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Impact of Applying Building Information Modeling on Steel Projects

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ملخص البحث

إن إستخدام برامج "نمذجة معلومات البناء" زاد في السنوات الأخيرة لتحقيق أكبر قدر من التنسيق بين الخدمات و العناصر التصميمية المختلفة خلال جميع مراحل التصميم و التصنيع و الإنشاء لجميع المشاريع عموماً. و إستخدام هذه البرامج في مجال المنشآت الحديدية يعتبر من باكورة هذه التطبيقات بنجاح لما يتطلبه تصميم و تصنيع و تركيب تلك المنشآت الحديدية من دقة عالية جداً أثناء جميع مراحله. و من تلك المنشآت الحديدية الكباري و المباني العالية و المصانع أيضاً. و قد جاء إستخدام هذه البرامج في البداية كتطور لنظام الأتوكاد الخطي "AutoCAD" و ذلك لربطها جميع تفاصيل المنشأ, مما أدى إلى سهولة إيجاد و حل تفاصيل الربط بين جميع وصلات المنشأ. و من أهم التطورات التي أدخلت في هذا المجال كان نظام "X-Steel" الذي يتعامل مع ربط التصميم بالتصنيع في جميع مراحله, مما أدى إلى تلافي معظم الأخطاء التي كانت قائمة قبل هذه التطبيقات. و من خلال تلك البرامج تم أخيراً إستحداث برامج "نمذجة معلومات البناء" “BIM” ليتم تطبيقها على جميع المشاريع الأخرى. و لدراسة تأثير إستخدام هذه البرامج على مدى تطور صناعة المنشآت الحديدية تم في هذا البحث عمل إستبيان لدراسة تأثير الـ “BIM” على مجموعة من الأخطاء التي قد تحدث أثناء خطوات تنفيذ المنشآت الحديدية. و تم عن طريق هذا الإستبيان تحديد دور هذه البرامج على تفادى تلك الأخطاء و علي تطور العمل بالمشروع, من خلال دراسة إحتمال حدوث هذه الأخطاء قبل تطبيق "برامج نمذجة معلومات البناء", و مقارنة هذه الإحتمالات مع نظيرتها بعد تطبيق "برامج نمذجة معلومات البناء" وذلك لدراسة تأثير تطبيق هذه البرامج علي إمكانية تفادي حدوث تلك الأخطاء. و لتحليل هذا الإستبيان تم إستخدام برنامج SPSS و سيتم إستعراض النتائج في الفصل المخصص لذلك في هذه الورقة العلمية.

ABSTRACT

The use of "Building Information Modeling" programs has increased in recent years to achieve the greatest degree of coordination between Electro Mechanical works (MEP) and different design elements (Architecture & Structure) during all stages of design, manufacturing and construction for all projects in general.
The use of these programs in the field of steel structures is one of the first successfully use of these applications because the design, fabrication and erection of these steel structures needs very high accuracy. From these steel structures are bridges, high rise buildings and factories. The use of these programs was initially conceived as an evolution of the “AutoCAD”, in order to link all the details of the steel structure, making it easy to find and solve the details of connections between all elements of steel structure. One of the most important developments in this area was the “X-Steel”, which links between the design and fabrication during all stages, which avoided most of the errors that existed before these applications.
Through these programs, “BIM” programs have recently been developed to be applied to all other projects. In order to study the impact of the use of these programs on the development of the steel industry, a questionnaire included with set of errors that may occur during the implementation of steel structures. As a result of this questionnaire, the impact of these errors will be determined for steel projects, and the possibility of these errors before applying "Building Information Modeling" and compare these possibilities

with their counterpart after applying "Building Information Modeling" to study the impact of these programs on the possibility of avoiding these errors. To analyze this questionnaire, the SPSS program was used and the results will be reviewed in the relevant chapter in this paper.

1. INTRODUCTION

The Building Information Modeling “BIM” is becoming a better known established collaboration process in the construction industry. Owners are increasingly requiring BIM services from construction managers, architects and engineering firms. Many construction firms are now investing in "BIM" technologies during bidding, preconstruction, construction and post construction.
The Building Information Model is primarily a three dimensional digital representation of a building and its intrinsic characteristics. It is made of intelligent building components which includes data attributes and parametric rules for each object.
There are plenty of Building Information Modeling tools. For example Revit Architecture, Revit Structure, Tekla Structures and ArchiCAD. Some of these softwares are also capable of scheduling and cost estimation.

1.1 Types for Applying BIM

There are different types for applying BIM:

- **“Hollywood” BIM**

High quality 3D renderings of a building can be generated from Building Information Models. If the contractor only uses the model to better communicate the BIM concept in 3D and does not further use the built-up information in the Building information Model, then this is referred to as “Hollywood” BIM.

- **“Lonely” BIM**

When Building Information Modeling is practiced internally within only a single organization of the project and not shared with the rest of the organizations.

