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## **Factors affecting productivity and improvement in building construction sites**

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**Abstract:** This research aims to identify and investigate factors affecting productivity in building construction sites. The importance of these factors has been studied extensively through a widely spread questionnaire among 183 participants. The research covers the MENA region, especially Egypt and Saudi Arabia as the main markets there and diversity of mega construction projects. The comparison of factors importance will help in making right investment decisions and better understanding of the nature of building construction sites, as well as it applies to a boarder construction environment as most of working construction companies there are international. Among all factors affecting productivity, 49 factors were carefully selected throughout carrying out extensive search and factor frequency of similar researches, they were categorised into seven groups. The survey was utilized for data gathering from Egyptian and Saudi construction sites. This research also provides simple and comprehensive recommendations and suggested method of determining loss in productivity that can be adopted by construction managers for an effective management of construction sites and higher productivity.

**Keywords:** productivity; construction sites; effectiveness; importance index; motivation; human factors; variance and statistical analysis.

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## 1 Introduction

Productivity rates of construction sites are one of the most required elements to estimate time and costs accurately. Projects can be better controlled if the variability of productivity is known and corrective actions are taken to enhance productivity, (Jain et al., 2016, Al Mehrzi and Singh, 2016; Parker et al., 2015). Meanwhile, inefficient management of construction resources can result in low productivity. Therefore, it is important for contractors and construction managers to be familiar with the methods leading to evaluate the productivity of the equipment and labour in different crafts.

To achieve these targets, it is important to have a good controlling hand on the productivity factors that contribute to the integrated production; like labour, equipment, cash flow, etc. (Abdel-Razek,1997).

The research selected two key countries in the MENA region to represent current changes in construction industry; Egypt and Saudi Arabia. Partially, as the two countries have extensive running mega construction projects with huge budgets. On the other hand, the impact of studying productivity will be obvious and beneficial due to the nature of these projects and abundance of factors affecting productivity there. The Saudi Arabian construction industry has been reported as the leading construction market in the region, according to Timetric's Report 2016, from the construction intelligence centre (CIC), the industry is constantly raised from a value of US\$105.6 billion in 2015 to US\$148.5 billion in 2020. The growth will be supported by increased governmental investments in sectors such as healthcare, education and infrastructure to diversify the country's economy away from oil related industries and to support economic growth (Timetric's Report Store, 2016).

In parallel, the Egyptian construction industry has an important effect on the country's economic growth. The Egyptian Ministry of Finance has reported that the performance of the industry is forecasted to accelerate, with an anticipated compound annual growth rate, CAGR, of 6.3% for the five year period 2016–2021, which is expected to drive the industry to a value of \$13.7 billion by the end of 2021 (Market Line Report, 2017).

The dual interference of construction projects in both countries has grown rapidly nowadays; it is about four Billion Dollar investments from the Saudi side in Egypt and more than one Billion Dollar from the Egyptian side in Saudi Arabia. This amount of investments needs a good understanding of the factors affecting project productivity in each country.

The research has investigated a wide range of factors affecting productivity in construction sites and figured out the most important ones, moreover, it suggested a simple method of determining loss in productivity can help project managers in monitoring productivity and take necessary corrective actions.

## **2 Literature review**

Factors influencing construction productivity have been the subject of inquiry by many researchers. In order to improve productivity, a study of the factors affecting it, whether positively or negatively, is necessary. Making use of those factors that positively affect productivity and eliminating (or controlling) factors of negative effect, will ultimately improve productivity, (Jafar, 2018, Al Mehrzi and Singh, 2016; Anitha, 2014). If all factors influencing productivity are known, it will also be possible to forecast productivity, (Sahay, 2005). However, there is no general agreement on the factors or their categories. This study reviews extensive researching works which handles the productivity that had carried out rigorous survey for most known factors affecting productivity. Among these researches, twenty selected researchers' work from different countries had compromised more than 120 different factors, and then frequency analysis was conducted to figure out which factors have the highest frequency to be considered in the current study. For all groups, seven groups are considered to distribute factors for this study as presented in Table 1.

**Table 1** Classification of factors groups

No	Group
1	Motivation factors
2	Time management factors
3	Project factors
4	Human factors
5	Supervision factors
6	Safety and health factors
7	Materials and equipment management

Frequency analysis of the factors which affect productivity are identified and presented in Table 2.

According to frequency analysis of the selected researches in the literature review, 49 factors with higher frequencies are considered for this study as presented in Table 3.

