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REDUCING REWORK AND INCREASING CONSTRUCTION QUALITY USING BUILDING INFORMATION MODELING (BIM) (RESIDENTIAL BUILDINGS)

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Abstract

Rework is the activities that try to bring the rejected items into an acceptable level with the product requirements or specifications or other expectations of the stakeholders. Rework is one of the most common concerns in construction industry projects, which increases the cost and time of the project, and it refers to unnecessary activities that are related to a process or an activity that is not done correctly or with the right quality from the beginning, and that activity needs to be done again. In the present study, the use of building information modelling (BIM) for residential buildings was investigated to reduce rework and increase construction quality. The current research method was a survey and information was collected by preparing a questionnaire. After analyzing the questionnaire data, it is determined that in construction projects, as a result of workshop rework, 6.1% is added to the construction cost and 9.3% to the construction time. The most rework occurs in the Rigidity and Facilities sectors, each experiencing more than an 8% cost increase due to rework. Also, joinery, skeleton, earth removal and foundation are in the next categories. By comparing the projects that used BIM and the project without BIM, it was found that the projects with BIM experienced a much lower cost increase and rework time. So that in projects without BIM, the cost increase due to rework was 7.2% and the time increase was 10.9%, While these figures in BIM projects were 2.6 and 4.3% respectively. The majority of BIM users use 3D modelling and the lack of BIM experts, the high cost of modelling, the unfamiliarity of most employers, consultants, and contractors, etc., are the obstacles to the development of BIM in Iran. The majority of the audience confirmed the ability of BIM to reduce costs and waste of time caused by rework in construction projects and considered the need for this technology to be high.

Keywords: Construction Quality, Rework, BIM

INTRODUCTION

One of the most critical aspects of construction projects is to complete the project in the minimum time bounded by the trade-off of time and cost. The planning of overlapping activities and their impact on the project under the constraints of limited resources should be considered (Abtahi et al., 2022).For decades, the construction industry has faced issues such as delays in completion time, increased costs, reduced quality and productivity of human resources, stakeholder dissatisfaction, increased human resource costs, and similar problems. The annual turnover of the construction industry in our country is 140 thousand billion to mans, and this is independent of the turnover of other construction projects. It is clear that solving the

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above problems can lead to extensive financial savings and improve the satisfaction of stakeholders and the quality of work. In this regard, it is necessary to mention the concept of success and its criteria in construction projects. A construction project is considered successful when it is completed within budget, to specifications, to the satisfaction of stakeholders, and on time. From 1370 until today, many researchers have tried to identify the success criteria and factors of construction projects, And day by day they developed the list of success factors without a specific assessment of the effectiveness of these factors on the success of the projects, In such a way that since the same year, about 70% of construction projects have always failed.12% of the country's employment is directly in the construction industry. The problem of rework during construction is one of the most important factors of resource wastage. Lack of proper management during design and construction, as well as lack of attention to constructability of some designs in the early stages of studies and design, causes some activities to be repeated again. Not knowing the details of the design of the components of a project, poor coordination between factors, incorrect estimation of time and cost, can lead to rework and lack of constructability of the project. Repetition and change in construction creates uncertainty and makes project management dynamic and unstable. Published statistics and information show that 30% of construction costs are attributed to rework. Additionally, change orders are known to be the largest source of construction waste. American Institute of Architects in 2007, IPD project implementation as a project implementation approach, which integrates factors, system, economic structure and habits, and toward a process that controls the collective talents and vision of all project stakeholders to optimize project outcomes, reduce waste, reduce rework, and increase efficiency in all phases of the project. This system benefits from high participation and cross-functional teams that consist of project life cycle stakeholders such as client, designer, contractor, engineers and vendors. Achieving success with this method requires that the team be formed as soon as possible, and all members have free and equal access to information and the rewards and risks of the project are equally shared between them. Relying on technical advances in sharing and sharing information through the World Wide Web, The team has become more powerful and even its members can cooperate with each other in geographical distances and complete the design and complete the project faster and cheaper (Hosseini and Rah Khodayi, 2021). One of the serious shortcomings of construction management is not paying attention to waste of costs during construction. The construction industry is one of the private industries whose capital providers are the customers. Unfortunately, no serious activity has been carried out in our country in the field of cost control and identifying cases of cost wastage. Rework during construction is the most important factor in wasting resources. Today, some cases of rework are accepted as an integral part of construction activities. Contractors and project owners try to build buildings with the highest quality level, but they do not pay much attention to how to reach these quality levels. Lack of proper management during design and construction will cause some activities to be repeated or some defects will be identified after the completion of construction. This imposes a significant cost on the project (Karimpour et al., 1400).Rework has become a threat in the construction industry as it leads to unwanted and unnecessary waste of resources. Quality, program performance and cost are affected and can be seen in both design and construction stages of construction projects, Therefore, in this article, the use of building information

