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BUILDING MODEL TO PREDICT LABOUR PRODUCTIVITY USING MULTIPLE LINEAR REGRESSION TECHNIQUE FOR "FORMWORK CONCRETE COLUMNS"

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ABSTRACT

The productivity rate is the main indicator for the development of construction projects for any developed country. The main goal of this paper is to evolve a mathematical model by using the multiple linear regression technique to predict the rate of production of concrete column molds. This is because the currently used methods in estimating productivity, such as the methods that rely on personal experience and old data, are traditional methods characterized by inaccuracy. So, there was a need to adopt new techniques to estimate the construction productivity in an accurate, fast, and easy way. In this study, eleven factors were identified which are the most affecting factors on construction productivity. They are considered independent variables that affect the productivity rate of the item column formworks. The dependent variable is the construction productivity. The work measurement form was designed for the purpose of collecting real initial data from the site. This model is based on 36 samples of data collected from various projects of Multi-story buildings for residential and commercial buildings, which are used to build the model and verify its performance. From the results of the multiple linear regression MLR results, an equation was derived to calculate the construction productivity of the column formworks. It was found that the multi-linear regression model provides a very good predictability of productivity (82.31%), and the correlation coefficient (R%) was 97.15%. The results showed that the relationship between the independent variables for "the built-in model is very good, and the values"calculated from the prediction model are commensurate with actual data".

KEYWORDS: Multiple Linear Regression Technique; Labor Productivity Rate; Formwork Works.

1. INTRODUCTION

In most countries, "experience and literature" proved "that" "construction labor costs" would account for (30-60) % of the total" project's cost (Gomar et al., 2002). Thus, Production of construction and the need to develop is one of the main challenges facing the construction sector disruption in Iraq. The most realistic measure of the productivity of construction operations is a measure of output during the hour achieved by worked workers in the workplace. Where labor productivity plays "a key" role in the success of" any "project. However, the production of construction may be affected by many factors and variables of unexpected difficulties. These variables may include factors related to labor, materials, tools, equipment, construction methods, political factors, finance, and the environment. "Low productivity of workers is" also one of the" main factors that causes cost overruns and affects time in construction projects. Consequently, this factor should be given a considerable attention by decision-makers and leaders in the construction industry (Mahamid et al., 2013).

2. RSEARCH OBJECTIVE

The aim of this research is to highlight the importance of using modern technologies; the most important technique is the MLR in predicting the labor productivity for the concrete columns molds through:

- Building a model to predict or estimate the labor productivity of molds of concrete columns by using (MLR).
- Comparison the results of linear regression with the results of the technique of artificial networks and determining which one is better in predicting the rate of productivity by using the same data.

3. RESEARCH MOTIVATIONS

The reasons for adopting this study are:

- Due to the absence of previous. studies in calculating the real productivity of the. column Formwork in Iraq, the researcher was interested in calculating the real productivity rate of the Formwork and factors affecting them.
- To define the rate of productivity by incorporating quantitative and qualitative factors in the forecasting equations to accurately estimate the productivity rates.
- Construction projects "in Iraq" need "to use new" effective "techniques" to predict "the performance of construction projects during the" "planning, estimating, scheduling" phases, for example, MLR, ANN, SVM, etc.

4. RESEARCH HYPOTHESES

Hypothesis as: "Multiple. Linear. Regression (MLR) has a strong modeling. technique with optimal mechanism and effective recognition. capabilities to estimate the production rates under any given case".

5. RESEARCH METHODOLOGY

Fig. 1 illustrates the methodology used in this research as follows:

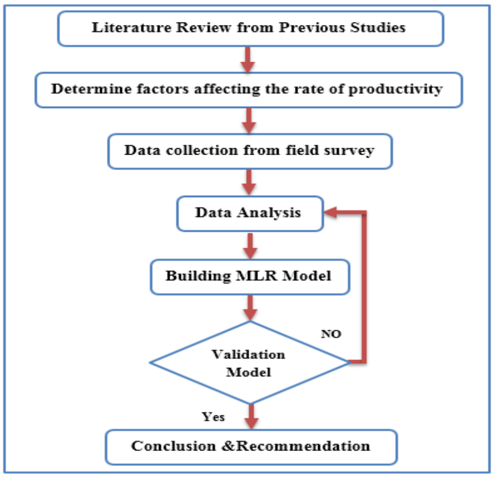

Fig. 1. Methodology of the Research.