**Table 2** Factors affecting productivity (see online version for colours)

Factor	Study reference		Frequency
	Motivation factors		
1 End of project effect/discontinuity of work/secured job	✓	Heale (1993) and Al Mehri and Singh (2016)	4
2 Lack of employee motivation/friendship/workers integrity	✓	Heale (1993) and Al Mehri and Singh (2016)	10
3 Rewards/incentive for good performance	✓	Heale (1993) and Al Mehri and Singh (2016)	7
4 Delay of payment/workers strike due to unpaid work/salaries on time	✓	Heale (1993) and Al Mehri and Singh (2016)	9
5 Team work, crew size, crew relationships, overcrowding, Site congestion effect	✓	Heale (1993) and Al Mehri and Singh (2016)	14
6 Project communication/poor communication	✓	Heale (1993) and Al Mehri and Singh (2016)	11
7 Lack of financial motivation system	✓	Heale (1993) and Al Mehri and Singh (2016)	3
8 Lack of labour recognition programs, appraisal where improvement needed are identified	✓	Heale (1993) and Al Mehri and Singh (2016)	3
9 Non-provision of transport from workers/far distance from home and population centres	✓	Heale (1993) and Al Mehri and Singh (2016)	4
10 Lack of places for eating and relaxation	✓	Heale (1993) and Al Mehri and Singh (2016)	3

**Table 2** Factors affecting productivity (continued) (see online version for colours)

Factor	Study reference	Frequency	
		1	2
11	Heale (1993) and M Mehta and Singh (2016)	✓	
12	Maatswaidom and Emsley (2001) and Singh et al. (2016)	✓	
13	Sapuan et al. (2005) and Furker et al. (2015)		✓
14	Dai (2006) and Antha (2014)	✓	
15	Kuykendall (2007) and Abdel-Kazek (1997)		✓
16	Alhoubi (2010) and Changath (2015)	✓	✓
17	Minerva et al. (2007) and Trimere's Report Store (2016)	✓	✓
18	Alhoubi (2010) and Changath (2015)	✓	✓
19	Alhoubi (2010) and Changath (2015)	✓	✓
20	Alhoubi (2010) and Changath (2015)	✓	✓
21	Alhoubi (2010) and Changath (2015)	✓	✓
22	Alhoubi (2010) and Changath (2015)	✓	✓
23	Alhoubi (2010) and Changath (2015)	✓	✓
24	Alhoubi (2010) and Changath (2015)	✓	✓
25	Alhoubi (2010) and Changath (2015)	✓	✓





**Table 2** Factors affecting productivity (continued) (see online version for colours)

Factor	Study reference		Frequency
	Project factors		
47	Delay in work permit	✓	2
48	Late issuance of progress payment by client to contractor	✓	1
49	Centralised decision making by headquarter	✓	1
50	Government regulation	✓	2
51	Client lack of experience	✓	1
52	Higher bank interest rate	✓	1
53	Project site far from suppliers	✓	1
54	Lack of coordination/interaction between different construction parties (client, contractor, consultant, execution crews)	✓	5
55	Interference from other trades or other crew members	✓	3
56	Quality control/quality of required work	✓	3
57	Poor construction methods, e.g. poor sequencing of work	✓	2
58	Political insecurity (external like wars or internal like competitions with in company)	✓	2
59	Disruption of services (water, power) shortage of temporary facilities	✓	5





**Table 2** Factors affecting productivity (continued) (see online version for colours)

Factor	Study reference		Frequency
	Human factors analysis	Other	
76 Labour disloyalty	✓		1
77 Labour/workers satisfaction/a job where your voice is heard and experience is valued	✓		3
78 Lack of creating competition leading to suggestions or ideas	✓		4
79 Lack of foreign and local workers in the market/strict government policy on recruitment of foreign workers	✓		2
80 Equal pay on projects in a geographic area/amount of pay/payment delay to workers	✓		6
81 Labour/employment age	✓		5
82 Labour personal problems	✓		1
83 Changes in work allocations	✓		1
84 Lack of skill/occupational education and training/lack of training sessions	✓		8
85 Supervision factors analysis	✓		11
86 Incompetence of site supervisor/leader ship skills of supervisors/poor supervision method/supervision delay	✓		4
87 Changing of foremen	✓		7
88 Inexperienced inspector	✓		8
89 Inspection delay/regulatory inspections	✓		





**Table 2** Factors affecting productivity (continued) (see online version for colours)

Factor	Al Mehrzi and Singh (2016)	Mahalswatom and Emsley (2001) and Singh et al. (2016)	Sapuan et al. (2015)	Dai (2014)	Kuykendall (2007) and Abdel-Razek (1997)	Almative et al. (2007) and Timetric's Report Score (2016)	Nirca et al. (2009) and Market Line Report (2017)	Albouni (2010) and Changa (2015)	Eshassi et al. (2007) and McKinsey and Company Magazine	Kazaz et al. (2008) and Heale (1993)	Jang et al. (2011) and Mahalswatom and Emsley (2001)	Singh (2010) and Sapuan et al. (2005)	Soekiman et al. (2011) and Ken (2012) and Casey (2007)	Grudecha (2012) and Henry et al. (2007)	Mahamid et al. (2013) and Shamil et al. (2009)	El-Gohary and Aziz (2013) and Nabil (2007)	Thomas and Sudhakumar (2014) and Adnan et al. (2007)	Robles et al. (2014) and Aymur et al. (2008)	Rida (2015) and Homyun et al. (2009)	Frequency
109	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
110	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
111	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	1
112	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
113	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	3
114	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	7
115	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	3
116	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	8
117	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	1
118	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14
119	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
120	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	5
121	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
122	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	5
123	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2