- **“Social” BIM**

It is a more collaborative approach which enables the sharing of the model between the engineer, architect, construction manager, and subcontractors.

- **“Intimate” BIM**

It is realized when the construction manager, design team and owner contractually share risk and reward. This is made possible through BIM-enabled integrated project delivery.

Intimate” BIM as well as “social” BIM encourages teams to collaboratively produce better drawings, reduce time and cost in a project.

2. QUESTIONNAIRE

After different surveys are made about the errors that could happen during the stages of constructing a steel structure, this questionnaire is established. At first, after distribution it on steel companies that work in design, fabrication and erection of steel structure around the globe by E-mail, Unfortunately, any response is not obtained from several trials. That leads to minimize the surveyed companies and make them limited to Egyptians and some Arabian ones.

The questionnaire was distributed on 8 companies, answered by 77 engineers who have at least 10 years of experience, Figure (1).

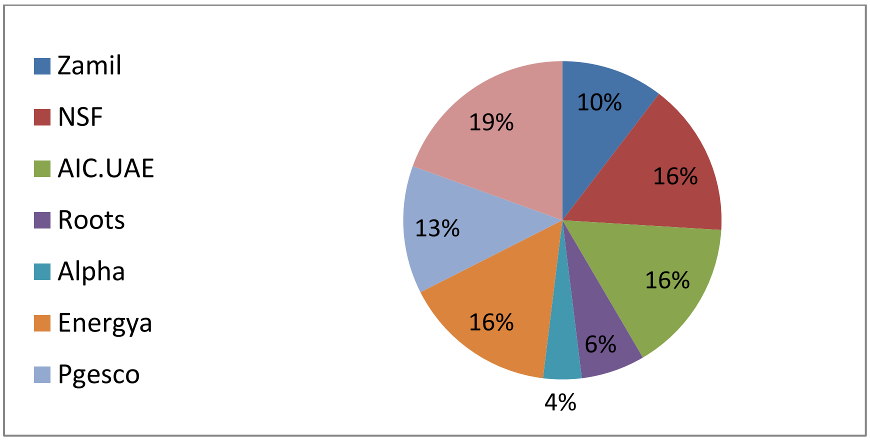

Figure 1: Companies interactive with the survey.

The companies have variant profiles, as shown in Figure (2).

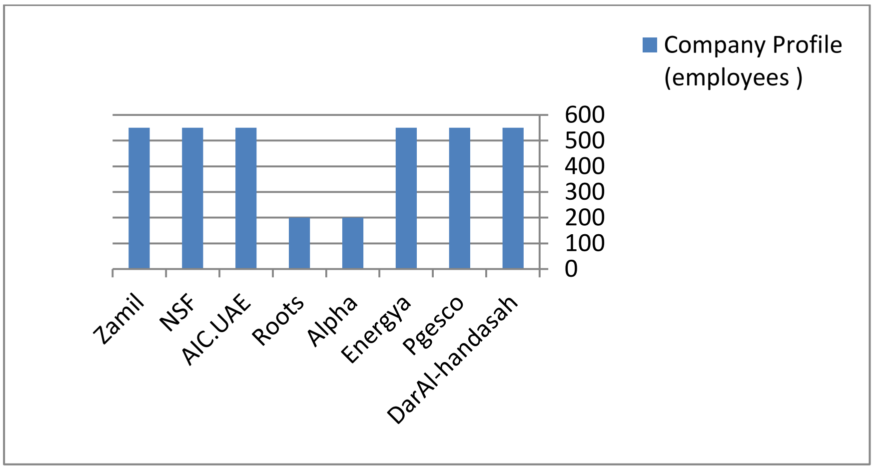

Figure 2: Profiles of Interactive Companies.

These companies started to apply BIM on their projects as shown in Figure (3).

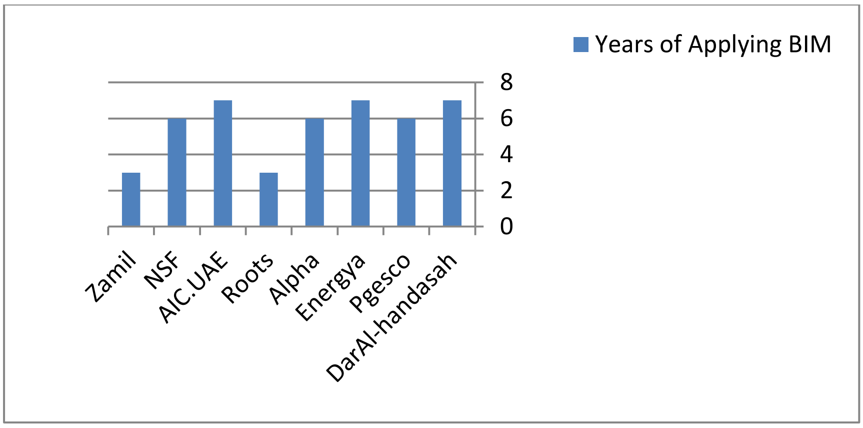

Figure 3: Years of Applying BIM.