6. PREVIOUS STUDIES

Studies and research regarding labor productivity in construction sector in Iraq are considered to be relatively limited and especially in calculation the productivity of finite works. Anyway, it was possible for the researcher to review a number of these researches (Al Taweel and Haddad, 1989; Saeed, 1990; Idan, 1996; Dawood, 2002). The researcher believes that the vast majority of this research was varied in productivity account and conjecture to the fact that guessing a factor depends upon personal experience or from previous projects as the engineer who does not rely on guessing high precision mathematical equation in calculating productivity. With the exception of two attempts by researchers (AL-Zwainy, 2008; Baker, 2011) which was the subject of guessing roads cost and productivity of construction bricks works, respectively. As for the Arab and foreign studies and researches, the researcher has been acquainted with a number of them, especially those that are based on the calculation of the structural productivity of different working paragraphs based on the technology of artificial neural networks, multi linear regression, and support vector machine (Tam, et al., 2002; Moselhi, "et al", 2005; "Ezeldin and Sharara, 2006"; AbouRizk, Song., 2008; Yan and Shi, 2010; Mady, M, 2013; Al-Zwainy, Saga, 2016; Ali Abdullah Eiada, 2016; Khaleel and Nassar., 2017).

7. FACTORS INFLUNCING PRODUCTIVITY RATE

Factors influencing productivity rate was "the subject of" a search "by many researchers. In order to" raise and "improve productivity rate, studying the factors impacting productivity rate whether" they are "positive or negative is very necessary to take advantage of those factors that have a positive impact on the rate of productivity, while reducing or deleting the factors that negatively affect the rate of productivity. "If all the factors affecting productivity can be determined, consequently the rate of productivity can be predicted" (Lema, 1995). Where the researcher did a previous study to study and identify the most important factors influencing rate of productivity in construction projects as (Khaleel and Nassar, 2017). The factors are as follows: "Availability of Materials", "Weather", "Religious occasions", "Number of working groups", "Ganger experience", "Workforce surveillance", "Ganger Age", "Working at high place", "Drawings and specifications alteration during execution", "Sequence of floor", and "Type Formwork used". Table 1 and 2 illustrate the classification of the influencing factors (independent variables) into two types: quantitative and qualitative variables, and each variable is coded. as well as, in this research, the productivity of the column formwork was adopted as a dependent variable.

Table 1. Subjective independent variable "Quality data"

Code	Variables	Units
V1	"Availability of Material"	"Low quantity=1", "Medium quantity=2", "High quantity=3"
V2	"Weather changes"	"Cold =1", "Hot=2", "Moderate=3"
V3	"Religious occasions"	"High occasions=1", "Medium occasion=2", "Low occasion=3"
V6	"Lack of Workforce" "surveillance"	"Low surveillance=1", "Medium "surveillance=2", "High surveillance=3"
V9	"Drawings and specifications alteration during Execution"	"High alteration =1", "Medium alteration =2" "Low alteration=3"
V10	"Floor number"	"Number (1=1st , 2=2st , … ele)"
V11	"Used Formwork type"	"Wood = 1", "Iron =2"

Table 2. Objective independent variable "Quantity data"

Code	Variables	Units
V4	"Number of working groups"	"Number (1=one team, 2=two, team, … ele)"
V5	"Workforce Experiences"	"No. Years"
V7	"Workforce Age"	"No. Years"
V8	"Working at high place"	"Length, (Meter)"

8. DATA COLLECTION FROM FIELD SURVEY

The researcher designed a work measurement form for column formwork, for the purpose of collecting data from construction sites as shown in Annex (1). Where the form included the factors affecting the rate of productivity which are independent variables, while the real productivity represents the dependent variables. Thus, 36 samples of construction sites were collected and analyzed statistically according to the laws of statistical analysis as shown in Annex (2). Table 3 shows the summary of statistical analyses.

