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PRODUCTIVITY PERFORMANCE ESTIMATION IN EGYPTIAN CONSTRUCTION PROJECTS BASED ON REGRESSION ANALYSIS

قياس أداء الإنتاجية فى مشروعات التشييد المصرية باستخدام تحليل الإنحدار

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الملخص العربى

يمكن التعبير عن الإنتاجية بدلاله انتاجيه العمال او العائد على راس المال المستثمر . فى العقد السابق تم ملاحظة انخفاض أداء الإنتاجية فى صناعة التشييد و الذي يعد واحد من اسباب زيادة التكلفة و الزمن فى مشروعات التشييد. لذا فان هذا البحث يهدف الى اقتراح نموذج يعتمد على تحليل الإنحدار من اجل التنبؤ بنسبة النقص او الزيادة فى أداء انتاجية التشييد، حيث تم تجميع ٣٧عامل من العوامل المؤثرة على انتاجية التشييد و ذلك من الدراسات السابقة. وتم اجراء استبيان تم توزيعة على مقاولى مشروعات التشييد (المبانى المكنية واعمال الهندسة المدنية) المصرية و ذلك من اجل تحديد درجة تاثير تلك العوامل على انتاجية التشييد. وقد تم معرفة اكثر تلك العوامل تاثير و هم ١٤ عامل و تمثل تلك العوامل المتغيرات المستقلة فى النمودج المقترح. ايضا تم تبنى ٦ مجالات للإنتاجية و قد اشتمل الإستبيان على تقييم تلك المجالات بقياس كل من درجة رضاء المشاركين فى الإستبيان عن تلك المجالات بصفة عامة و كذا الوزن النسبى لدرجة أهمية كل مجال من وجهه نظر المشاركين. تم حساب مجموع حاصل ضرب متوسط تلك الدرجات و الوزن النسبى لدرجة الأهمية المناظر و هى تمثل المقام لموشر قياس الإنتاجية المقترح .البسط لهدا المؤشر هو مجموع حاصل ضرب درجة رضاء المشارك بالنسبة لمشروع معين تحت الإعتبار نتيجة الظروف الفعلية لهذا المشروع و الوزن النسبى لدرجة الأهمية السابق. هذا المؤشر يمثل المتغير التابع في النموذج المقترح. ايضا تم تجميع معلومات تخص العوامل المؤثرة على انتاجية التشييد لعدد ٢٥ مشروع سابق. تم تقسيم المشروعات الى جزئين،الجزء الأول يشمل ١٥ مشروع لبناء النموذج و قد اظهرت النتائج وجود علاقة قوية بين مؤشر قياس الإنتاجية و ١٣ عامل من ١٤ عامل المؤثرة على انتاجية التشييد . كما تم عمل اختبار للنموذج المقترح باستخدام الجزء الثانى من المشروعات(١٠) و قد اظهرت النتائج مقدرة النموذج المقترح على التنبؤ بأداء إنتاجية التشييد بدرجة مرضية.

ABSTRACT

Productivity is sometimes expressed in terms of output from labour or from services or from capital invested. Productivity performance in the construction industry has declined in the last decade. Poor performance of construction productivity is one of the causes of cost and time overruns in construction projects. This research aims to develop a regression model that predicts the percentage loss or increase of construction productivity performance. 37 factors that affect construction productivity gathered from literature. The degree of significance of these factors was obtained based on a questionnaire survey made on construction contractors of building and civil engineering projects in Egypt. 14 factors were obtained as the most significant factors that affect construction productivity and these are the independent variables of the proposed model. 6 areas of productivity were adopted. Both degree of satisfaction for each area from participants' point of view and the corresponding weights were developed from the survey. Multiplication the average of satisfaction level of these areas and corresponding average of weights produce the denominator of a proposed productivity performance index (PPI). The numerator of PPI is the multiplication of degree of satisfaction of these areas for a specific project and the previous average weights. PPI is the dependent variable in the model. Data for 25 projects was collected and divided into two sets. The first set contains 15 projects for the purpose of model building. The results revealed that there is a strong linear relationship between PPI and 13 factors from 14 factors that significantly affect construction productivity. Based on model validation made using the other 10 projects, it can be concluded that the proposed model predicts construction productivity performance with satisfied results.