The Annual production Rate for each company is shown in Figure (4).

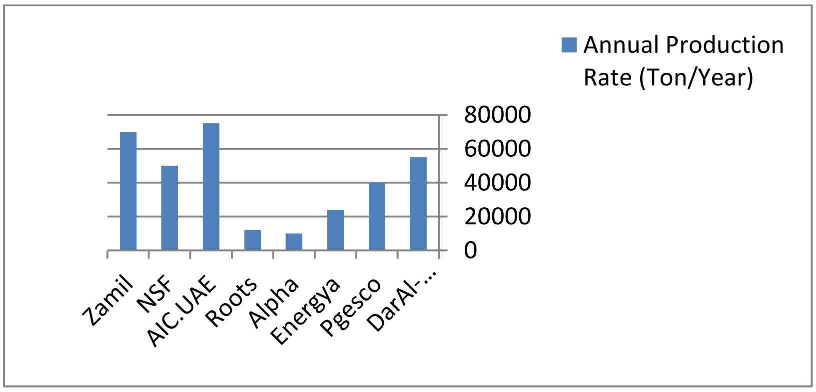

Figure 4: Annual production Rate.

The working fields of 6 companies are Pre-engineering, Design, Fabrication and Erection of steel structure. The other 2 companies working fields are Pre-engineering and Design only Figure (5).

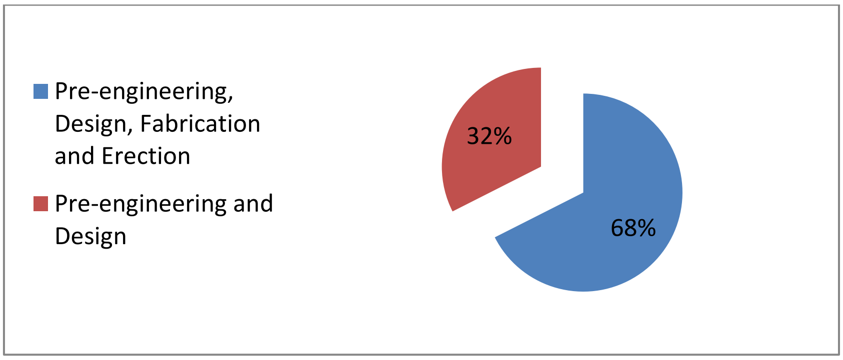

Figure 5: Working Fields for Interactive Companies.

All companies are using Tekla –Structure to draw their steel projects except Dar-Al-handasah is using Revit-Structure, Figure (6).

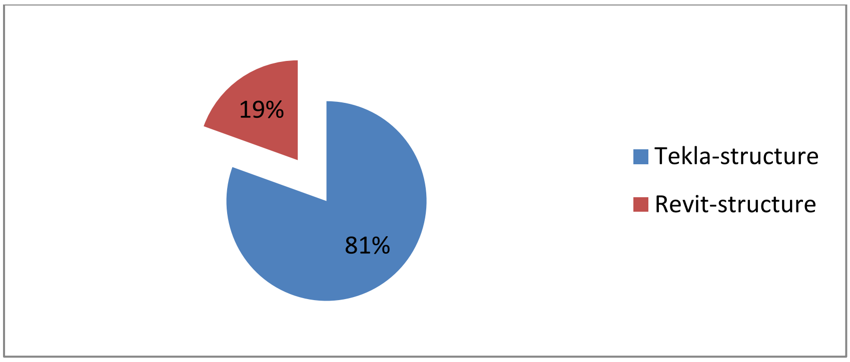

Figure 6: Programs used in drawing and detailing of steel structures.

Building Information Modeling is the process of developing the Building Information Model. There are different types for applying BIM; Hollywood BIM, Lonely BIM, Social BIM and Intimate BIM. Each company choses its way to apply BIM in their projects as shown in next Figure (7).

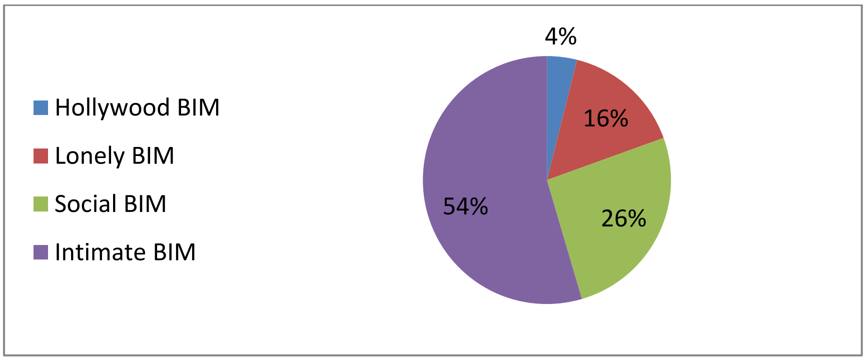

Figure 7: Different types for applying BIM in Interactive Companies.

