



ASSESSMENT OF CHANGE ORDER IMPACT FACTORS ON CONSTRUCTION PROJECT PERFORMANCE USING ANALYTIC HIERARCHY PROCESS (AHP)

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Abstract. Complexity is very high in construction project and constrained by money and time. Change orders are commonly required during the execution of construction projects. They may increase, omit or adjust tasks in the project. Change orders affect the performance of construction job because they disturb current jobs and affect their schedule. The motive behind this study is to outline a complete assessment on change orders impacts. A review on past studies was performed to capture change order factors that affect project performance. Literature review and interviews with the industry professionals were used to finalize the factors into 16 critical factors. A questionnaire was distributed to industry specialists to capture the effect of these 16 factors on project performance. Complete answers of 102 surveys were received. Analytic Hierarchy Process (AHP) and Relative Important Index (RII) were utilized to analyze the responses. This study differs from other past studies by studying change order impact factors on three different change order types namely additional, omission and substitutional works. The most important change orders impacts factors as per the analysis outcomes are increased project management efforts, increased project re-planning, loss of efficiency due to work interruption, increased reworks/demolition works and delay of payments. This paper would help construction professionals to recognize change order impacts and would assist them in taking proactive actions to limit these impacts.

Keywords: change orders, construction industry, analytic hierarchy process, relative importance index.

JEL Classification: C83, L74, O22.

Introduction

Modifications are normally required through the project construction because of client's demand, design modification and unexpected situations. The owners have major concerns about the change orders due to their significant on the project budget and program (Shrestha & Maharjan, 2018). Change orders were classified for delays and cost increases in many researches (Khanzadi, Nasirzadeh, & Dashti, 2018). In one study by (Love, Irani, Smith,

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Regan, & Liu, 2017), Change orders after signing contract found to increase the project cost by 23.75% on average. Change order management is very important in construction project. Change orders mismanagement may result in conflicts.

AHP has been widely utilized due to its high flexibility and extensive applicability (Ho & Ma, 2018). Many researchers used AHP to organize and analyze complex decisions (Aghdaie, 2017; Jain, Sangaiah, Sakhuja, Thoduka, & Aggarwal, 2018; Aghdaie & Alimardani, 2015; Beltrão & Calvarho, 2019; Kim & Nguyen, 2018). There is no previous study in the literature about the impact of change order factors which would affect performance of projects. This study is needed to support critical decisions on mitigating the change order impacts.

This paper's objective is to outline a complete analysis of change orders impacts in construction projects. Literature review and interviews with the industry professionals were used to finalize the factors into 16 critical factors. To achieve this, a questionnaire was administered to industry experts to get their perception on these factors. Complete answers of 102 surveys were received. Analytic Hierarchy Process (AHP) and Relative Important Index (RII) were utilized to analyze the responses.

1. Literature review

Change orders are commonly faced and affect many aspects of construction (Cheng, Wibowo, Prayogo, & Roy, 2015). The change order impacts are well studied in the literature (Khanzadi et al., 2018). The estimation of change order negative impacts on projects is not easy to estimate (Moselhi, Assem, & El-Rayes, 2005). Increase in costs, delays, and conflicts are major negative effects of changes. Different studies in the literature studied different aspects of change order impacts. The risk by change order frequency and size for various change order types were studied by Taylor, Uddin, Goodrum, McCoy, and Shan (2012). Cheng et al. (2015) studied the labor efficiency factor on change orders. Choi, Lee, Bae, and Bilbo (2016) studied the effect of accelerated contract provisions (ACPs) on change orders. Lee, Tae, Jee, and Shin (2015) analyzed change order impacts by LDA (Loss Distribution Approach) for risks.

Considering AHP and decision-making, there are recent studies. Ho and Ma (2018) reviewed the past studies between 2007 and 2016 and made a comparison analysis. Aghdaie (2017) proposed a novel integrated approach to supplier evaluation and segmentation. Jain et al. (2018) presented a unique solution for headlamp vendor selection. Aghdaie and Alimardani (2015) used AHP and TOPSIS by analyzing size, competitor size, and profit for the market.

This study compiled the impact factors of change orders after an extensive literature review. The impact factors and their relevant references are presented in Table 1. In the later sections of this paper, these 16 factors will be analyzed and rated to capture their importance level through AHP.

Based on the gathered change order impact factors, a questionnaire was sent to the construction industry professionals. The questionnaire helped identify the most significant change order impact factors in construction projects.