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modelling (BIM) for residential buildings was discussed to reduce rework and increase the quality of construction.

A REVIEW OF PREVIOUS STUDIES

In 2021, Karimpour et al conducted a study under the title of identifying and controlling rework in construction projects to manage and reduce costs. Their article introduced the basic principles of project cost management in construction and re-construction, and a suitable framework for identifying the factors of rework and rooting its causes based on the factors related to rework. Rework is one of the most important problems in the field of construction and every construction project has its own problems depending on the implementation conditions. Project cost management is one of the key tasks of project managers and this is not possible without knowing the cost structures and management techniques. The next step in cost management knows the actual costs of the project. Due to the nature of construction works, developing a framework that includes all costs is very difficult and at the same time vital. Knowing the actual costs will clarify the rework items and knowing the rework items will help find the key problems in the construction. Being aware of this will prevent many future problems and eventually a significant part of the capital will be preserved (Karimpour et al., 2021).

Qolizadeh and Fard Moradinia conducted a study in 2021 entitled evaluating the role of BIM technology in reducing workload due to rework in large-scale projects. The purpose of their article is to investigate the most important capabilities of building information modelling in reducing the workload caused by rework in large-scale construction projects, After identifying the most important factors and analyzing their reliability and validity, 34 capabilities in 6 main factors were collected by the community experts in a survey (through the Likert scale), And after analyzing the data in SPSS and performing Kolmogorov Smirnov statistical tests and Friedman's non-parametric test, the most important capabilities were identified. The results showed the possibilities of creating a visual visualization of the environment and the project site, and the possibility of creating a preview and visual view And using accurate and advanced design software to get minimum errors that can be ignored in the process of designing and implementing the project, And the possibility of visualizing the design for renovation in order to make the space compatible with the environment and financial management and economic estimation of the project with an average value of Friedman 23.08, 24.28, 24.49, 25.49, 26.5 have respectively won the first to sixth ranks among BIM capabilities in reducing rework of large-scale projects (Qolizadeh and Fard Moradinia, 2021). In 2018, Nimir al-Shammari and Shariatmadari conducted a study titled prioritization of rework factors in construction projects using the network analysis process algorithm (case study of Iraq).In their research, in order to obtain the experiences of experts in the field of rework in Iraq, a questionnaire was compiled in three sections: cost, time and quality of construction projects, And then a combined algorithm based on the Dimatel method and the network analysis process was used to rank the factors and their sub-criteria and obtain the importance weights of each one. According to the obtained results, the most important factor influencing the rework of construction projects in terms of cost and time is the employer's factor, with the four relevant sub-criteria and the

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weighted total, respectively 0.403 in the cost section and 0.376 in the time section; it has the first rank among other factors. In the quality department, contractors (both main and sub-contractors) are ranked first with 5 sub-criteria and a weighted total of 0.384, and consultants are ranked second with an effective weight of 0.330.In the end, based on the obtained results, practical solutions have been presented in order to reduce the amount of rework of projects (Namir al-Shammari and Shariatmadari, 2018). In 2017, Alaei Varki and Qomi Avili conducted a study titled time and cost management of changes in construction contracting companies using the Building Information Modelling (BIM) system. They believed that building information modelling or BIM system in short has emerged as an important process of building design and in order to meet this need. By using a building information modelling system, many different aspects of a project are able to be simulated before the project begins, rather than being analyzed in detail during or after completion, and in this way to ensure their shortcomings before the implementation of the project. The hospital studied in their research is the Clean Room department of Shahid Motahari Hospital in Tehran, which has an area of about 600 square meters. Which in 2014 changed the use of the existing space and became a clean room for the hospital? In the construction done in the traditional way in this project, the lack of coordination of all the components of a project, such as the draftsman, accountant, and the facilities department, etc., who works separately with each other, caused many errors. These errors, in addition to increasing time and cost, caused the dissatisfaction of the employer. In this project, using the BIM method, it was shown that moving away from 2D maps and converting them to 3D maps can manage the time and cost of the project and avoid rework, and created more coordination between the employer, contractor and consultant (Alai Varki and QomiAwili, 2017).