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Keywords: Productivity Performance; Regression Analysis; Questionnaire Survey; Construction Project

1. INTRODUCTION

One of the most important tasks confronting planners in the construction industry is the performance estimation of operations prior to commencement of construction. Productivity has been used as one criterion for explaining operational performance.

Productivity is defined by the business Roundtable [1] as a ratio between output and input. A more general definition is offered by the ASCE committee on productivity, "delivery of a quality construction product that achieves total cost effectiveness through the optimise use of resources" (Kohn and caplan) [2]. Productivity is an overall conception, which is difficult to express or to measure. It is sometimes expressed in terms of output from labour, or from services, or from capital invested. These partial expressions often do not give an accurate picture of all the overall position. Although they are measurements of some or all of the inputs and outputs of the industry; but they failed to combine these measurements into any satisfactory measure of efficiency (Choy)[3]. Strandell [4] defined productivity as "factor" or "total" productivity in which the former is the ratio of output to one type of input (labour, for example), and the latter is the ratio of output to all input factors (labour, capital, land and other investment). The definition of productivity as total productivity will be adopted in this research.

Strandell [5] gave that construction professionals and owners agree that productivity in construction industry is a problem that needs to be studied seriously because of its significance effect on the cost and duration of construction projects. Hope and Hope [6] gave that productivity is the engine of economic both for a country and for an individual organization.

Makulsawatudom and Emsley [7] described that although some research has been carried out on factors influencing productivity, there still a lot to be done even in developed countries for improving construction productivity. Identifying and evaluating these factors are critical issues faced by construction managers (Motwani et al.)[8].

Various factors have been identified by different researchers in different construction industries. Makulsawatudom and Emsley [7], reported that the most significant factors affecting construction productivity in Thailand are: lack of materials, incomplete drawings, incompetent supervisors, lack of tools and equipment, absenteeism, poor communication, instruction time, poor site layout, inspection delay, and rework. Kaming et al. [9] found out that lack of materials, rework, worker interference, absenteeism, and lack of equipment were the most significant problems affecting workers in Indonesia. Olomolaiye et al. [10] declared that the most significant factors in Nigeria are: lack of materials, rework, lack of equipment, supervision delays, absenteeism, and interference. Zakeri et al. [11] gave that lack of materials, weather and physical site conditions, lack of proper tools and equipment, design, drawing and change orders, inspection delays, absenteeism, safety, improper plan of work, repeating work, changing crew size, and labour turnover are the most critical factors. Lema [12] found that the major factors that influence productivity in Tanzania are leadership, level of skills, wages, level of mechanisation and monetary incentives. Lim and Alum [13] through a survey of contractors in Singapore found that the major problems with labour productivity are recruitment of supervisors, recruitment of workers, high rate of labour turnover, absenteeism at the work place, communication with foreign workers and inclement weather. Motawani et al. [8] through a survey in USA found out that there are five major problems that affect productivity. These are adverse site conditions, poor sequencing of works, drawing conflict/lack of information, searching for tools& materials, and poor weather.

However, Charamokos & Mc Kec [14] reported that there are two main groups of areas, which have potential for productivity improvement, these are: head office and site. The factors related to head office are planning, procurement, scheduling, estimating, Specification. Site related areas include: labour relations, cost control, supervision, material delivery, material storage, material availability, labour training, labour availability, recruitment, financial motivation, equipment capacity, equipment maintainability, equipment utilization, pre-cast elements, pre-assemble modulars.