The process of project delivery variant from one company to another, next Figure (8) shows the project delivery that each company prefers to use.

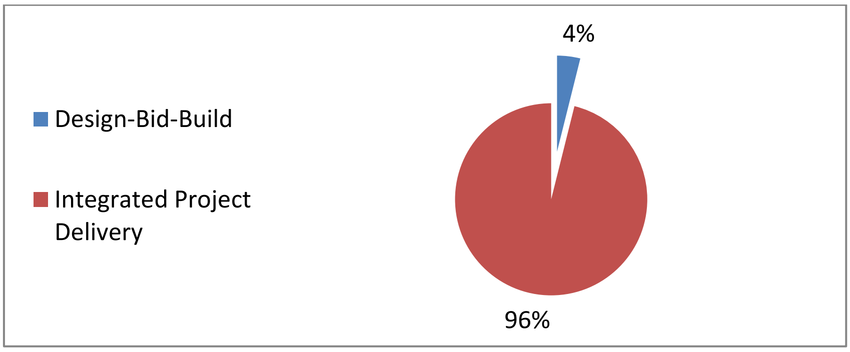

Figure 8: Project delivery in Interactive Companies.

Most companies consider that the use of BIM technology is must for the quality of their projects, Figure (9).

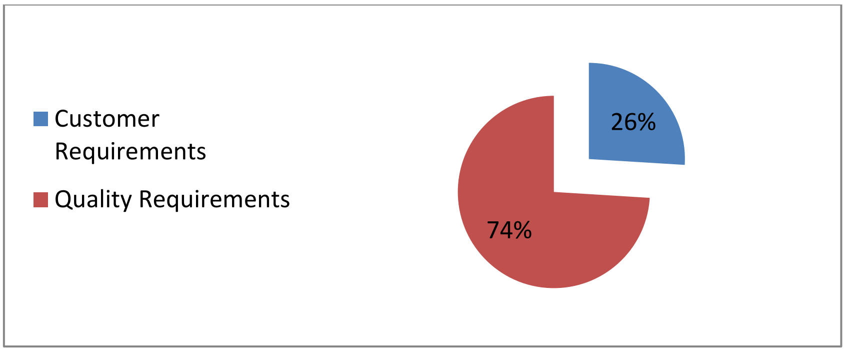

Figure 9: The use of BIM technology; customer or quality requirements.

The questionnaire studied the errors that could happen through construction of steel structure in the following stages:

i. Pre-engineering Stage.
ii. Pre-design and Detailing Stage.
iii. Fabrication Stage.
iv. Erection Stage.

The probability of errors is to be determined before applying BIM and after applying it on a scale from 1 to 5. Also, it is care to know the effect of every error on steel construction process using the same scale. The scale starts from 1 which means very low, 2 means low, 3 means medium, 4 means high and ends with 5 which means very high.

Table 4: Reliability& Validity for errors before using BIM, after using BIM and effect of errors.

Cronbach's Alpha for	Number of Errors	Reliability (Cronbach's Alpha)	Validity $(\text{Cronbach's Alpha})^{0.5}$
Probability of Errors Before using BIM	22	0.869	0.932
Probability of Errors After using BIM	22	0.820	0.906
Effect of Errors	22	0.893	0.945

On the following pages the state of research results will start with the Pre-engineering Stage and will explain the effect of every error in each stage.

i. <u>Pre-engineering Stage:</u>

▪ Effect of errors:

In this stage the total number of respondents is 77 engineers and there are 9 errors in this stage. The effect of errors that could happen in this stage is to be evaluated first. Cronbach's Alpha for the effect of errors in this stage is 0.815.

The errors that have highest effect in this stage of are: Misunderstanding the building and Change in requirements according to the owner. After this stage's analyses to be made if there is a huge impact on this high effect errors or not.

- ### Probability of errors before and after using BIM:

Start to make the analyses, and then a study of the probability of errors is made before using BIM and compare it with the probability of errors after using BIM in Pre-engineering stage, keeping an eye on the errors that have highest effect in this stage.

Table 2: Probability of Error in Pre-engineering Stage Before using BIM. The results according to Likert Scale Quintet.