In 2017, Tavakoli and Safa conducted a study under the title of rework and its different approaches, financial effects on the project, schedule, mental and psychological, environment and waste production. In their study, rework and its different approaches, financial effects on the project, schedule, mental and psychological effects, environment and waste production have been discussed. The population studied in this research is divided into two general groups: the first group includes university professors who are experts in the field of construction management and the second group includes experts, managers and engineers working in construction projects. In fact, the sampling method in this research is a combination of two targeted non-probability sampling (judgmental) and snowball sampling. According to the nature of the sampling method, finally, the sample size of this thesis is equal to 45 experts who are available and willing to cooperate in construction projects. Therefore, based on the opinions and professional experience of experts, managers and engineers working in construction projects within a range of seven, The weighted average of the variable state of financial effects on the project equals 382.5;and the weighted average of the schedule variable status equal to 4733.5;and the weighted mean of the mental and psychological variable status is equal to 4733.5;And the weighted average of environmental variable status is calculated as 417.5.On the other hand, the result of Cronbach's alpha test or the reliability of the research tool is more than 8,which has high reliability (Tavakoli and Safa, 2017).

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RESEARCH METHODS

This research is practical in terms of its purpose, in terms of its path; it is descriptive-survey type in which the relationship between independent and dependent variables is tried to be investigated. In terms of time, the current research is a section in which observations are made only in a short period of time during which data is collected. In terms of the method of data collection, it is a field method that includes collecting primary data or new information from the subjects themselves through methods such as observation, questionnaire, interview, etc. The statistical population is the construction companies and workshops of Shirvan and Bojnoord (North Khorasan).

Targets

Various goals were pursued in this research, the most important of which are:

- Investigating rework costs in construction projects
- The amount of cost increase due to rework in each of the working parts of the building
- Investigating the effect of using building information modeling on improving construction quality and reducing rework in construction projects
- Examining the current costs of BIM implementation and its optimal costs in the country
- Identifying and ranking reasons for rework in construction projects
- Identify and provide solutions to reduce redundancies

History of BIM

Since the early 1960s, the manufacturing industry has faced a gradual decline in manpower productivity. Meanwhile, other non-agricultural industries were making use of human resources. This meant that more man-hours were required for each dollar of contract amount. This highlighted the lack of new ideas to increase labor productivity in the construction industry. In general, this industry was mentioned with nicknames such as low efficiency, loss-making, controversial, troublesome, etc., and it was in need of progress and improvement in America and abroad.

Building Information Modelling (BIM)

Due to the number of people involved in construction projects, from designers and accountants to installation technicians and operators, expert managers and capital owners, each of whom has his own perspective and motivations, And from a point of view, they are partners in the interests of the work, it is necessary to get a result and optimize the implementation of the building. With extensive studies that have been conducted in this field worldwide, it has been determined that the most important pillar is to establish effective communication and cooperation among different departments. The first manifestation of this cooperation and communication is reducing the time of going back and forth between documents and maps and going up in these documents because it shortens the communication distance and reduces errors. In this industry, any small error may affect all project goals. Coordination and