Materials and equipment management factors analysis

**Table 3** Factors affecting productivity

<i>No.</i>	<i>Factors</i>
Group 1 Motivation factors	
1	1 Employee motivation by promote cooperation and integrity between them.
2	2 Rewards and incentive for good performance.
3	3 Paying employees' salaries on time.
4	4 Providing transport means, and how far is work location from home and population centres.
5	5 Effect of approaching the end of the project on project staff productivity and keeping their positions (secured job).
Group 2 Time management factors	
6	1 Use of planning and scheduling tools.
7	2 Efficiency of using Shift work system.
8	3 Increase the number of labours in order to accelerate work.
9	4 Increasing overtime hours in order to increase productivity.
Group 3 Project factors	
10	1 Change orders or variations from the owner or designer.
11	2 Availability of design or shop drawings.
12	3 The accuracy and completeness of drawings.
13	4 Workspace availability, and site layout condition, and working conditions (e.g., high places, shape, etc.).
14	5 Commitment to succession of periodic meeting between management and site persons.
15	6 Quality of site management skills.
16	7 Clear and updated construction specifications and standardisation.
17	8 The effect of crew size on the performance of the individual worker.
18	9 Compliance in payments to suppliers and how much power supplies department of the project.
19	10 Coordination between the various parties to the project (client, contractor, consultant, execution crews).
20	11 Disturbance of services (water, power)/shortage of temporary facilities.
21	12 Design or work complexity.
22	13 Effect of project size on productivity.
23	14 Availability of communication channels between project parties.
24	15 The availability of the use of information technology and its efficiency.
Group 4 Human factors	
25	1 Skill and experience of project staff.
26	2 Compliance with the attendance of the project staff.
27	3 Changing crew members and reallocation.
28	4 Misunderstanding among labours.
28	4 Misunderstanding among labours.
29	5 Availability of competitive atmosphere and listing for suggestions or ideas.
30	6 Equal pay on projects in different geographic areas.
31	7 Appropriate labour/employment age of the required work.
32	8 Provide training courses for project staff.

**Table 3** Factors affecting productivity (continued)

<i>No.</i>	<i>Factors</i>
Group 5 Supervision factors	
33	1 Efficiency and leadership skills of staff supervising the execution (contractor side).
34	2 Staff supervision experience (consultant side).
35	3 Commitment of inspection dates.
36	4 Adequate instruction and clear task assignment.
37	5 Rework (the number of reworks).
Group 6 Safety and health factors	
38	1 Weather/climatic conditions (temperature/humidity/rains/wind).
39	2 Adequacy of training on health and safety precautions.
40	3 Safely working conditions.
41	4 Compliance with safety precautions.
Group 7 Materials and equipment management factors	
42	1 Availability of materials on time.
43	2 The skills of managing and tracking tools and its quality.
44	3 Considering the quality of materials and raw materials.
45	4 The skills of managing and tracking of materials.
46	5 Availability of equipment on time.
47	6 Availability of appropriate stores for materials.
48	7 Availability of equipment's management skills.
49	8 Efficiency of equipment maintenance and/or repair.

### **3 Research methodology**

The adopted methodology can be summarised as follows:

- Extensive literature review of similar researches to figure out factors affecting productivity in construction sites.
- A structured questionnaire including all determined factors which affecting the productivity was sent to construction practitioners for determining the importance of factors in different building construction projects in Egypt and Saudi Arabia.
- Data analysis of survey results was conducted to rank the factors and determine the factors of the highest impact on productivity in both countries.
- Statistical comparison of factors which affecting productivity between Egypt and Saudi Arabia.
- Revising the methods of improving productivity, and collecting opinions of experts and workers in construction field through the questionnaire, to clarify the best methods to improve productivity.
- Developing a simple method of evaluating loss of productivity in construction sites.

#### 4 Data collection and analysis

The questionnaire extracted the opinions of the construction management personnel's regarding the questionnaire was distributed in different project sizes in Egypt and Saudi Arabia. The sample size is calculated as the following equation:

$$SS(\text{sample size}) = \frac{z^2 \times p(1-p)}{e^2} \quad (1)$$

where  $z = 1.64$  at 95% confidence,  $p = 0.20$ ,  $e = 0.080$ .

$$SS(\text{sample size}) = \frac{1.64^2 \times 0.2(1-0.2)}{0.08^2} = 68$$

Another equation used for correction with finite population

$$SS_{new} = \frac{ss}{1 + \frac{ss-1}{pop}} \quad (2)$$

where  $pop$  is the population which is considered for this research as the number of all engineers in the construction industry in Egypt and Saudi Arabia, the number of  $pop$  is 860,000, by using the equation:

$$SS_{new} = \frac{68}{1 + \frac{68-1}{860,000}} = 69$$

The factors under each group are ranked by the measurement of their importance index. Based on this importance index factor with high importance index could be identified. The importance index could be calculated as the following equation:

$$RII(\text{Relative importance index}) = \frac{5(n5) + 4(n4) + 3(n3) + 2(n2) + (n1)}{5(n1 + n2 + n3 + n4 + n5)} * 100 \quad (3)$$

where

$n1$  The number of respondents who selected: very low effect.