Errors in Pre-engineering Stage **Before BIM**	Probability Of Error	Very Low	Low	Medium	High	Very High	Mean	Std. Dev.	Result
Misunderstanding the building.	**Frequency**	**4**	**13**	**31**	**25**	**4**	3.16	**0.947**	Medium
	Percent	**5**	**17**	**40**	**33**	**5**			
Change in requirements according to the owner.	**Frequency**	**9**	**8**	**19**	**26**	**15**	3.39	**1.248**	Medium
	Percent	**12**	**10**	**25**	**34**	**19**			
Results for probability of errors Before applying BIM in Pre-engineering Stage.	Frequency	108	132	245	173	35	2.85	0.643	Medium
	Percent	16	19	35	25	5			

Table 3: Probability of Error in Pre-engineering Stage After using BIM. The results according to Likert Scale Quintet.

Errors in re-engineering Stage **After BIM**	Probability Of Error	Very Low	Low	Medium	High	Very High	Mean	Std. Dev.	Result
Misunderstanding the building.	**Frequency**	**69**	**8**	**0**	**0**	**0**	**1.10**	**0.307**	**Very Low**
	Percent	**90**	**10**	**0**	**0**	**0**			
Change in requirements according to the owner.	**Frequency**	**59**	**13**	**3**	**1**	**1**	**1.34**	**0.736**	**Very Low**
	Percent	**77**	**17**	**4**	**1**	**1**			
Results for probability of errors After applying BIM in Pre-engineering Stage.	Frequency	609	70	12	1	1	1.15	0.167	Very Low
	Percent	88	10	1.7	0.15	0.15			

Generally, the result for probability of errors in this stage before applying BIM is MEDIUM and after applying BIM is VERY LOW, which means that applying BIM is very effective in this stage.

ii. Pre-Design and Detailing Stage:

- ### Effect of errors:

In this stage the total number of respondents is 77 engineers. The effect of errors that could happen in this stage is first discussed. Cronbach's Alpha for the effect of errors in this stage is 0.848.

The error that has highest effect in this stage of constructing a steel structure is: Design member hard to assembly. After this stage's analyses will be made to state if there is a huge impact on this high effect error or not.

- **Probability of errors before and after using BIM:**

Then starting to make the analyses then comparing the probability of errors in this stage before using BIM with the probability of errors after using BIM, then define the results, keeping an eye on the error that has highest effect in this stage.

Table 4: Probability of Error in Pre-Design and Detailing Stage Before using BIM. The results according to Likert Scale Quintet.

Errors in Pre-design and Detailing Stage **Before BIM**	Probability Of Error	Very Low	Low	Medium	High	Very High	Mean	Std. Dev.	Result
Design members hard to assembly.	**Frequency**	**13**	**12**	**22**	**23**	**7**	**2.99**	**1.230**	Medium
	Percent	**17**	**15**	**29**	**30**	**9**			
Results for probability of errors Before applying BIM in Pre-design and Detailing Stage.	Frequency	82	71	98	48	9	2.45	0.842	Low
	Percent	26	23	32	16	3			

Table 5: Probability of Error in Pre-Design and Detailing Stage After using BIM. The results according to Likert Scale Quintet.

Errors in Pre-design and Detailing Stage **After BIM**	Probability Of Error	Very Low	Low	Medium	High	Very High	Mean	Std. Dev.	Result
Design members hard to assembly.	**Frequency**	**64**	**11**	**1**	**0**	**1**	**1.22**	**0.599**	**Very Low**
	Percent	**83**	**15**	**1**	**0**	**1**			
Results for probability of errors After applying BIM in Pre-design and Detailing Stage.	Frequency	272	29	5	1	1	**1.15**	0.264	Very Low
	Percent	88	9.40	2	0.30	0.30			

Generally, the results for probability of errors in this stage before applying BIM are MEDIUM and LOW, after applying BIM it became VERY LOW. That means "Applying BIM in this important stage makes difference".

iii. Fabrication Stage:

- **Effect of errors:**

In this stage the total number of respondents became 52 engineers because two companies are working in pre-engineering and pre-design and detailing only. The effect of errors that could happen in this stage will be stated. Cronbach's Alpha for the effect of errors in this stage is 0.652.

The errors that have high effect in this stage of constructing a steel structure are: Miss to include or duplicate some members in fabrication list and Wrong dimensions for steel members. After this stage's analyses will be made to state if there is a huge impact on this high effect errors or not.

- **Probability of errors before and after using BIM:**

Start to compare between the probability of errors before and after using BIM in this stage, keeping an eye on the error that has highest effect in this stage.

Table 6: Probability of Errors in Fabrication Stage Before using BIM.The results according to Likert Scale Quintet.

Errors in Fabrication Stage **Before BIM**	Probability Of Error	Very Low	Low	Medium	High	Very High	Mean	Std. Dev.	Result
Miss to include or duplicate some members in fabrication list.	**Frequency**	**10**	**12**	**14**	**10**	**6**	**2.81**	**1.284**	Medium
	Percent	**19**	**23**	**27**	**19**	**12**			
Wrong dimensions for steel members.	**Frequency**	**6**	**11**	**13**	**18**	**4**	**3.06**	**1.162**	Medium
	Percent	**12**	**21**	**25**	**34**	**8**			
Results for probability of errors Before applying BIM in Fabrication Stage.	Frequency	34	55	86	66	19	2.93	0.775	Medium
	Percent	13	21	33	26	7			

Table 7: Probability of Errors in Fabrication Stage After using BIM. The results according to Likert Scale Quintet.