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cooperation both in the design phase and in the construction and operation phase reduces costs and time and takes into account the relevant considerations, So that all departments reach a profitable outcome for themselves and each other by consensus and do not suffer during the transfer of information in one phase or between phases. In this regard, due to the advancement of information technology science in all industrial and non-industrial fields worldwide, and the extensive use of software and computer aids by construction industry experts, A method called BIM building information modelling or comprehensive building configuration has been invented which by harmonizing all software and construction work departments, has reduced the occurrence of errors and inconsistencies to a great extent, And it makes the experts able to express all their professional potential in the project. In other words, BIM turns the work space into a self-sufficient village where all its parts are connected and therefore any problem is solved before expansion and the need to return or destroy.BIM technology has been used by many organizations and companies, and each has provided a specific definition for it. The General Services Administration (GSA) is an independent agency of the United States government that was established in 1949 to help manage and support the activities of federal agencies. With approximately 7,800 buildings and 24.3 million square meters under its management, GSA is the nation's largest asset manager.GSA has implemented nine pilot projects to examine the implications of BIM adoption.GSA estimated that the cost savings associated with just one of the nine pilot projects would be as much as the cost of running the nine pilot projects for two years. These results made the aforementioned organization order the application of BIM in all its projects in November 2006.

DISCUSSION AND CONCLUSION

Loss of cost and time due to rework and the impact of BIM on its reduction

According to the definition, rework is retrying to perform a process or activity that was not done correctly the first time, or destroying or removing some parts of the project. The total workshop rework factor, which is the most important indicator for measuring rework in the workshop, is defined according to the following relationship.

(1) Total workshop rework factor =

$$\frac{\text{Total direct rework cost}}{\text{The total cost of the construction phase}}$$

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Analysis of answers to demographic questions