$n2$  The number of respondents who selected: low effect.

$n3$  The number of respondents who selected: moderate effect.

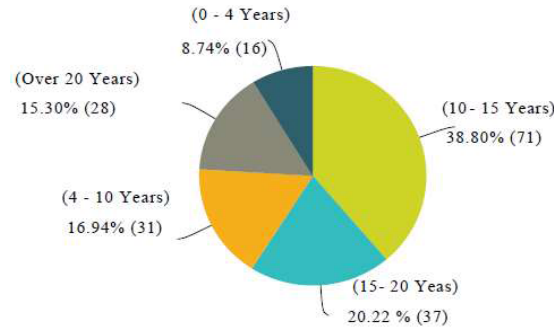
$n4$  The number of respondents who selected: high effect.

$n5$  The number of respondents who selected: very high effect.

While the actual collected sample size was used for this study is 183, in order to get more accurate and effective results, the experience of questionnaire respondents is illustrated in Figure 1.



**Figure 1** Respondent’s profile; experiences (see online version for colours)



The questionnaire aimed to elicit views from projects which sizes are medium, large and mega size, adapting the project size categories of the PMBOK-5th; depend on budget, number of team members involved, complexity of deliverables to be produced and Timeframes involved in delivery, so the responses which elected from small size projects are disregarded, projects sizes for respondents are presented in Table 4.

**Table 4** Projects sizes in Egypt and Saudi Arabia

Location	Size	Medium projects	Large projects	Mega projects	Total
Egypt		(32) 53.33%	(12) 20.00%	(16) 26.67%	(60) 32.79%
Saudi Arabia		(40)32.52%	(27) 21.95%	(56) 45.53%	(123) 67.21%
Total		72	39	72	183

In order to complete the study, steps were used to analyse the survey results.

- Analysis of factors to improve the validity of the study hypotheses by conducting reliability analysis.
- Rank the factors in calculating their relative importance index (RII).
- Analyse the factors in calculating person correlation, to find out their correlation strength, and conducting the T-test, and analysis of variance (ANOVA) analysis, to find out the effect of independent variables (project location, project size, experience) on the dependent variables (the significant factors which affect productivity).

#### 4.1 Reliability analysis

The assessment of Scale Reliability is a measurement of the internal consistency of the constructed items in this research, in order to evaluate the reliability of each factor Cronbach’s alpha coefficient and item total correlation is used, the value of Cronbach’s alpha for acceptable reliability is 0.8, and any factor which has the value of corrected item-total correlation below 0.3 would be considered rejected (Kien, 2012).The analysis shows that Cronbach’s alpha value of all factors is (0.937) which is higher than 0.8.

#### 4.2 Factors ranking

The RII is used to rank factors and to explore importance levels. Table 5 presents the values of the RII for all factors after being sorted from largest index to smallest index, and factors are classified as per importance level from very high to very low, the difference between highest index and smallest index is taken as a guide for factors classification,  $D$  (difference) =  $77.27$  (highest RII) –  $58.91$  (lowest RII) =  $18.36$ , divided by  $100 = (18.36/100) = 0.1836$ , While the intervals are considered to be equal for all levels.

**Table 5** Factors importance index levels

<i>Importance</i>		<i>Very low</i>	<i>Low</i>	<i>Moderate</i>	<i>High</i>	<i>Very high</i>
From		Up to 20%	20%	40%	60%	80%
To			40%	60%	80%	100%
RII value	From	58.91	62.59	66.26	69.93	73.60
	To	62.58	66.25	69.92	73.59	77.27

**Table 6** Ranking of factors affecting productivity

<i>Rank</i>	<i>Factor</i>	<i>RII</i>	<i>Importance</i>
1	Disturbance of services (water, power)/shortage of temporary facilities.	77.27	Very high
2	Availability of equipment on time.	76.83	
3	Availability of design or shop drawings.	76.72	
4	Compliance with the attendance of the project staff.	76.72	
5	The skills of managing and tracking tools and its quality.	76.50	
6	Skill and experience of project staff.	76.28	
7	Availability of materials on time.	76.17	
8	Staff supervision experience (consultant side).	74.21	
9	Commitment of inspection dates.	73.77	
10	Considering the quality of materials and raw materials.	73.77	
11	Coordination between the various parties to the project (client, contractor, consultant, execution crews).	73.44	
12	Paying employees' salaries on time.	73.33	High
13	Efficiency and leadership skills of staff supervising the execution (contractor side).	73.22	
14	The accuracy and completeness of drawings.	73.11	
15	Availability of equipment's management skills.	73.01	
16	Availability of communication channels between project parties.	72.35	
17	Rework (the number of reworks).	72.02	
18	Adequate instruction and clear task assignment.	71.80	
19	The quality of site management skills.	71.48	
20	Efficiency of equipment maintenance and/or repair.	71.15	