In this paper, a multiple regression model for predicting productivity performance for construction projects in Egypt is developed. The independent variables are a number of qualitative variables that affect construction productivity gathered from literature. These variables are candidate according to their significance through a questionnaire survey. The paper is organized as follows: first, research methods are highlighted. Factors affecting construction productivity based on literature are identified. A questionnaire survey is then prepared and validated through pilot studies. The survey response is then analysed and discussed. A statistical predictive model is then established. Finally, the model is validated.

3. RESEARCH METHOD

Research in construction is usually carried out through experiments, case studies or surveys (Fellow and liu)[15]. Experiments on factors that affect construction productivity would take a long time to yield results and they are difficult to control and would therefore be expensive. Case studies would not provide results that are easy to generalize as different companies face different problems. Surveys through questionnaires were found appropriate because of the relative ease of obtaining standard data appropriate for achieving the objective of this study. Surveys are an effective means to gain a lot of data on attitudes, on issues and causal relationships and they are inexpensive to administer (Alinaitwe et al.[16].Accordingly, survey through questionnaires will be adopted as a research method to collect data about the significance of factors affect construction productivity.

2. QUESTIONNAIRE SURVEY

Based on factors affecting the productivity and presented in [7 -14], 36 factors were primarily identified as shown in Table 1 (the first 36 factors). These factors will serve as the independent variables in the predictive model of productivity performance.

A questionnaire was developed to collect data about the significance of the factors compiled in Table 1. The participants were asked to assign a number from 1 to 5 to each factor to represent its significance. The participants were asked to describe their degree of satisfaction for productivity areas in general obtained from Abu-Asbah [17] shown in Table 2, by marking the appropriate choice from their point of view. Five degrees were presented, these are: extremely dissatisfied, dissatisfied, no dissatisfied no satisfied, satisfied, and extremely satisfied. Also, they were asked to identify a weight for each productivity area according to its importance from the participants' point of view. Multiplication the average of satisfaction level and average of weights of these areas produce the denominator of productivity performance index (PPI). The numerator of PPI is the multiplication of degree of satisfaction of productivity areas for a specific project according to actual behaviour and the previous average weights. PPI is used as the dependent variable in the predictive model of construction productivity performance.

As an example for calculating PPI, assume that the importance indices (calculated from questionnaire) for construction workers, equipment, methods, site management, office management, and firm's overall productivity are: 3.25, 3.5, 3.75, 4, 3.5, 3.25 and the corresponding weights are: 0.15, 0.18, 0.2, 0.17, 0.16, 0.14, respectively. Then, denominator of PPI =3.25*0.15+3.5*0.18+3.75*0.2+4*0.17+ 3.5*0.16+3.25*0.14 = 3.563. Also, assume that the degree of satisfaction of productivity areas for a specific project are: 4, 2, 3, 4, 3 and 4 for the previous areas, respectively. Then, numerator of PPI= 4*0.15+2*0.18+3*0.2+4*0.17+3* 0.16 +4 *0.14 =3.28. Accordingly, PPI=0.921 (3.28/3.563). Also, the questionnaire included collection of data for past construction projects in a structured format. The data included occurrence of previous factors shown in Table 1 on a yes / no basis.

4. PILOT STUDIES

Pilot studies were carried out to ensure the clarity and relevance of the questionnaire to contractors, also to validate and improve it. The questionnaire was shown to two researchers in the same field. One of them advocated the addition of funds availability from the clients as one of the most important factors that affect productivity performance. This factor (number 37) was added to previous factors in Table 1.

5. TO WHOM THE QUESTIONNAIRES WERE DIRECTED

The survey gathered data from contracting companies specialized in building and civil projects. Thirty-five contracting companies participated in the survey. Some of the questionnaires were sent via mail after contacting the participants through telephones, whereas, the other part was sent by some persons. Most of the participants were at the level of general manager or project manager.