Figure 1: Respondents' education

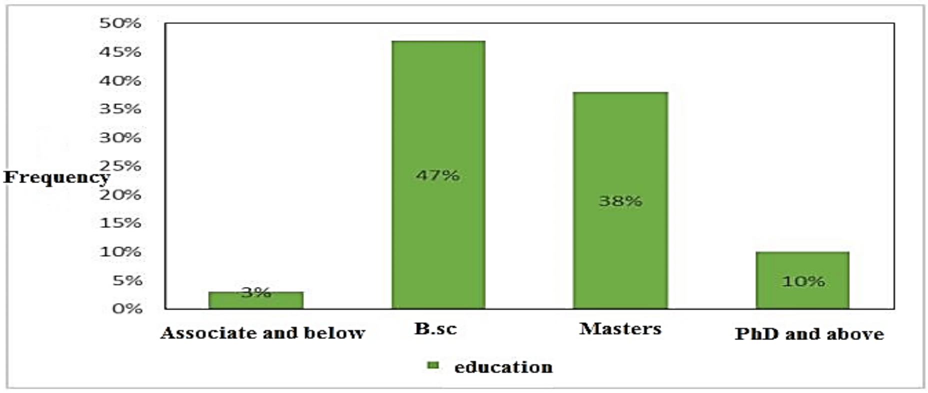


Figure 2: field of study of the respondents

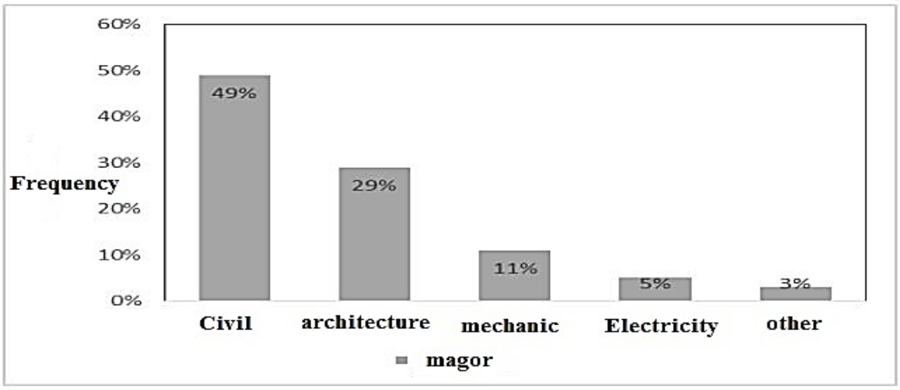
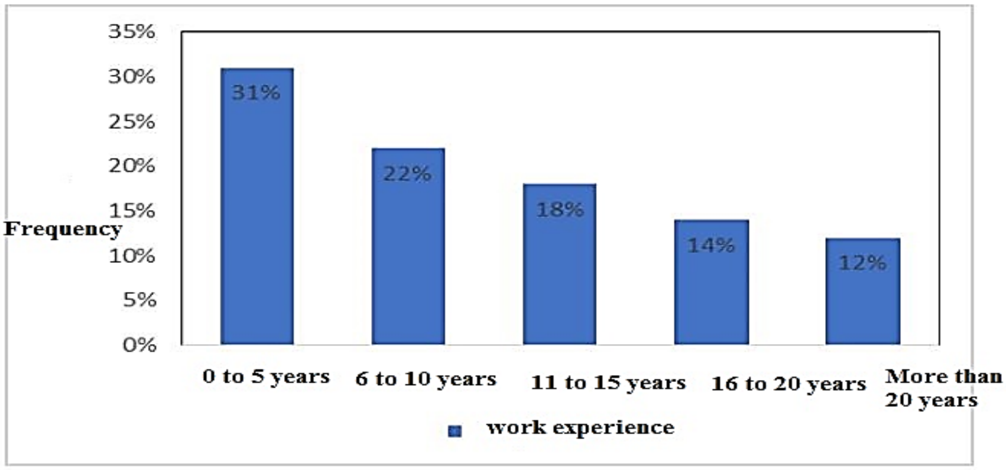


Figure 3: work history of the respondents



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Increase in project cost and time due to rework

Rework leads to waste of construction time and loss of resources and as a result increase the financial costs of the project. In this research, after collecting statistics from 154 people, the following results were obtained: According to Table 1, on average, in the construction projects of this research, 6.1 percent has been added to the project costs due to rework, and this figure is 9.3 percent due to the increase in project time. In the cost increase section, the lowest and highest percentages are 0 and 30%, respectively, and in the time increase section, the time increase has occurred between 0 and 67% of the initial time.

Table 1: descriptive statistics of percentage increase in project cost and time due to rework

kurtosis		skewness		standard deviation	mean	maximum	minimum	Number	item
standard error	Statistical value	standard error	Statistical value						
0.389	5.448	0.195	2.016	5.11349	6.0896	30	0	154	Percentage increase in cost
0.389	9.329	0.195	2.932	10.50475	9.3214	67	0	154	Time increase percentage

In addition to the above values, which are related to the entire project, rework information was also collected in each work section, and the results are as follows: The highest average cost increase has been achieved in the stiffening section of the building with 8.6%, followed by facilities with 8.3%.Joinery increased by 5.9%, skeleton by 4.2%, and excavation and foundation by 3.2%.Also, the biggest difference between the lowest and the highest value was related to the building facilities sector, which fluctuated between 0 and 50%.The maximum cost increase of 42% in excavation and foundation, 20% in skeleton, 40% in stiffening, and 30% in joinery was reported (Table 2).

Table 2: descriptive statistics of cost increase percentage due to rework in each work department

0.389	15.21	0.195	3.82	7.41	3.23	42	0	154	Excavation and foundation
0.389	1.4	0.195	1.37	4.48	4.24	20	0	154	skeleton
0.389	4.33	0.195	2.12	8.95	8.95	40	0	154	hardening
0.389	1.42	0.195	1.35	5.78	5.78	30	0	154	joinery
0.389	5.16	0.195	2.01	9.36	9.36	50	0	154	facilities

As for the increase in time due to rework, according to Table 3, rigid work ranks first with 10.9% increase in time. After that, facilities with 8.7%, carpentry with 6.9%, skeleton with 6% and excavation and foundation with 5.5% average time increase. Based on these two tables, it can be seen that the greatest increase in time and cost occurs in the hard work and facilities sector.

