has been considered. They applied the proposed engineering approach to model construction labor productivity of two construction crafts, carpentry and fixing reinforcing steel bars of different types of concrete foundations, using the artificial neural network (ANN) technique and utilizing the transfer function of the hyperbolic tan function (tanh). The results showed an adequate convergence with reasonable generalization capabilities, and more accurate and credible results compared with not only the traditional method.

Bonham et al. (2017), present a methodological approach to develop a practical data collection metric for productivity based on established industry factors of influence. This method is developed to capture the systematic and integrative behaviors of complex piping installation factors in a simple master code structure. Although the methods applied are used to develop productivity metric for mechanical piping, the methods could be applied to develop productivity metrics for other systems using relevant data sources.

III. FACTORS AFFECTING PRODUCTIVITY OF FLAT SLAB REBAR INSTALLTION LABORS IN EGYPT

This paper identifies factors which affect productivity of flat slab rebar installation labors in Egypt. Identifying these factors can help accurately determine the productivity of flat slab rebar installation labors. Table (3) shows thirty factors are selected based on literature review. These factors were categorized under four groups including: industry related factors, project related factors, design related factors, and labor related factors. Two forms of questionnaire were prepared in this research; first, aims to rank these factors according to their importance and frequency of occurrence based on interviews with the construction experts. Then, the most important factors are identified.

Table (3): List of Factors Affecting Productivity of Flat Slab Rebar Installation Labors

Group No.	Factor No.	Suggested Factors
A		Industry Related Factors
	A.1	Safety and Health Regulations
	A.2	Steel type
B		Project Related Factors
	B.1	Site Layout
	B.2	Project Organization& Communication
	B.3	Degree of Supervision
	B.4	Materials Availability
	B.5	Tools Availability
	B.6	Time Planning and Scheduling
	B.7	Quality Control
	B.8	Location
	B.9	Type of Project According to Repetitiveness
	B.10	Project Size
	B.11	Job Size
	B.12	Method of Construction (Method of Cut & bent)
	B.13	Weather
C		Design Related Factor
	C.1	Specifications
	C.2	Beams Found or Not
	C.3	Drop Panels Found or Not
	C.4	Column Heads Found or Not
	C.5	Rebar Diameter

	C.6	Reinforcement Quantity
	C.7	Slab Geometry
	C.8	Slab Thickness
	C.9	Floor Level
D		Labor Related Factors
	D.1	Crew Size
	D.2	Crew Composition
	D.3	Labor Skill ness
	D.4	Types of Labors' Employment
	D.5	Motivation
	D.6	Over Time

IV. QUESTIONNAIRE SURVEY

According to literature review a well designed questionnaire was developed. The questionnaire investigating the most effective factors affecting the flat slab rebar installation labors productivity. The design of the questionnaire was based on the fact that they had to be simple, clear and understandable for the respondents and at the same time they should be able to be interpreted well by the researcher. In all questionnaires, questions possible answers are identified and the respondent is asked to choose one of the answers.

The questions depend on two scale measures the first measure was considered the frequency of how much concerned factor was taken into consideration when the respondent gives the productivity of flat slab rebar installation labors for his projects. The second measure was considered the impact and the importance of the concerned factor on the productivity of flat slab rebar installation labors. Measure of the two scales is its interval form (1 to 10) (Yahia, 2010).

A. *DETERMINATION OF RQUIRED SAMPLE SIZE*

Bartlett et al. (2001) used the following formula to compute the required sample size for unlimited population:

$$n = \frac{K^2 \text{ x } P(1-P)}{E^2} \quad \text{---------- (1)}$$

Where,

n is the required sample size for finite population, K value equals to 1.645 when confidence level equals to 90%, P is the proportion of population i.e. P degree of variance between the elements of population (the critical value of P is 0.5), E is the acceptable margin of error = 10% for confidence 90%. By substituting of these parameters in Equation (1), the required sample size of this study for finite population is 68 as a minimum value.

B. *CLASSIFICATION OF THE SURVEYED EXPERTS*

A questionnaire survey was piloted among construction experts to identify the most important construction project duration factors. The respondents to the questionnaire were classified according to their experience as shown in Figure (1). A closer inspection to Figure (1) clearly shows that about 28% of the respondents have experience less than 5 years; 49% have experience between 5 years and 10 years; 15% was found between 10 years and 15 years and finally 8% of respondents have experience greater than 15 years. Figure (2) shows Classification according to their job as supervisor, site engineer, site or project manger and contractor. 73% of respondents were site engineers, 15% were supervisors, 8% were site mangers and finally 4% were contractors.