**Table 6** Ranking of factors affecting productivity (continued)

<i>Rank</i>	<i>Factor</i>	<i>RII</i>	<i>Importance</i>
21	Compliance in payments to suppliers and how much power supplies department of the project.	69.84	Moderate
22	The skills of managing and tracking of materials.	69.84	
23	Change orders or variations from the owner or designer.	69.73	
24	Use of planning and scheduling tools.	69.51	
25	Misunderstanding among labours.	69.51	
26	Providing transport means, and how far is work location from home and population centres.	69.40	
27	Workspace availability, and site layout and working conditions (e.g., high places, shape, etc.).	69.07	
28	Commitment to succession of periodic meeting between management and site persons.	69.07	
29	The availability of the use of information technology and its efficiency.	69.07	
30	The regularity of construction specifications and standardisation issuance.	68.85	
31	Appropriate labour/employment age of the required work.	68.74	
32	Safely working conditions.	67.87	
33	Employee motivation by promoting cooperation and integrity between them.	67.76	
35	Effect of approaching the end of the project on project staff productivity (as a secured job).	67.54	
35	Availability of appropriate stores for materials.	67.32	
36	Rewards and incentive for good performance	66.67	
37	The effect of crew size on the performance of the individual worker.	66.34	
38	Compliance with safety precautions.	65.79	Low
39	Equal pay for projects in different geographic areas.	65.57	
40	Design or work complexity.	64.92	
41	Changing crew members and reallocation.	64.81	
42	The availability of competitive atmosphere and listing for suggestions or ideas.	64.81	
43	Increase number of labours in order to accelerate work.	64.15	
44	Weather/climate condition (temperature/humidity /rains/wind).	62.62	
45	The efficiency of using shift work system.	61.42	Very low
46	Effect of project size on productivity.	60.33	
47	Increasing overtime hours in order to increase productivity.	60.22	
48	Adequate training on health and safety precautions.	59.89	
49	Provide training courses for project staff.	58.91	

The factors are ranked after calculating RII and levelled according to previously calculated values in Table 6, factors ranking is presented in Table 6. Also, the factors in each group to be ranked according to RII calculations to reflect the significant factors

which affect the productivity of each group, the first significant factors for each group from the seven groups are presented in Table 7.

**Table 7** Significant factors for each group

<i>No</i>	<i>Group</i>	<i>Factor</i>
1	Motivation	Paying employees' salaries on time
2	Time management	Use of planning and scheduling tools
3	Project	Disturbance of services (water, power)/shortage of temporary facilities
4	Human	Skill and experience of project staff
5	Supervision	Staff supervision experience (consultant side)
6	Safety and health	Safely working conditions
7	Materials and equipment management	Availability of equipment on time

## 5 Statistical analysis

Data analysis used in this research includes: Pearson correlation coefficient to examine the relationship among the productivity factors, chi-square test to configure the relationship between the independent variables (project location, project size, and experiences), T-test is used to study the effect of one independent factor with not more than two parameters on dependent variables, ANOVA it is used to study the effect of one independent factor with more than two parameters or more on dependent variables.

### 5.1 Pearson correlation

The first 20 factors in Table 6 which have very high or high importance degree are taken to calculate Pearson correlation coefficient values to configure the correlation between these factors each other, these correlations are important to determine which factors have a significant relations to other factors in the effect on productivity, after calculating Pearson correlation coefficient, the most strong factor, which is connected to all other twenty factors with strong or very strong correlation is (the quality of site management skills), where management skills are the main key of productivity.

### 5.2 Chi-square test

The result of conducting the chi-square test between the independent variables (project location, project size, and experiences), is that the only statically significance relation is between project location and project size, as presented in Table 8.

**Table 8** Chi-square test results

<i>Couple independent ordinal variables</i>		<i>Pearson chi-square sig. value</i>
Project location	Project size	0.017 < 0.05
Experiences	Project size	0.130 > 0.05
Experiences	Project location	0.130 > 0.05

### 5.3 T-test

Is used to study the effect of one independent factor (project location) on dependent variables (20 significant factors), T-test results for all factors show that just one factors have a difference for the effect on productivity this factor is (paying salaries on time) in building construction sites between both countries (Egypt, Saudi Arabia), other factors have no difference for the effect on productivity in building construction sites between both countries (Egypt, Saudi Arabia).

### 5.4 Analysis of variance

Is conducted to study the effect of one independent variable(project size) on dependent variables (20 significant factors), the result of conducting ANOVA test reflects that: for all factors are  $\alpha = 0.05$ , which mean there are no statistically significant differences between means of these factors effect according to independent factor (project size), it means there is no difference between the effect of factors on productivity regarding to project size, another ANOVA test conducted for independent variable (respondents experiences) on dependent variables (20 significant factors), the result of ANOV test reflects that: for all factors are  $\alpha = 0.05$ , which mean there is no statistically significant difference between means of these factors' effect according to independent factor (respondents experiences).