Errors in Fabrication Stage **After BIM**	Probability Of Error	Very Low	Low	Medium	High	Very High	Mean	Std. Dev.	Result
Miss to include or duplicate some members in fabrication list.	**Frequency**	**47**	**4**	**0**	**0**	**1**	**1.15**	**0.607**	**Very Low**
	Percent	**90**	**8**	**0**	**0**	**2**			
Wrong dimensions for steel members.	**Frequency**	**43**	**6**	**2**	**1**	**0**	**1.25**	**0.622**	**Very Low**
	Percent	**82**	**12**	**4**	**2**	**0**			
Results for probability of errors After applying BIM in Fabrication Stage.	Frequency	219	34	5	1	1	1.20	0.318	Very Low
	Percent	84.2	13	2	0.4	0.4			

Generally, the results for probability of errors in this stage before applying BIM is MEDIUM and after applying BIM is VERY LOW, which means that applying BIM is very effective in fabrication stage.

iv. Erection Stage:

- **Effect of errors:**

In this stage the total number of respondents is 52 engineers. Starting with the effect of errors that could happen in this stage, Cronbach's Alpha for the effect of errors in this stage is 0.498.

The error that has highest effect in this stage of constructing a steel structure is: Member in wrong place. After this stage's analyses will be made to state if there is a huge impact on this high effect error or not.

- **Probability of errors before and after using BIM:**

Moving to the probability of errors in this stage before using BIM and then comparing it with the probability of errors after using BIM.

Table 8: Probability of Errors in Erection Stage Before using BIM. The results according to Likert Scale Quintet.

Errors in Erection Stage **Before BIM**	Probability Of Error	Very Low	Low	Medium	High	Very High	Mean	Std. Dev.	Result
Wrong position or level of column bases.	**Frequency**	**8**	**16**	**23**	**4**	**1**	**2.50**	**0.918**	**Low**
	Percent	**15**	**31**	**44**	**8**	**2**			
Member in wrong place.	**Frequency**	**6**	**13**	**27**	**6**	**0**	**2.63**	**0.841**	Medium
	Percent	**12**	**25**	**51**	**12**	**0**			
Results for probability of errors Before applying BIM in Erection Stage.	Frequency	38	55	90	21	4	2.51	0.636	Low
	Percent	18	27	43	10	2			

Table 9: Probability of Errors in Erection Stage After using BIM. The results according to Likert Scale Quintet.

Errors in Erection Stage **After BIM**	Probability Of Error	Very Low	Low	Medium	High	Very High	Mean	Std. Dev.	Result
Wrong position or level of column bases.	**Frequency**	**47**	**3**	**2**	**0**	**0**	**1.13**	**0.444**	**Very Low**
	Percent	**90**	**6**	**4**	**0**	**0**			
Member in wrong place.	**Frequency**	**44**	**6**	**0**	**2**	**0**	**1.23**	**0.645**	**Very Low**
	Percent	**84**	**12**	**0**	**4**	**0**			
Results for probability of errors After applying BIM in Erection Stage.	Frequency	184	16	4	2	2	1.18	0.524	Very Low
	Percent	88	8	2	1	1			

Generally, the results for probability of errors in this stage before applying BIM are MEDIUM and Low, and after applying BIM is VERY LOW, which means that applying BIM is very effective in this stage.

A. Coefficient of Correlation (Pearson Correlation) Between Different Stages (Pre-Engineering, Pre-Design, Fabrication & Erection):

We will study this coefficient before and after applying BIM. If Pearson Correlation coefficient close to 1it gives strong positive correlation. In the next table we will arrange the stage's correlation before & after applying BIM in descending order.

I. Correlations Between Stages Before Applying BIM:

Pearson Correlation Before BIM	Stages
0.627	Pre-Design & Fabrication
0.580	Fabrication & Erection
0.579	Pre-Design & Erection
0.544	Pre-Engineering & Pre-Design
0.343	Pre-Engineering & Fabrication
0.264	Pre-Engineering & Erection

II. Correlations Between Stages After Applying BIM:

Pearson Correlation After BIM	Stages
0.685	Pre-Design & Erection
0.498	Fabrication & Erection
0.489	Pre-Design & Fabrication
0.478	Pre-Engineering & Pre-Design
0.371	Pre-Engineering & Erection
0.346	Pre-Engineering & Fabrication

B. Stages which Fabrication Depends on After Applying BIM:

From the previous questionnaire the stages of impact fabrication process will be determined. First the Null Hypotheses will be used (H_0):

1. No relation that is statistically significant at 95% level of trust between Pre-engineering and Fabrication.
2. No relation that is statistically significant at 95% level of trust between Pre-design and Fabrication.