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Table 3: descriptive statistics of percentage increase in time due to rework in each of the work sections

Elongation		crookedness		The standard deviation	Average	the most	the least	Number	
Statistical average	standard error	standard error	Statistical average						
0.389	14.58	0.195	3.76	12.04	5.54	70	0	154	Excavation and foundation
0.389	59.6	0.195	6.74	9.72	6	100	0	154	skeleton
0.389	0.94	0.195	1.31	9.54	10.89	40	0	154	Rigidity
0.389	35.91	0.195	4.57	7.3	6.86	70	0	154	joinery
0.389	40.54	0.195	5.23	12.6	8.68	120	0	154	facilities

So far, general statistics of rework have been presented, but it is necessary to check these statistics more precisely based on the use of BIM, the type of structure, and other demographic factors in order to understand the differences between them. In the first step, we examine the cost and time increase of the entire project and then each of the work sections based on the use or non-use of BIM in construction projects. The percentage of cost increase in projects that used BIM is 2.6% and in projects without BIM it is 7.2%.Also, the increase in time due to rework in projects without BIM was equal to 10.9% and in projects with BIM it was equal to 4.3% (Table 4).

Table 4: Percentage increase in cost and time by using BIM

Percentage increase in time due to rework	Percentage increase in cost due to rework	Use of BIM	
10.91	7.20	medium	NO
117	117	Number	
11.57	5.36	The standard deviation	
4.30	2.57	medium	YES
37	37	Number	
1.96	1.29	The standard deviation	
9.32	6.09	medium	TOTAL
154	154	Number	
10.50	5.11	The standard deviation	

Independent T-test was used to examine the above two variables i.e. increase in time and cost under the influence of BIM, the results of which are as follows: Since the value of two-sided significance level (sig) of Leven's test was lower than the error level of 0.05%, it is assumed that the variances are equal, So, assuming the inequality of variances from the second level, the value of sig is equal to 0, which rejects the assumption of equality of means. Also, in the difference column, the average value of $\mu_1-\mu_2=4.63$ for cost increase has been obtained, which shows that the average cost increase in projects without BIM was greater than in projects

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with BIM.A similar analysis applies to time increments where $\mu_1 - \mu_2 = 6.61$ is obtained. The average is for the non-BIM mode and the average for the BIM mode (Table 5).

Table 5: T-test for the equality of means according to the use of BIM

t test for equality of means						Lunn's test for equality of variances		assuming	Percentage increase
95% confidence interval		mean difference	Significance level	df	T statistic	Significance level	F statistic		
lower limit	upper line		two way						
6.4	2.87	4.64	0	152	5.2	0	30.8	Equality of variances	Cost
5.7	3.57	4.65	0	146.1	8.61			Inequality of variances	
10.39	2.83	6.61	0.001	152	3.46	0	16.76	Equality of variances	Time
8.82	4.4	6.61	0	134.4	5.92			Inequality of variances	

The average increase in cost and time due to rework according to the use and non-use of BIM is shown in Table 6.

Table 6: percentage increase in cost and time of each work item by using BIM

Average			Work items	Percentage increase
Total	Not using BMI	Using BMI		
3.23	3.98	0.87	Excavation and foundation	Cost
4.24	5.22	1.15	skeleton	
8.58	10.23	3.39	Rigidity	
5.86	6.8	2.86	joinery	
8.58	10.14	2.65	facilities	
5.54	6.77	1.67	Excavation and foundation	TIME
6	7.07	2.64	skeleton	
10.89	12.83	4.73	Rigidity	
6.86	7.47	4.92	joinery	
8.68	10.33	3.476	facilities	

By performing an independent T-test, the reduction of cost and rework time due to BIM was confirmed with a confidence level of 95%.In the above table, the largest cost increase due to rework occurs in the stiffening and facilities sector, and excavation and foundation have the smallest contribution. Also, rigid work causes the biggest waste of time. In all work sectors,

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there is a significant difference between using and not using BIM. The impact of BIM in the field of skeleton and excavation and foundation is significant with a 78% reduction in cost and more than 60% in time. In Iran's construction industry, due to the difficulty of manufacturing steel parts in the workshop as well as some laws, regulations and standards, almost all steel frame parts are cut, welded and transported to the workshop in the factory, And in the workshop, they are simply installed on top of each other. For this, factories use shop drawings, which are usually drawn by Tekla Structures software. Therefore, it is expected that less rework will occur in steel frame buildings due to the prefabricated parts. This issue was clarified for the researcher in many workshops where the data collection was in the form of interviews, but in Table 7, as a comparison, we again examine the work with the skeleton type variable.