Table 3. The descriptive statistics of the data

No. of Sample	Column Formwork												
	Statistical Parameters	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11*	Y*
N=36	Max	3	3	3	2	30	3	45	13.5	3	4	2	**3.45**
	Min	1	1	1	1	9	1	28	0	1	0	1	**1.01**
	Range	2	2	2	1	21	2	17	13.5	2	4	1	**2.44**
	Mean	2.53	2.0	2.22	1.50	18.25	1.89	37.89	6.69	2.22	1.94	1.44	**2.18**
	S.D	0.56	0.7	0.87	0.51	6.99	0.78	5.00	4.49	0.80	1.37	0.50	**0.68**

Y*=Actual Productivity; V1, V2, V11*, ...=Represent Factors affecting on labor productivity

9. MULTI VARIABLES LINEAR REGRESSION "MLR"

The "multi-linear regression of advanced statistical methods that ensure the accuracy heuristics in order to improve search results through the optimal use of data to find causal relationships between the subject in research (Wang, et al., 2010). "MLR" is a "mathematical equation that expresses the relationship" between two variables, and it is used to estimate past values and predict future values. It "is also a regression of the dependent variable (Y)" on "many independent variables" (V1, V2, …. Vp). It can predict the productivity rate in column formwork, for example, depending on the factors affecting the rate of productivity, such as age and experience, Labor, availability of raw materials, and others (David, 2009).

"MLR" is not just one method but a set of methods that can be used to determine the relationship between dependent variable (a response variable) and a number of independent variables that are usually explanatory variables.

The linear equation in multiple linear regression is:

$$Y_i = \beta_0 + \beta_1 v_{i1} + \beta_2 v_{i2} + \beta_3 v_{i3} + \ldots + \beta_p v_{ip} + \varepsilon_i \quad (1)$$

where: " i= 1,2,3…… ,n"

Furthermore, assumes the following:

- "Yi: is the dependent variable"
- "v1, v2, v3 ..., vp". are independent variables.

- "β0, β1, …., βp" are "The coefficients in the linear Relationship".

For a single factor (p = 1), β0 is the intercept, and β1 is the slope of the straight line defined. ε1, ε2, ..., εn are errors that create "scatter around the linear Relationship" at each of the i =1 to n observations.

10. RESULTS "MLR" TECHNIQUE

In this research, the "Statistical Package for Social Sciences" program (SPSS) version (23) was used. It was used in analyzing the data and building a predictive model of the productivity rate. The aim of this program is to find linear regression coefficients of Equation (1). Table 4 illustrated "a summary for" the model, " which contains some very important statistical outcome. The outcome of this "statistical analysis were conducted for MLR" model (CFPR) "between input variables" "V1, V2, V3...V11" and measured productivity of the site "actual productivity". Moreover, the "correlation of coefficient" R value for "CFPR)"model is equal to 93.6%, which explains a very high correlation. In addition to the result of the coefficient of determination (R2) was (87.5)% indicates the proportion of the variation in input variables that is forecasting from the output variables".

Table 4. A summary of statistical Analysis "CFPR" Model.

Model	R (%)	(R^2)%	Adj. (R^2)%	Std. Error
CFPR*	93.6	87.5	81.8	0.291

CFPR*= Column Formwork Productivity Rate

Where: CFPR is "the estimated productivity rate for the model"; its unit is (m2/h).

As it is noted in Table 5" that includes analysis of variance values" "ANOVA" "which can be defined through the explanatory model" as a" whole force by statistical F, as it can be seen from the" high contrast of the moral analysis of the F test table (P=Sig <0.0001) "highly significant affect", which confirms the high explanatory power of the model MLR of the statistically. That gives a good estimate through utilizing this model.

Table 5. Summary ANOVA Regression analysis "CFPR" Model

	Model	Sum of Squares	Df	Mean Square	F	Sig
(CFPR) Model	Regression	14.272	11	1.297	15.335	0.00
	Residual	2.031	24	0.085		
	Total	16.303	35			

In Table 5, the value of the constants, regression coefficients and statistical significance of independent variables on dependent variable. This table can be summarized as follows:

Table 6. MLR Analysis Results "CFPR" Model

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**T**	**Sig.**
	B	Std. Error	Beta		
"Constant"	-.994	.652	---	-1.52	.141
V1	.102	.150	.084	.682	.502
V2	.107	.072	.116	1.485	.150
V3	.106	.084	.134	1.253	.222
V4	.570	.134	.424	4.271	0.00
V5	.001	.009	.010	.106	.916
V6	.209	.093	.240	2.246	.034
V7	.022	.015	.160	1.508	.144
V8	-.037	.080	-.246	-.469	.643
V9	.060	.099	.069	.602	.553
V10	.042	.269	.084	.156	.878
V11	.281	.129	.207	2.184	.039

Dependent Variable : "Columns Reinforcement Productivity Rate" (M2/hour)

Table 6 illustrates MLR "prediction; the" outcomes show that (v4, v6, v11)" recorded the only variables "to consider highly significant" impact "at $P<0.05$. while, residual independent variables have" no significant effect at $P>0.05$".