Alternative Hypotheses for this study H_A:

1. There is a relation that is statistically significant at 95% level of trust between Pre-engineering and Fabrication.
2. There is a relation that is statistically significant at 95% level of trust between Pre-design and Fabrication.

Least Squares Method will be used in the analyses of linear regression. The dependent variable is Fabrication Stage after using BIM. The independent variables are: Pre-engineering & Pre-design Stages after using BIM.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.501[a]	.251	.220	.28089

The previous table states the coefficient of Correlation R between Pre-Engineering, Pre-Design and the dependent variable fabrication after using BIM 0.501. The accuracy in determining the dependent variable (R Square) is 25.1%.

ANOVA

Model		Sum of Squares	Degree of freedom	Mean Square	F	Sig.
1	Regression	1.293	2	.647	8.195	.001[b]
	Residual	3.866	49	.079		
	Total	5.159	51			

The previous table studies the appropriateness of the linear regression for the data and Null Hypotheses:

1) Summation of regression squares is 1.293 and residual squares are 3.866. Where the total number of squares are 5.159.
2) Degree of freedom for regression is 2 and for residual are 49.
3) Mean Square for regression is 0.647 and mean Square for residual is 0.079.
4) The value of ANOVA test is 8.195.
5) The significant 0.01 less than Null Hypotheses assumption 0.05 so we refuse it and the linear regression appropriate with the data.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.390	.256		1.520	.135
	Pre-Engineering after BIM	.224	.257	.126	.873	.387
	Pre-Design after BIM	.479	.164	.423	2.924	.005

The previous table states the coefficients of straight line equation:

$$Y = a + b\,X$$

Where (a) is the intersection with Y axis and it equals 0.390. The slope of regression line is (b) and it equals 0.224 for Pre-engineering Stage and 0.479 for Pre-Design Stage. Y is the dependent variable (Fabrication Stage). The equations for the 2 independent variables are as follow:

First independent variable (Pre-engineering)

$$Y=0.390+0.224X$$

Second independent variable (Pre-Design)

$$Y=0.390+0.479X$$

Results of T-test for Pre-engineering Stage are 0.873 and 2.924 for Pre-Design Stage. The intersection with Y axis is 1.520. By studying the significant for T-test we found that 0.387 is more than Null Hypotheses assumption 0.05 so it is accepted and there is no relation between Pre-engineering and Fabrication Stages. The significant of Pre-Design is 0.05 which is less than Null Hypotheses assumption 0.05 so it will be refused and there is a relation between Pre-design and Fabrication Stages. The equation of the line will be:

$$Y=0.390+0.479X$$

❖ Reanalyze the linear regression using Pre-design Stage only as independent variable with the same dependent variable which is Fabrication Stage.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.489[a]	.239	.224	.28022

The previous table states the coefficient of Correlation R between the independent variable Pre-Design and the dependent variable fabrication after using BIM 0.489. The accuracy in determining the dependent variable (R Square) is 23.9%.

ANOVA

Model		Sum of Squares	Degree of freedom	Mean Square	F	Sig.
1	Regression	1.233	1	1.233	15.702	.000[b]
	Residual	3.926	50	.079		
	Total	5.159	51			

The significant 0.000 less than Null Hypotheses assumption 0.05 so will be refuse and the linear regression appropriate with the data.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.561	.165		3.399	.001
	Pre-Design after BIM	.553	.140	.489	3.963	.000

Result of T-test for Pre-Design Stage is 3.963. The intersection with Y axis is 3.399. By studying the significant for T-test we found that the significant of Pre-Design is 0.000 which is less than Null Hypotheses assumption 0.05 so will be refused and thus there is a relation between Pre-design and Fabrication Stages. The equation of the line will be:

$$Y=0.561+0.553X$$

❖ **<u>Results for Fabrication Stage:</u>**

The results from the statistical analysis are:

1. Acceptance of Null Hypotheses for first assumption [No relation that is statistically significant at 95% level of trust between Pre-engineering and Fabrication], where the significant was 0.387 at 95% level of trust.
2. Refusal of Null Hypotheses for second assumption [No relation that is statistically significant at 95% level of trust between Pre-design and Fabrication] and acceptance of the Alternative Hypotheses [There is a relation that is statistically significant at 95% level of trust between Pre-design and Fabrication], where the significant was 0.005 at 95% level of trust.
3. The linear regression equation is :

$$Y=0.561+0.553X$$

C. Stages which Erection Depends on After Applying BIM:

From the previous study it is found that the Fabrication Stage does not depend on Pre-engineering Stage that is why the dependency of Erection Stage on Pre-engineering Stage is not studied. From the previous questionnaire we will determine the stages impact the erection process. First we will use Null Hypotheses (H_0):

1. No relation that is statistically significant at 95% level of trust between Pre-design and Erection.
2. No relation that is statistically significant at 95% level of trust between Fabrication and Erection.