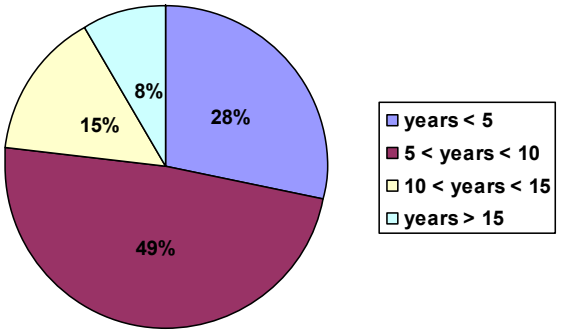

Figure (1): Classification of Participated Respondents Based on Their Experience

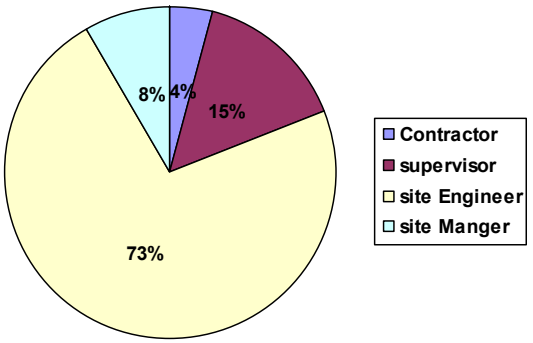

Figure (2): Classification of Participated Respondents Based on Their Work Field

V. DATA ANALYSIS

The questionnaire respondents have provided numerical scoring expressing their opinions based on their experience in the construction field in Egypt. 120 questionnaires were collected which achieve the minimum number of the sample size. The questionnaire respondents were asked to provide numerical scoring expressing their opinions based on their experience in the construction field in Egypt. The respondents have inserted two scores in front of each factor. First is the frequency of occurrence of each factor. Second the degree of impact and importance of each factor on rebar installation labours productivity. The ranking of each factor was determined by using two indices. First is the frequency index. Second is the importance index which their formulas are shown as follow:

$$\text{Frequency Index} = \frac{\sum_{n-1}^{n} F_i}{a \times N} \quad \text{---------- (2)}$$

$$\text{Importance Index} = \frac{\sum_{n-1}^{n} M_i}{a \times N} \quad \text{---------- (3)}$$

Where,

- $\sum_{n-1}^{n} F_i$ and $\sum_{n-1}^{n} M_i$ = The sum of frequency and importance scores of each factor from the total respondents. The weighting range from 1 to 10, where 1 means in the frequency measure that this factor not to be used in determining productivity, also means in the importance measure that this factor not to be impact productivity.10 means that this factor is repeated when determining productivity according to frequency measure and has very impact on productivity according to importance measure.
- a = the upper scale for each measure which equals to 10.
- N= the number of Respondents which is constant and equals to 120.

Finally, Table (4) shows the final rank of each factor calculating final index which equals to multiplying two previously indices and then the most important factors have largest value from final index (shash, 1993).

Table (4): Factors Ranking According to Final Indices

	Factors	Total Score of Frequency Measure	Frequency Index	Total Score of Importance Measure	Importance Index	Final Index%
1	A.1	507	0.42250	720	0.60000	25.4%
2	A.2	374	0.31167	424	0.35333	11.0%
3	B.1	1030	0.85833	1018	0.84833	72.8%
4	B.2	627	0.52250	791	0.65917	34.4%
5	B.3	1030	0.85833	1048	0.87333	75.0%
6	B.4	780	0.65000	831	0.69250	45.0%
7	B.5	766	0.63833	821	0.68417	43.7%
8	B.6	611	0.50917	771	0.64250	32.7%
9	B.7	610	0.50833	742	0.61833	31.4%
10	B.8	616	0.51333	721	0.60083	30.8%
11	B.9	850	0.70833	1008	0.84000	59.5%
12	B.10	621	0.51750	655	0.54583	28.2%
13	B.11	593	0.49417	623	0.51917	25.7%
14	B.12	865	0.72083	925	0.77083	55.6%
15	B.13	647	0.53917	734	0.61167	33.0%
16	C.1	977	0.81417	972	0.81000	65.9%
17	C.2	1021	0.85083	1017	0.84750	72.1%
18	C.3	1016	0.84667	1011	0.84250	71.3%
19	C.4	1003	0.83583	999	0.83250	69.6%
20	C.5	1003	0.83583	974	0.81167	67.8%
21	C.6s	1002	0.83500	969	0.80750	67.4%
22	C.7	994	0.82833	931	0.77583	64.3%
23	C.8	978	0.81500	934	0.77833	63.4%
24	C.9	1024	0.85333	1043	0.86917	74.2%
25	D.1	997	0.83083	1033	0.86083	71.5%
26	D.2	1047	0.87250	1057	0.88083	76.9%
27	D.3	951	0.79250	1035	0.86250	68.4%
28	D.4	1010	0.84167	1035	0.86250	72.6%
29	D.5	572	0.47667	886	0.73833	35.2%
30	D.6	568	0.47333	857	0.71417	33.8%