6. SURVEY RESPONSE

As a result of mailing and follow up a total of twenty-five usable questionnaires were completed and returned. All the questionnaires were combined for the analysis. The respondents included general managers, technical office managers, and construction managers. 84% of the contractors are involved in administrative & commercial buildings and residential buildings whereas, 60% are involved in civil engineering projects. The author believes that the variations in positions besides the variations in the specialization for the participants will enrich this field study to a great extent. To give additional credibility for the findings of this survey, the participants (companies and respondents) were asked about their length of experience. 88% of the companies have an experience more than 10 years, whereas 72% have an experience equal to or greater than 25 years. 52% of respondents have an experience more than 10 years, experience whereas, 32 % have an experience more than 20 years. 76% of companies have an annual volume of work more than LE 50 millions, whereas 52% have an annual volume of work LE 250 millions. The author believes that obtaining the needed information from such active contractors is one of the strengths of this survey. An importance index (II) was established to assess the degree of significance for each factor, which affect the productivity performance as given in Eq. 1. Table 3 shows the factors rearranged in descending order according to their corresponding II.

Table 1: Factors affecting construction productivity performance

Factor No.	Factor Identification	Factor No.	Factor Identification
1	Materials availability	20	Absenteeism
2	Equipment Availability	21	Rework
3	Labor Availability	22	Change orders
4	Procurement of resources	23	Labor interference
5	Equipment Capacity	24	Training
6	Level of Skill	25	Changing crew size
7	Cost Control	26	Shop drawings
8	Planning Site	27	Labor relations
9	Specification Clearance	28	Labor turnover
10	Cost Estimating Accuracy	29	Recruitment
11	Materials Storage	30	Productivity improv. Programs
12	Motivation and financial incentives	31	Weather conditions
13	Materials Delivery	32	Safety means
14	Equipment Maintainability	34	Pre-cast elements
15	Planning	35	Pre-assemble modulars
16	Satisfied wages	36	Methods for measuring Produc.
17	Late inspection	37	Funding Availability
18	Scheduling		
19	Poor sequencing of work		

Table 2: Productivity areas

Productivity Area
Construction Workers Productivity
Method Productivity
Equipment Productivity
Site Management Productivity
Office Management Productivity
Overall Productivity of the firm

$$\text{Importance Index (II)} = \frac{\text{Rank} * \text{corresponding no. of respondents}}{\text{Total no. of respodents}} \qquad (1)$$

Materials availability comes out as the most important factor that affect productivity, it was received the highest II (4.6). This factor consumes a lot of contractors' time. Also, the main cost incurred due to shortages is for the idle time that labors have to wait for materials. Equipment availability received the second II (4.44), since some equipment is not readily available in some places even for hiring. Both labor availability and procurement of resources received an II of (4.36). Scarce of labor affect time, also, procurement of resources in a timely manner is important for the success of a project. Equipment capacity received an II of (4.2). The selection of the appropriate type and size of construction equipment often affects the required amount of time and effort and thus the job-site productivity of a project. Both level of skill and funding availability received an II of (4.16). Level of skills seriously affects the time to accomplish tasks, the cost of labor and the quality of products achieved. Some of the respondents gave that funding availability from clients affect their cash flow and in turn affect all the project aspects: labor, materials, equipment, which affect the time, cost and quality of products achieved. Both cost control and poor site layout received the same II (4.08). Cost deviation during execution of construction projects is usually occur, thus, cost control is a mandatory requirement. Poor site layout interrupts work-flow, for example material search difficulties, equipment transportation difficulties or access problem. Specification clearance, estimating accuracy, materials storage received the same II (4.04). Good materials storage decrease the wastage and keeps cost of materials within the planned budget. Some of the respondents advocated that specification should be clear and explained to the executing team to avoid rework and to make the job easier. They added that bidding in large projects with many items and variables make estimating more difficult and more important to productivity. Thus, the more accurate the estimate, the better the chance of having satisfactory productivity. Motivation and financial incentives, and materials delivery received the same II (3.96).