Alternative Hypotheses for this study HA:

1. There is a relation that is statistically significant at 95% level of trust between Pre-design and Erection.
2. There is a relation that is statistically significant at 95% level of trust between Fabrication and Erection.

The dependent variable is Erection Stage after using BIM. The independent variables are: Pre-design & Fabrication Stages after using BIM.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.710[a]	.504	.484	.37670

The previous table states the coefficient of Correlation R between independent variables Pre-Design and Fabrication and the dependent variable Erection after using BIM 0.710. The accuracy in determining the dependent variable (R Square) is 50.4%.

ANOVA

Model		Sum of Squares	Degree of freedom	Mean Square	F	Sig.
1	Regression	7.061	2	3.531	24.881	.000[b]
	Residual	6.953	49	.142		
	Total	14.014	51			

The previous table studies the appropriateness of the linear regression for the data and Null Hypotheses:

1) Summation of regression squares is 7.061 and residual squares are 6.953. Where the total number of squares are 14.014.
2) Degree of freedom for regression is 2 and for residual are 49.
3) Mean Square for regression is 2.354 and mean Square for residual is 0.145.
4) The value of ANOVA test is 24.881.
5) The significant 0.000 less than Null Hypotheses assumption 0.05 so we refuse it and the linear regression appropriate with the data.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.482-	.246		-1.961-	.056
	Pre-Design after BIM	1.080	.215	.580	5.024	.000
	Fabrication after BIM	.354	.190	.215	1.863	.068

The previous table states the coefficients of straight line equation:

$$Y = a + b X$$

Where (a) is the intersection with Y axis and it equals -0.482. The slope of regression line is (b) and it equals 1.080 for Pre-Design Stage and 0.354 for Fabrication Stage. Y is the dependent variable (Erection Stage). The equations for the 2 independent variables are as follow:

First independent variable (Pre- Design)

$$Y=-0.482+1.080X$$

Second independent variable (Fabrication)

$$Y=-0.482+0.354X$$

Results of T-test for Pre-Design Stage are 5.024 and 1.863 for Fabrication Stage. The intersection with Y axis is -1.961. By studying the significant for T-test it is found that 0.068 is more than Null Hypotheses assumption 0.05 so it will be accepted and there is no relation between Fabrication and Erection Stages. The significant of Pre-Design is 0.000 which is less than Null Hypotheses assumption 0.05 so it will be refused and there is a relation between Pre-Design and Erection Stages. The equation of the line will be:

$$Y=-0.482+1.080X$$

- ❖ Reanalyze the linear regression using Pre-design Stage only as independent variable with the same dependent variable which is Erection Stage.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.685[a]	.469	.458	.38590

The previous table states the coefficient of Correlation R between the independent variable Pre-Design and the dependent variable Erection after using BIM 0.685. The accuracy in determining the dependent variable (R Square) is 46.9%.

ANOVA

Model		Sum of Squares	Degree of freedom	Mean Square	F	Sig.
1	Regression	6.569	1	6.569	44.110	.000[b]
	Residual	7.446	50	.149		
	Total	14.014	51			

The significant 0.000 less than Null Hypotheses assumption 0.05 so it will be refused and the linear regression appropriate with the data.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.284-	.227		-1.249-	.217
	Pre-Design after BIM	1.276	.192	.685	6.642	.000

Result of T-test for Pre-Design Stage is 6.642. The intersection with Y axis is -1.249. By studying the significant for T-test it is found that the significant of Pre-Design is 0.000 which is less than Null Hypotheses assumption 0.05 so it will be refuse and there is a relation between Pre-design and Erection Stages. The equation of the line will be:

$$Y=-0.284+1.276X$$

❖ <u>Results for Erection Stage:</u>

The results from the statistical analysis are:

1. Acceptance of Null Hypotheses for second assumption [No relation that is statistically significant at 95% level of trust between Fabrication and Erection], where the significant was 0.068 at 95% level of trust.
2. Refusal of Null Hypotheses for first assumption [No relation that is statistically significant at 95% level of trust between Pre-design and Erection] and acceptance of

the Alternative Hypotheses [There is a relation that is statistically significant at 95% level of trust between Pre-design and Erection], where the significant was 0.000 at 95% level of trust.

3. The linear regression equation is :

$$Y=-0.284+1.276X$$

and the result for T-test is 6.642 with significant 0.000.

3. CONCLUCIONS

BIM has a huge impact on reducing the probability of errors through all stages of constructing a steel structure. Pre-Design Stage is the most important stage that will affect the Fabrication and Erection Stages. Present recommendation is to give much care for Pre-Design stage to avoid the errors that could happen through the stages that come after it.

4. REFERENCES

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