6. MOST IMPORTANT FACTORS AFFECTING PRODUCTIVITY OF FLAT SLAB REBAR INSTALLTION LABORS IN EGYPT

The factors are considered highest important factors based on a survey with construction sector in Egypt were all factors where final indices greater than 50%. Therefore, the top 17 factors and their final indices are shown in Table (5).

Table (6) shows a summary list of categories before and after ranking. It clearly illustrates that no factors were considered under industry related factors. Moreover, instead of thirteen factors, four factors were only considered under project related factors. Moreover, all nine factors were considered under design related factors. Finally, for the category of labor related factors it was shown that the total number of factors was decreased from six factors to four factors only.

Figure (3) also reveals a comparison in total number of factors in each category before and after ranking. It demonstrates that the weight of project related factors, design related factors, and labor related factors are 23.53%, 52.94%, and 23.53% respectively.

According to the analysis of the different groups, it shows that the first group "industry related factors" doesn't has any factor affecting productivity because this group contains factors such as "Safety and Health Regulations" factor which is almost constant at most project. Another factor in this group is "Steel type" which doesn't affect productivity because the specifications of different types almost are the same.

Table (5): The Most Important Factors Affecting Productivity of Flat Slab Rebar Installation Labors

Factors	Total Score of Frequency Measure	Frequency Index	Total Score of Importance Measure	Importance Index	Final Index
D.2	1047	0.87250	1057	0.88083	76.9%
B.3	1030	0.85833	1048	0.87333	75.0%
C.9	1024	0.85333	1043	0.86917	74.2%
B.1	1030	0.85833	1018	0.84833	72.8%
D.4	1010	0.84167	1035	0.86250	72.6%
C.2	1021	0.85083	1017	0.84750	72.1%
D.1	997	0.83083	1033	0.86083	71.5%
C.3	1016	0.84667	1011	0.84250	71.3%
C.4	1003	0.83583	999	0.83250	69.6%
D.3	951	0.79250	1035	0.86250	68.4%
C.5	1003	0.83583	974	0.81167	67.8%
C.6	1002	0.83500	969	0.80750	67.4%
C.1	977	0.81417	972	0.81000	65.9%
C.7	994	0.82833	931	0.77583	64.3%
C.8	978	0.81500	934	0.77833	63.4%
B.9	850	0.70833	1008	0.84000	59.5%
B.12	865	0.72083	925	0.77083	55.6%

Table (6): Factors Affecting Productivity of Flat Slab Rebar Installation Labors with Their Ranking Groups

No.	Category	All Factors before Ranking		All Factors after Ranking	
		Sum	Weight	Sum	Weight
1	Industry Related Factors	2	6.67%	0	0.00%
2	Project Related Factors	13	43.33%	4	23.53%
3	Design Related Factors	9	30.00%	9	52.94%
4	Labor Related Factors	6	20.00%	4	23.53%
Total		30	100.00%	17	100.00%