As shown in Table 5, Beta values of the relative importance of each factor have an effect on the productivity rate. It was observed that the most important factors were (v4=0.424, v6=0.24, v11=0.207).

The MLR "analysis of model CFPR is given in" Table (5), "which can be written as the equation (2) below":

$$\textbf{CFPR} = -0.994 + 0.102(V1) + 0.107(V2) + 0.106(V3) + 0.57(V4) + 0.001(V5) + 0.209(V6) + 0.022(V7) - 0.037(V8) + 0.06(V9) + 0.042(V10) + 0.281(V11) \quad 2$$

11. VERIFICATION MLR MODEL

There are several methods and techniques utilized to guarantee that the model matches specifications and hypothesis with respect to the model concept. It includes "examination and evaluation of the model developed with some testing processes" (Banks, et al., 2011; Carson, 2002). Thus, based on statistical techniques and utilizing "data gathered from" different projects in Iraq as shown in annex 2, for activity (Formwork) for columns, the "correlation of coefficient" "(R) between actual and predict productivity was found to" "test performance of verification of the model". In Table 7, it can be observed that the verification model has a good performance because it provides a very strong correlation (R) (97.15) % between the real (actual) data and the estimated or predictor productivity rate. From Fig. 2 it was observed that MLR model capability of prediction where the value of the coefficient of determination (R2) (94.39) %. Thus, "it can be concluded that this model shows" an ideal approval with the real "measurements".

TABLE 7. VERIFICATION "CFPR" MODEL

Obs.	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	A.P*	E.P*	Error
1	2	2	1	1	15	1	30	2.8	1	1	1	1.77	1.263	0.507
2	2	2	1	2	30	1	40	12	1	3	1	2.52	1.812	0.338
3	3	2	3	2	25	2	32	7.5	2	2	2	2.88	2.620	0.261
4	2	2	1	1	18	1	32	12.5	1	4	1	1.36	1.078	0.283
5	3	2	3	2	18	2	32	7.5	3	2	1	2.77	2.392	0.379
6	3	2	3	2	18	3	40	7.5	3	2	2	3.25	3.058	0.193
Correlation (R): between Actual & Estimate productivity												97.15%		

"A. P*= Actual (real) Productivity", "E. P*= Estimate (predict) Productivity"

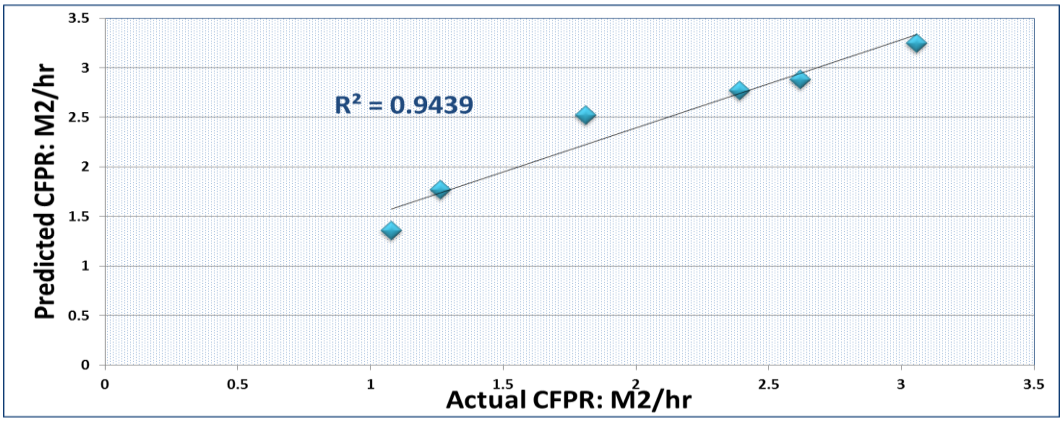

Fig. 2. Comparing between predicted and actual data.

12. EVALUATION "MLR" MODEL

The objective of the verification is to verify" "the precision and performance of actual system representation model". Six important "statistical equations will be" utilized "to examine the validity of MLR" model (CFPR). The "statistical measures utilized to measure the performance" and accuracy of the model included are" (Sargent, 2013):

"Mean. Percentage .Error", "$\boldsymbol{MPE} = \{\sum \frac{A-E}{A} / \boldsymbol{n}\}$ *100%" 3

Where:

A: "actual (real) value productivity"

E: "estimated (predict) value"

n: "number of cases"

The MPE is calculated to "find the agreement between predict and actual measurements".