## 6 Comparison between results in both countries (Egypt and Saudi Arabia)

One of the research aims is to present a good understanding of the factors affecting projects productivity and progress in both countries Egypt and Saudi Arabia. This will help in making right investment decisions and a better understanding of other side building construction sites nature.

To accomplish with this aim RII value to be calculated for each country respondents separately, after calculating RII values the factors to be ranked for every country separately to configure the most significant factors which affect productivity in each county. Tables 9 and 10 are presenting the top ranking factors with very high importance degree in each country.

**Table 9** Significant factors affect productivity in Egypt

<i>Rank</i>	<i>Factor</i>	<i>RII</i>	<i>Importance</i>
1	Paying employees' salaries on time	79.67	Very high
2	Disturbance of services (water, power)/shortage of temporary facilities	78.67	
3	Availability of equipment on time	76.67	
4	Skill and experience of project staff	75.33	
5	Commitment of inspection dates	75.00	
6	Availability of materials on time	75.00	

**Table 10** Significant factors affect productivity in Saudi Arabia

<i>Rank</i>	<i>Factor</i>	<i>RII</i>	<i>Importance</i>
1	Availability of design or shop drawings.	77.72	Very high
2	Compliance with the attendance of the project staff.	77.72	
3	The skills of managing and tracking tools and its quality.	77.40	
4	Availability of equipment on time.	76.91	
5	Skill and experience of project staff.	76.75	
6	Availability of materials on time.	76.75	
7	Disturbance of services (water, power)/shortage of temporary facilities.	76.59	
8	Considering the quality of materials and raw materials.	74.47	
9	Efficiency and leadership skills of staff supervising the execution (contractor side).	74.31	
10	Staff supervision experience (consultant side).	74.15	
11	Availability of equipment's management skills.	74.15	
12	The accuracy and completeness of drawings.	73.66	

**Table 11** Top ten factors affect productivity in building construction sites

<i>Rank</i>	<i>Factor</i>	<i>RII</i>
1	Disturbance of services (water, power)/shortage of temporary facilities.	77.27
2	Availability of equipment on time.	76.83
3	Availability of design or shop drawings.	76.72
4	Compliance with the attendance of the project staff.	76.72
5	The skills of managing and tracking tools and its quality.	76.50
6	Skill and experience of project staff.	76.28
7	Availability of materials on time.	76.17
8	Staff supervision experience (consultant side).	74.21
9	Commitment of inspection dates.	73.77
10	Considering the quality of materials and raw materials.	73.77

From RII values for each country factors, there are three factors have the greatest difference between their RII values, these factors are: factor no. 38 (weather/climate condition), the difference is 10.85, the higher RII is for K.S.A projects, which reflects the high effect of weather/climate condition on productivity in K.S.A projects more than projects in Egypt, according to respondents' opinions. This is the logic as per the hot weather in summer in K.S.A which leads to reducing working hours and also stops working from 12.00 PM to 3.00 PM as per government instructions.

- Factor no. 4 (paying salaries on time), the difference is 9.34, the higher RII is for Egypt projects, which reflects how important to pay salaries on time in Egypt projects more than projects in K.S.A, according to respondents' opinions. This result are logic because of high salaries in K.S.A and good economic situation, conversely in Egypt people cares more about paying salaries on time because of low salary amounts and weak economic situation with high prices for staffs.

- Factor no. 21 (design or work complexity), the difference is 8.05, the higher RII is for Egypt projects, which reflects the high effect of design or work complexity on productivity in Egypt projects more than projects in K.S.A, it can be attributed the nature of contracting in mega projects for executing engineering, procurement, construction (EPC) is to implemented through one main contractor who will be responsible for coordinating different rates either by involving many subcontractors, in the other hand in Egypt it is remarked for such projects to be implemented through separate contracting which requires more focus on overlapping and coordinate of different rates, thus the productivity may be affected.

The top ten factors which affect productivity in building construction sites according to their importance index value are presented in Table 11.

## **7 Suggested improvement for the productivity in building construction sites**

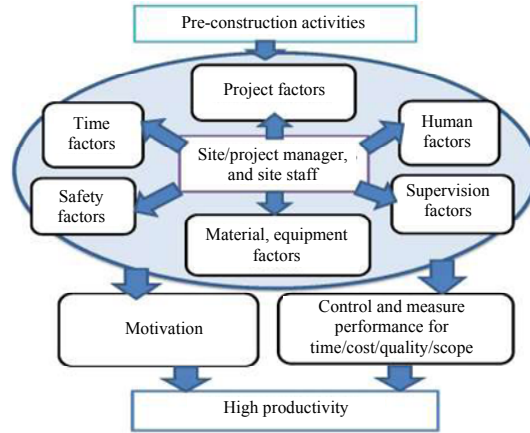
Improving construction productivity depends on many processes, from preconstruction activities and passing through the next phases of construction, according to this concept and the determined factors in this study and finally the inclusion of professional's opinions to improve productivity in distributed questionnaire, a process model for improving productivity factors is presented to simplify the way to control factors through project life cycle, as presented in Figure 2. In conjunction with experts opinion which collected as a part of the designed questionnaire, many suggestions are presented to improve the productivity in building construction sites distributed to the study main groups:

- Motivating group suggestions:
  - 1 Employee motivation by promote cooperation and integrity between them.
  - 2 Rewards and incentive for good performance.
  - 3 Paying employees' salaries on time, and to find controls and deterrent penalties for delaying in payments.
  - 4 Identify scale for salaries to prevent injustice.
  - 5 Provide transportation means from home to work.
  - 6 Provide employees with feeling of job security.
- Time management group suggestions:
  - 7 Proper and efficient use of planning and scheduling tools.
  - 8 Adequate and appropriate analysing of the returned value from increasing working hours or increasing number of workers to accelerate work.
  - 9 Better forecasting from historical data, enabling estimates to be based on prior projects and tasks, and defining major milestones.
- Human group suggestions:
  - 10 Continue developing and training labours and employees
  - 11 Build self-confidence and raise workers culture.

- 12 Adequate crew's individual numbers.
  - 13 Listening to all members' suggestions and ideas and creating an ethical spirit of competition between them.
  - 14 Justice and equality in wages.
- Project group suggestions:
    - 15 Attention to shortage of temporary facilities (water, power).
    - 16 Keep following design and shop drawings issuance.
    - 17 Coordination between the various parties of the project.
    - 18 Review of accuracy and completeness of drawings.
    - 19 Improving site management skills.
    - 20 Compliance of payments to suppliers.
    - 21 Reducing the amount of change orders.
    - 22 Provide adequate work space, watching site layout condition, and working conditions.
    - 23 Conduct periodic meeting among management and site persons.
    - 24 Raise efficiency of using information technology.
    - 25 Regularity of construction specifications and standardisation issuance.
    - 26 Attention to project risk management includes the processes of conducting risk management planning, identification, analysis, response planning, and controlling.
  - Supervision group suggestions:
    - 27 Increase the technical skills and leadership skills of all staffs which supervising the project work from all sides.
    - 28 Reduce reworks as much as possible and keep recording the main causes of reworks as lesson learned for the current project and for future projects.
    - 29 Provide adequate instructions and clear task assignment to avoid misunderstanding.
  - Safety group suggestions:
    - 30 Consider safely working conditions.
    - 31 Keep all project persons to accomplish with safety precautions.
    - 32 Keep watching to weather forecasts.
    - 33 Provide adequate training on health and safety precautions.
  - Material and equipment group suggestions:
    - 34 Keep the availability of equipment, tools and materials as required just in time at appropriate storage places.
    - 35 Attention to the quality of materials, tools and raw materials, and keep tracking of them.
    - 36 Skilfulness in equipment management and maintenance.



**Figure 2** Process model for improving productivity factors (see online version for colours)



### 7.1 Template form for measuring productivity loss on site

Regarding to the results which obtained from the study, factors which affect productivity in building construction sites are being ranked according to RII values, 20 significant factors are the most important factors among all factors, these factors were evaluated periodically on site, the factors were weighted relative to its RII value, the total percentage 100% is distributed according to every factor weight, Table 12 presents the weight for the 20 significant factors, and Table 13 is presenting an example for productivity loss measurement . In Table 13, an example sheet is introduced for construction managers in sites to estimate the productivity loss according to their relative importance.

**Table 12** Twenty factors weights according to RII value

No	Factor	RII	Weight
1	Disruption of services (water, power)/shortage of temporary facilities.	77.27	5.21
2	Availability of equipment.	76.83	5.18
3	Availability of design or shop drawings.	76.72	5.17
4	Compliance with the attendees of the project staff.	76.72	5.17
5	Availability of tools.	76.50	5.16
6	Skill and experience of project staff.	76.28	5.14
7	Availability of materials.	76.17	5.14
8	Staff supervision experience (consultant side).	74.21	5.00
9	Commitment of inspections dates.	73.77	4.97
10	Attention to the quality of materials, tools and raw materials.	73.77	4.97
11	The ability to coordinate between the various parties to the project (client, contractor, consultant, execution crews).	73.44	4.95
12	Paying employees' salaries on time.	73.33	4.94
13	Efficiency and leadership skills of staff supervising the execution (contractor side).	73.22	4.94

**Table 12** Twenty factors weights according to RII value (continued)

<i>No</i>	<i>Factor</i>	<i>RII</i>	<i>Weight</i>
14	The accuracy and completeness of drawings.	73.11	4.93
15	Skilfulness in equipment management.	73.01	4.92
16	Availability of communication channels between project parties.	72.35	4.88
17	Rework (the effect the amount of work needs to be reworked on project progress).	72.02	4.86
18	Adequate instruction and clear task assignment.	71.80	4.84
19	Quality of site management skills.	71.48	4.82
20	Efficiency of equipment maintenance and/or repair.	71.15	4.80
<i>Total</i>			<i>100%</i>