It is clear that motivation and financial incentives increase the enthusiastic of labor to be more productive. The respondents declared that delivery of materials to the job site in a timely manner is essential to keep things going and maintain high productive level.

Factors received II less than 4 will not be considered in the predictive model to reduce the number of variables to a manageable number except financial motivation and materials delivery received an II (3.96), which is close to 4. Table 4 lists the final 14 factors (independent variables) used to develop the predictive model.

7. STATISTICAL PREDICTIVE MODEL

Data for 25 projects was collected and divided into two sets. The first set contains 15 projects for the purpose of model building. The second set contains 10 projects for validation purposes. Initial experimentation with a regression model that includes all 14 variables resulted in a model with less performance using SPSS 8 software. Forward-stepping and backward-stepping were used. Forward stepping begins with entering the most significant variable at the first step, and continues adding and deleting variables until none can significantly improve the fit. Backward stepping, on the other hand begins with all candidate variables, then removes the least significant variable at the first step and continues until no insignificant variable remains. The results are shown in Table 5.

Based on the results in Table 5, the backward-stepping technique was more accurate in predicting the productivity performance for construction projects with a higher adjusted squared multiple R=1 indicating that the model is able to explain 100 % of the variability in the data, which is an excellent indicator of the model's expected performance. The variable of cost control was excluded. The underlying formula of model B is PPI= 0.578 -0.254 (materials availability)-0.124(equipment availability) +0.0586(labor availability)+0.0963 (procurement of resources)+0.332(equipment capacity)+0.168(level of skill)- 0.196 (funding availability)+0.157(planning site)-0.0681(specification clearance)+0.0277(cost estimating accuracy)+0.0812 (materials storage)+ 0.163 (financial motivation)+0.0588 (materials delivery) where each of the 13 variables can have a 0 (unused) or 1 (used) value.

8. MODEL VALIDATION

The other 10 projects excluded during model development were used for validation purposes.

The model was used to produce 10 predicted values for the PPI of the 10 projects. As an example, the model used in predicting PPI for project 4 (Table 6) with the following characteristics: the materials are not available (0); the equipments were available (1); the labors were available (1); the resources were not procured in a timely manner (0); equipments capacity were satisfactory (1); level of skill is not satisfactory (0); funds were available (1); the site is good planned (1); specifications were not clear (0); Cost was not estimated accurately (0); materials were good stored (1); there were no financial motivations (0); materials were delivered in a timely manner (1).The predicted PPI will be obtained as follows:

Table 3: Factors affecting construction productivity performance and their II

Factor	Imp. Index (II)	Factor	Imp. Index (II)
Materials availability	4.60	Scheduling	3.84
Equipment Availability	4.44	Poor sequencing of work	3.80
Labor Availability	4.36	Absenteeism	3.72
Procurement of resources	4.36	Rework	3.68
Equipment Capacity	4.20	Change orders	3.68
Level of Skill	4.16	Labor interference	3.64
Funding Availability	4.16	Training	3.56
Cost Control	4.08	Changing crew size	3.44
Planning Site	4.08	Shop drawings	3.30
Specification Clearance	4.04	Labor relations	3.28
Cost Estimating Accuracy	4.04	Labor turnover	3.24
Materials Storage	4.04	Recruitment	3.20
Motivation and Financial incentives	3.96	Productivity improv. Programs	2.80
Materials Delivery	3.96	Weather conditions	2.80
Equipment Maintainability	3.92	Safety means	2.80
Planning	3.92	Pre-cast elements	2.76
Satisfied wages	3.92	Pre-assemble modulars	2.68
Late inspection	3.88	Methods for measuring produc.	2.52