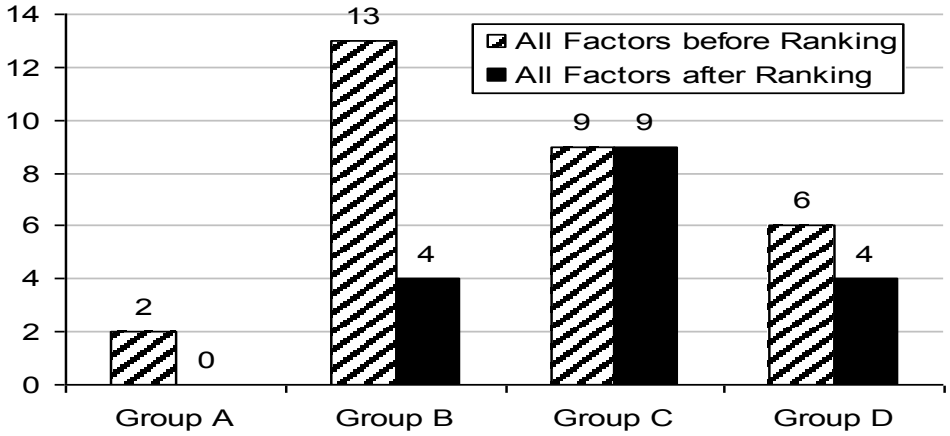

Figure (3): Comparison by Number of Factors in Each Category before and After Ranking.

CONCLUSION

The most important factors affecting productivity of flat slab rebar installation labors includes the following items, ranked by their relative importance; (1) Crew Composition, (2) Degree of Supervision, (3) Floor Level, (4) Site Layout, (5) Types of Labors' Employment, (6) Beams Found or not, (7) Crew Size, (8) Drop panels Found or not, (9) Columns head Found or not , (10) Labor Skill ness, (11) Rebar Diameter, (12) Reinforcement Quantity, (13) Specifications, (14) Slab Geometry, (15) Slab Thickness, (16) Type of Project according to repetitiveness and (17) Method of Construction (Method of Cut and Bent).

According to the ranking of the four groups, the most important group which affected productivity of flat slab rebar installation labors is design related factors with ranking of 52.94% from 17 important factors, the second group in importance is labor related factors with ranking of 23.53%, the third group in importance is project related factors with ranking of 23.53%, finally industry related factors group doesn't affect productivity of flat slab rebar installation labors.

REFERENCES

[1] Abdel-Azeem, A. S. (2009) “Predicting Production Rates of Egyptian Bricklayers Using Artificial Neural Networks and Regression Models” MSc., Thesis, Faculty of Engineering, Zagazig University, Egypt.

[2] Abdellateef, M. A. M. (2010). "Benchmarking model for masonry labors productivity improvement". PhD. Thesis, Faculty of Engineering, Cairo University, Egypt.

[3] Abdel-Samad, D. (2006). “Predicting Production Rates of Pouring Concrete in Egypt Using Artificial Neural Networks Model” MSc. Thesis, College Of Engineering And Technology, Arab Academic For Science, Egypt.

[4] Abdel-Shakour, H. (1994). “Improving Productivity of Construction Projects Via Improving on Site Construction Management” MSc., Thesis, Faculty of Engineering, Zagazig University, Egypt.

[5] Bartlett, j. E., Kotrlik, W. and Higgins, C. (2001). "Organizational Research: Determining Appropriate Sample Size in Survey Research." Learning and Performance Journal, 19(1), 43-50.

[6] Bonham, D. R., Goodrum, P. M., Littlejohn, R., & Albattah, M. A. (2017). "Application of Data Mining Techniques to Quantify the Relative Influence of Design and Installation Characteristics on Labor Productivity". *Journal of Construction Engineering and Management*, *143*(8), 04017052.

[7] El-Gohary, K. M., Aziz, R. F., & Abdel-Khalek, H. A. (2017). "Engineering Approach Using ANN to Improve and Predict Construction Labor Productivity under Different Influences". *Journal of Construction Engineering and Management*, *143*(8), 04017045.

[8] Hafez, S. M., Aziz, R. F., Morgan, E. S., Abdullah, M. M., & Ahmed, E. K. (2014). "Critical factors affecting construction labour productivity in Egypt". *American Journal of Civil Engineering*, *2*, 35-40.

[9] Jarkas, A. M. (2010). "The effects of buildability factors on rebar fixing labour productivity of beamless slabs". *Construction Economics and Building*, *10*(1-2), 16-35.

[10] Kisi, K. P., Mani, N., Rojas, E. M., & Foster, E. T. (2016). "Optimal Productivity in Labor-Intensive Construction Operations: Pilot Study". *Journal of Construction Engineering and Management, 143(3), 04016107.*

[11] Shash, A. A. (1993). Factors considered in tendering decisions by top UK contractors. *Construction management and economics*, *11*(2), 111-118.

[12] Sumanth, D. J. (1985). "Productivity engineering and management". McGraw-Hill Book Company.

[13] Yahia, H., Hosny, H., & Razik, M. E. A. (2011). "Time Contingency Assessment in Construction Projects". *Internation Journal of Computer Science Issues*, 523-531.