**Table 13** Productivity total loss calculation example

Project name:  
Productivity total loss monthly report

June 2017

<i>No</i>	<i>Factor</i>	<i>Factor weight %</i>	<i>Losses percentage %</i>	<i>Losses weight %</i>
1	Disruption of services (water, power)/shortage of temporary facilities.	5.21	10.00	0.52
2	Availability of equipment.	5.18	15.00	0.78
3	Availability of design or shop drawings.	5.17	26.60	1.38
4	Compliance with the attendees of the project staff.	5.17	8.00	0.41
5	Availability of tools.	5.16	5.00	0.26
6	Skill and experience of project staff	5.14	0.00	0.00
7	Availability of materials.	5.14	15.00	0.77
8	Staff supervision experience (consultant side).	5.00	20.00	1.00
9	Commitment of inspections dates.	4.97	10.00	0.50
10	Attention to the quality of materials, tools and raw materials.	4.97	0.00	0.00
11	The ability to coordinate between the various parties to the project (client, contractor, consultant, execution crews).	4.95	25.00	1.24
12	Paying employees' salaries on time		4.94	33.33
13	Efficiency and leadership skills of staff supervising the execution (contractor side).		4.94	3.00
14	The accuracy and completeness of drawings.		4.93	5.00
15	Skilfulness in equipment management.		4.92	50.00
16	The ability to coordinate between the various parties to the project (client, contractor, consultant, execution crews).	4.88	10.00	0.49
17	Paying employees' salaries on time.		4.86	15.00
18	Efficiency and leadership skills of staff supervising the execution (contractor side).	4.84	5.00	0.24
19	The accuracy and completeness of drawings.	4.82	2.00	0.10
20	Equipment management.	4.80	30.00	1.44
<i>Productivity total loss</i>				<i>14.35%</i>

## **8 Conclusions**

This study investigates all possible factors through a structured questionnaire in Egypt and Saudi Arabia projects. The survey results were analysed, and the ranking of factors was calculated using the RII. The main purpose is to study various factors affecting labour productivity on construction in both countries to help decision makers in construction industry. Forty nine factors were categorised in seven different groups; motivation, time management, project, human, supervision, safety and health, materials and equipment management. Total of 286 questionnaires were distributed in building construction sites in Egypt and Saudi Arabia due to the availability of different project sizes, budgets and nature, moreover to the availability of conducting direct interviews. 183 questionnaires (64% response rate) were completed and accomplished with the study scope. The valid responses used for this study were 60 (32.80 %) responses from Egypt projects and 123(67.20 %) response from Saudi Arabia projects. After collecting responses and conducting statistical analysis it is concluded that; the factors which have the highest importance rank are different in Egypt and Saudi Arabia projects. As presented in the study, the first importance level ranked factor in Egypt is paying employees' salaries on time, and the first ranked factor in Saudi Arabia is the availability of design or shop drawings. After conducting correlation analysis between all factors, it is concluded that the factor which have the highest effect is the quality of site management skills, where the management skills are the main key of productivity improvement success. Another aim has been achieved in this study is introducing and understanding productivity improvement various suggestions, in conjunction with professional's opinions to improve productivity, these professional's opinions are collected as a part of the distributed questionnaire. There are many different ways to improve productivity in building construction sites, these methods are presented in the study as a suggested improvement for the productivity. A simple tool is introduced in this study; (productivity total loss) template. This template is designed to guide site managers to quantify the loss of productivity in a given period of time, which helps to follow the causes of productivity losses along the project life cycle.

Construction tasks are expensive and frequently associates with cost overrun and delays in activities, which generally affects progress of construction projects. The environment of construction organisations should be suitable to implement projects with successful completion. In the construction industry, it is necessary to find out obstacles in order to solve and overcome them.

## **9 Recommendations for productivity improvement**

The recommendations for improving productivity in buildings construction industry are:

- A financial incentive in the form of best employee of the year or month should be implemented to create competition among the employees, this achieving better productivity.
- Listen to all members' suggestions and ideas and create an ethical spirit of competition between work crews, which affect directly and improve productivity.

- Absence at work site can be reduced with inclusion of appropriate paid time off and vacations to all employees.
- To achieve desired results, the time required for implementing change orders and to make corrections in drawings and specifications should be estimated and scheduled without affecting the project-time completion, complex design and incomplete drawings should be avoided, regular meetings should be arranged with all project parties.
- Proper and efficient use of planning and scheduling tools and defining major milestones is one of the key successes in construction projects.
- To avoid failure in project management, attention to shortage of temporary facilities (water, power), keep following design and shop drawings issuance, continuous coordination between various parties of the project, continuous improving of site management skills, raise efficiency of using of information technology and attention to project risk management.
- Increase the technical skills and leadership of all staffs which supervising work, reduce reworks, and provide clear task assignments.
- Provide safely working condition, and provide adequate training on health and safety precautions.
- Purchased material and tools should be stored at proper location and should be easily accessed and close to constructed buildings to avoid wasting time for multiple-handling materials, and attention to the skilfulness in material and equipment management and maintenance.

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