Table 7: comparison of work again

MEAN				
TOTAL	Steel frame	Concrete skeleton		
3.23	1.36	5.66	Excavation and foundation	Percentage increase in cost
4.24	2.97	5.89	skeleton	
8.58	8.7	8.44	hardening	
5.86	4.83	7.19	joinery	
8.34	7.41	9.54	facilities	
5.54	3.02	8.81	Excavation and foundation	Time increase percentage
6	4.57	7.86	skeleton	
10.89	8.04	14.58	hardening	
6.86	6.34	7.52	joinery	
8.68	7.77	9.86	facilities	

The independent T-test confirmed the equality of the means of stiffening and installation cost increases at the 95% confidence level, and for other work sections, it was confirmed that concrete structures are more expensive than steel ones in rework costs. Also, in the time increase due to rework; the equality of the averages was confirmed in the carpentry and facilities departments. And in other sectors, concrete structures have experienced more time increases due to rework.

DISCUSSION AND CONCLUSION

Rework and interference are among the problems that are very visible in today's construction process. On the other hand, as construction technology and developing systems become more complex, it seems that the traditional method of design to implementation is not the answer to this rapid growth of information and technology; On the other hand, these rework and interactions affect the cost, time and productivity of the projects. Therefore, the traditional construction process needs to change to adapt to the rapid development process in the information age. Building information modelling technology is one of the most effective methods invented in recent decades, which can be a suitable solution for construction problems, especially solving project cycle rework (Rizwani Far and Muslim Yazdi, 2015). Therefore, in

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this research, by using the field and survey method and preparing a questionnaire, the use of building information modelling (BIM) for residential buildings was investigated to reduce rework and increase the quality of construction, After analyzing the questionnaire data, it is determined that in construction projects, as a result of workshop rework, 6.1% is added to the construction cost and 9.3% to the construction time. The most rework occurs in the Rigidity and Facilities sectors, each experiencing more than an 8% cost increase due to rework. Also, joinery, skeleton, excavation and foundation are in the next categories. By comparing the projects that used BIM and the project without BIM, it was found that the projects with BIM experienced a much lower cost increase and rework time. So that in projects without BIM, the cost increase due to rework was 7.2% and the time increase was 10.9%, While these figures in BIM projects were 2.6 and 4.3% respectively. The majority of BIM users use 3D modelling, and the lack of BIM experts, the high cost of modelling, the unfamiliarity of most employers, consultants, and contractors, etc., are the obstacles to the development of BIM in Iran. The majority of the audience confirmed the ability of BIM to reduce costs and waste of time caused by rework in construction projects and considered the need for this technology to be high.

Offers

Due to the lack of collecting and recording data related to rework, it seems that case studies on all types of projects, with various uses and contracts, are appropriate to know the exact amount of rework. Also, modelling a case project with BIM software and checking the reduction of rework by it can be a suitable topic for research. Time planning in the building information model can be called the fourth dimension of BIM. This information can be contained in the BIM model itself or it can be connected, integrated or related to project management and planning of construction activities and time sensitivity estimates and systems analysis. Time in this concept refers to two applications: animation and construction sequence. Animations are basically a series of scenes in graphic form taken from a 3D model. For example, in an animation related to the sun, after specifying the position, time period (for example, a day or year) and an angle, the animation of shadows on the site and inside the building can be created. Another common form of animation is a walking animation, where after a path and elevations along the path are defined, an animation is created to simulate what a person would see as they walk or pass through a building. The BIM model can be sent for use in other more complex animation and graphics software. Also, the BIM model can be connected to a game engine where the graphics and animations can be converted by the user. One of the simple uses of BIM is to create animated phases that match the construction in the project. Although it is not difficult to do in software, the knowledge required for it can be extensive depending on the complexity of the project. The number of phases in projects can vary from less than a hundred to thousands. Modelling data can be entered through BIM, and details about planning, including time, contracts and key stages, can be entered through separate project management software. Project data, if properly updated, can be used to interpret the current status of the project. It is also possible to visually compare the actual work progress with the 3D virtual model.

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