Table 4: Candidate independent variables final list

No.	Variable	Importance Index (II)
1	Materials availability	4.60
2	Equipment Availability	4.44
3	Labor Availability	4.36
4	Procurement of resources	4.36
5	Equipment Capacity	4.20
6	Level of Skill	4.16
7	Funding Availability	4.16
8	Cost Control	4.08
9	Planning Site	4.08
10	Specification Clearance	4.04
11	Cost Estimating Accuracy	4.04
12	Materials Storage	4.04
13	Financial motivation	3.96
14	Materials Delivery	3.96

PPI= 0.578 - 0.254 * 0 - 0.124 * 1 + 0.0586 *1 + 0.0963 *0 +0.332*1+ 0.1681* 0- 0.196*1+0.157 * 1 - 0.068 * 0+0.0227*0+0.0812*1+ 0.163*0 +0.0588 * 1=0.946=94.6%

This result means that this project is expected to have a poor performance equal to 5.4%. Thus, 5.4 % is considered an expected value for a percent loss of productivity. Table 6 shows the actual values of PPI (APPI) and the predicted values of PPI (PPPI), the average percentage error is approximately 10%. Afterwards, a correlation was performed between the predicted and the actual PPI for the 10 projects. The resulting correlation coefficient was r =0.65, indicating that the developed model B has satisfied predictive capabilities as shown in Table 6.

9. SUMMARY AND CONCLUSIONS

This paper investigated the effect of qualitative factors affecting productivity of construction projects in Egypt through a questionnaire survey. These factors were established from literature. The questionnaire survey was also used a structured format to obtain information related to the occurrence of the previous factors in actual projects on yes/no basis.

Based on the results of the questionnaires an importance index was established for each factor to quantify its effect on construction productivity performance. It was intended that factors received an importance index equal to or higher than 4 are significant and will be incorporated into the model as independent variables. Accordingly, 14 significant variables were identified. A single quantifiable measure, the productivity performance index (PPI) was developed to measure the productivity performance of the surveyed projects and was considered the dependent variable in model development.

Two models were developed to predict the construction productivity using statistical regression analysis depending on forward-stepping and backward-stepping techniques. Data of 15 projects was used for model development, while the data of remaining 10 projects was used for validation purposes. The model depended on backward- stepping was more accurate in predicting the productivity performance, with 13 variables and an associated higher adjusted squared multiple R. Thus, this model was chosen for construction productivity performance prediction. Validation of this model revealed that the proposed model predict construction productivity performance with satisfied results.

This research is relevant to both industry practitioners and researchers. It provides a systematic approach for practitioners to predict productivity performance for construction projects. In addition, it provides researchers with a methodology to build regression models suitable for productivity performance.

Table 5: Statistical models

Model (A): Forward Stepping [a]		Model (B): Backward Stepping [b]	
Variable	Coefficient	Variable	Coefficient
Constant	0.636	Constant	0.5780
Planning Site	0.295	Materials Availability	-0.2540
Financial motivation	0.209	Equipment Availability	-0.1240
Storing	-0.113	Labor Availability	0.0586
		Procurement of resources	0.0963
		Equipment Capacity	0.3320
		Level of Skill	0.1680
		Funding Availability	-0.1960
		Planning Site	0.1570
		Specification Clearance	-0.0681
		Cost Estimating Accuracy	0.0277
		Materials Storage	0.0812
		Financial motivation	0.1630
		Materials Delivery	0.0588
[a] Adjusted squared multiple R =0.862		[b] Adjusted squared multiple R =1.00	

Table 6: Validation for model B

Project	Actual PPI	Predicted PPI	% Error= | APPI- PPPI| / PPPI *100
1	0.880	0.997	11.74
2	1.140	1.081	5.46
3	1.050	1.170	10.26
4	0.970	0.946	2.54
5	0.760	0.944	19.49
6	1.080	1.310	17.56
7	0.940	0.880	6.82
8	0.860	0.804	6.96
9	1.124	1.079	4.17
10	0.987	1.165	15.28
% Average error			10.03
r	0.65		

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