"Root Mean Squared Error": $RMSE = \sqrt{\frac{\sum_{i=1}^{n}(E-A)^2}{n}}$ 4

"Mean Absolute Percentage Error": "$\mathbf{MAPE} = \sum \frac{|\mathbf{A-E}|}{\mathbf{A}} * \mathbf{100}\%)/n$" 5

The MAPE and percentage RMSE are "measures of average error".

"Average Accuracy Percentage": "AA%= 100%-MAPE" 6

"AA%: is calculated to obtain the" "degree of accuracy".

"The Coefficient of Determination" (R^2)

"The Coefficient of Correlation" (R)

Coefficient of determination" (R^2) "measures the extent to match the" model output with the target value. The results of the study are given in Table 8. "The MAPE and Average Accuracy Percentage" (AA) % created by the "MLR model were found to be" 17.69% and 82.31% for the CFRP "Model, respectively. Therefore, it can be concluded that the MLR model" illustrates a very good agreement with the actual measurements.

Table 8. Results of Statistical Techniques of "CFPR" Model

Description	Result
MPE	17.69%
RMSE	0.425
MAPE	17.69%
AA%	82.31%
R	97.15%
R2	94.39%

To achieve these solutions", many experiments were conducted. "During these trials error" grade was set up for conceptual predict proposed (Schexnayder and Mayo, 2003). The error of productivity rate predicting is approximately + 25%. In this research error categorization" was based on MAPE, Table 9. According to this table, MAPE of the model is very good.

Table 9. Error Categorization (%)

"MAPE"		
Good	Fair	Poor
Less than 25	25-50	More than 50

13. COMPARISON BETWEEN ANN AND MLR TECHNIQUES

"Artificial Neural networks" "ANN" are advanced. methods. and modern. that are utilized. to predict. the. productivity. rate in the construction projects, and the researcher utilized the outcomes of the past research intended by (Khaleel and Nassar, 2017), for the purposes of the comparison with. the outcomes. of this research. the prediction results of the two techniques are compared using six measurements as illustrate in Table 10. The outcomes can show that the ANN technique. gives basely better. results. than the MLR technique in nearly all six comparisons. The results show that both techniques are used to plot the relationship between the independent variables (the influencing factors) and the dependent Variable (the productivity rate) through the strong correlation coefficient (R)% for all the techniques (97.76%, 97.15%), respectively, as well as the percentage of accuracy (AA)% (88.82%, 82.31%), respectively. These results indicate that both technologies have the potential to predict productivity well.

Table 10. Comparison between the results of ANN and MLR Techniques

Types of Models	R%	R^2%	MPE	RMSE	MAPE	AA%
ANN	97.76%	95.56	-11.18%	0.387	14.55%	85.45%
MLR	97.15%	94.39%	17.69%	0.425	17.69%	82.31%

14. CONCLUSIONS AND RECOMMENDATIONS

This research. aimed at building. productivity. rate predicting. model for formwork of columns utilizing MLR. The model was built based on 36 samples of data gathered from construction projects in Iraq.

Through the results offered in this paper, the next conclusions can be reached:

- "MLR" can be utilized to check various variables at once and the mutual relations between them. And, MLR model has a "high degree of accuracy" with 82.31%, and the coefficients of correlation (R) for the built model equals to 97.15%.
- In this paper, eleven factors affect building productivity rate predicting model. "Number of working groups", "Lack of Workforce surveillance", "Used. Formwork type" (V4, V6, V11) "have the most significant effect on the productivity" rate in formwork works. While, the other input" variables "have moderate impact on the productivity" rate.
- By comparing ANN technique. and MLR technique., it is observed that both. techniques. have a strong correlation coefficient (R) as well as high accuracy in prediction, but networks are better than. linear regression by very little difference, by assuming that neural networks deal with variables within nonlinearity while linear regression. deals with variables within linearity Are less accurate than nonlinear data modeling.

15. RECOMMENDATIONS

- It is recommended to use the MLR and ANN equations developed in this research to estimate the productivity rate of construction projects in all engineering departments in the state departments in Iraq.
- Site inspections must be conducted permanently during the project design phase to avoid design changes during the implementation phase.
- Encouraging government projects and contracting companies to record and retain historical data of the factors that affect labor productivity to be used by researchers in private future researches.

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ANNEX (1)
Form of Work Measurement
For the work of concrete columns
(Reinforcement Works, Formwork Works, Casting Works)

First: General information about the project: No. of Form( )							
Type of Work: Reinforcement ☐ Formwork ☐ Casting ☐							
1	**Project name**						
2	**Project site**						
3	**Height of column**						
4	**Column dimensions and type**						
5	**Floor number or floor sequence**						
6	**High workplace**						
7	**Date of work**	**Start of work ( )**			**End of work ( )**		
8	**Type of Formwork used**	**Wooden**		**Iron**		**Plastic**	
9	**Units Produced for**						
Reinforcement Works (Ton/h)		**Formwork Works (M^2/h)**		**Casting Concrete Works (M^3/h)**			

Second: Team information					
1	**Age of the head of workers**				
2	**Average number of years of experience of the head workers**				
3	**The implementing the project**				
4	**Number of work totals**				
5	**Average number of workers per group**				
6	**Number of daily working hours**				
7	**Type of workers (Nationalty)**	**Local workers**		**Foreign workers**	

Third: Conditions of the Site Work					
1. Availability of Material					
1	Low quantity	2	Medium quantity	3	High quantity
2. Weather changes					
1	Cold	2	Hot	3	Moderate
3. Religious occasions					
1	High occasions	2	Medium occasion	3	Low occasion
4. Drawings and specifications alteration during execution					
1	High alteration	2	Medium alteration	3	Without alteration
5. Lack of Workforce surveillance					
1	Low surveillance	2	Medium surveillance	3	High surveillance

ANNEX (2)

No. of Obs.	Actual Data for Formwork Columns											
	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**Y**
1	3	2	2	1	20	2	42	0	2	0	2	**2.39**
2	3	2	3	2	15	3	36	3.6	3	1	1	**3.12**
3	3	2	3	2	16	2	34	0	3	0	1	**2.73**
4	2	2	1	1	13	1	36	2.75	1	1	1	**1.54**
5	2	2	1	2	25	1	42	12.5	1	3	1	**1.83**
6	3	2	3	2	19	2	36	7.4	2	2	2	**2.17**
7	2	2	1	1	15	1	36	12.5	1	4	1	**1.3**
8	3	2	3	2	15	2	34	7.4	3	2	1	**2.43**
9	3	2	3	2	30	3	45	7.8	3	2	2	**3.12**
10	3	2	2	1	15	1	36	0	3	0	1	**1.15**
11	3	2	1	2	18	1	45	10.5	1	3	2	**2.45**
12	2	3	1	1	30	1	45	5	1	1	1	**1.91**
13	2	3	2	1	21	2	42	7.4	2	2	1	**1.99**
14	3	3	3	2	24	3	45	0	3	0	2	**3.45**
15	2	1	1	1	30	1	34	12.5	2	4	2	**1.55**
16	2	2	3	2	18	2	36	12.5	2	4	2	**2.45**
17	3	3	3	1	9	1	28	10.5	2	3	1	**1.39**
18	1	3	2	1	12	2	42	12.5	2	4	1	**1.37**
19	3	1	3	2	9	3	28	0	3	0	2	**3.2**
20	3	3	3	1	18	3	42	10.5	3	3	1	**2.6**
21	3	3	3	2	30	3	34	6	3	2	2	**2.81**
22	2	1	1	1	25	1	45	7	1	2	1	**1.01**
23	3	1	3	1	9	2	36	0	3	0	2	**2.51**
24	2	1	3	2	9	2	36	12.5	2	4	2	**2.45**
25	2	1	2	1	9	1	36	9.8	2	3	1	**1.26**
26	2	3	3	2	25	2	42	8.5	3	3	2	**3.05**
27	3	2	2	1	9	1	32	8	2	2	1	**1.43**
28	2	2	1	1	18	3	42	0	2	0	2	**2.15**
29	3	1	3	2	23	2	35	7.5	1	2	1	**2.37**
30	3	1	3	2	28	3	45	7.5	3	2	2	**2.79**
31	2	2	1	1	28	2	42	6	3	2	1	**2.04**
32	2	1	2	1	18	1	36	7.4	1	2	1	**1.3**
33	3	2	2	2	9	2	28	0	2	0	1	**2.01**
34	3	3	1	2	18	3	37	7.5	3	2	2	**2.81**
35	3	3	3	2	15	1	37	4.2	3	1	2	**3.03**
36	2	2	3	1	12	2	37	13.5	3	4	1	**1.45**