Table 1. Change orders impact factors

Factors	References
Delay of progress payments	(Staiti, Othman, & Jaaron, 2016), (Keane, Sertyesilisik, & Ross, 2010), (O'Brien, 1998)
Delay of retention payment	(O'Brien, 1998)
Increased project financing	(J. Ma, Z. Ma, & Li, 2017), (Senouci, Alsarraj, Gunduz, & Eldin, 2017), (Sunday, 2010), (Alnuaimi, Taha, Al Mohsin, & Al-Harathi, 2010), (Love et al., 2017)
Increased reworks and demolition works	(Moselhi et al., 2005), (Sunday, 2010), (Alnuaimi et al., 2010)
Decrease in contractor reputation	(Staiti et al., 2016), (Sunday, 2010), (Alnuaimi et al., 2010)
Poor contractor relationship with the client	(Moselhi et al., 2005), (Staiti et al., 2016), (Ismail, Pourroostam, Soleymanzadeh, & Ghoyouchizad, 2012), (Du, El-Gafy, & Zhao, 2016)
Loss of opportunity for new projects	(Ismail et al., 2012), (Sunday, 2010), (Alnuaimi et al., 2010)
Increased contractor overhead expenses	(Moselhi et al., 2005), (Ismail et al., 2012), (Alnuaimi et al., 2010)
Increased site logistics requirements	(Staiti et al., 2016), (Sunday, 2010)
Increased project re-planning	(Taylor et al., 2012), (Sunday, 2010), (Alnuaimi et al., 2010)
Loss of efficiency due to work interruption	(Moselhi et al., 2005), (Alnuaimi et al., 2010), (Hanna & Iskandar, 2017), (Cheng et al., 2015)
Loss of efficiency due to lack of equipment	(Moselhi et al., 2005), (Sunday, 2010), (Alnuaimi et al., 2010)
Increased project management efforts	(Hanna & Iskandar, 2017), (Staiti et al., 2016), (Sunday, 2010), (Du et al., 2016), (Gunduz & Hanna, 2005)
Increased material unit prices	(Moselhi et al., 2005), (Ismail et al., 2012), (Sunday, 2010), (Alnuaimi et al., 2010), (Taylor et al., 2012)
Decreased project health and safety levels	(Staiti et al., 2016), (Sunday, 2010)
Decreased project quality levels	(Moselhi et al., 2005), (Staiti et al., 2016), (Ismail et al., 2012), (Sunday, 2010)

2. Methodology

A survey was developed and shared with construction experts to rate the importance level of change order impact factors on project performance. The first part of the questionnaire covers the participant's information such as total experience, position and the organization role. The second part includes the three change orders types ranking and the rank of impact factors. Likert-scale of nine was employed (9-very high impact, 5-medium impact and 1-very low impact). Complete answers of 102 surveys were collected. The Spearman's Rank Correlation Test and relative importance index were employed. Consequently, ranking for all change order types was calculated using AHP method. This study is unique as it utilizes AHP to investigate the effect of different change order types (additional, omission and substitution works) on project performance.

3. Data characteristics

An website (Survey Monkey) was used to utilize the survey and share it with the construction professionals. 102 answers were collected. The online questionnaire did not allow for partially filled out forms. The sample of the questionnaire is added in the Appendix.

Respondents were classified into four groups using the total years of experience. The distribution can be seen in Figure 1.

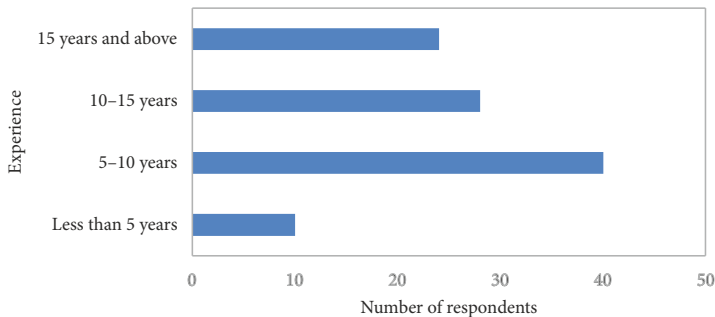


Figure 1. Number of respondents based on total years of construction experience

A percentage of 39% (40 out of 102 respondents) had 5 to 10 years of experience and 27% (28 respondents) had 10 to 15 years of experience. Rest had 10+ years experience.

Contractors are the largest portion of respondents with 61 responses (59.8%). Consultants, the second largest contributors of the survey, form almost 18% of the total participants. Owner and project management companies make 12.7% and 7.8% of the responses respectively.

45.1% of the respondents (46 out of 102) hold the title managers. 40.2% of the respondents (40 out of 102) hold job title of engineers. The rest of the titles are distributed among other titles such as academics, etc. The data was collected during period January-August 2017. The distribution of the respondents is mainly international engineers with different nationalities working in Qatar. Data from engineers in Asia, Europe and America was also collected through personal contacts and professional engineering societies.

4. Data analysis

The participants were requested to rate the impact of change order types (additional works, omission works and substitution works) on construction project performance. Moreover, the participants were requested to assess each predetermined factor and rank them in reference to change orders types. A nine point Likert scale was used in this questionnaire (9-very high impact, 5-medium impact and 1-very low impact). Spearman's Test and relative importance index were employed to analyze the data, which will be explained in the coming sections.

4.1. Relative Importance Index (RII)

RII method is used to evaluate the responses data and provide initial ranking

$$RII = (\sum P_i X_i) / N(n),$$

where *RII* = relative importance index; *P_i* = weight given to each attribute (1 to 9); *X_i* = number of respondents chose the same weight *P_i*; *n* = the highest scale weight (9 in this case); *N* = total number of participant (102).

RII results for all factors under each change order type are listed in Table 2 below.

Table 2. RII value results and ranking for impacts factors

ID	Factors	Additional works		Omission works		Substitution works	
		RII	Rank	RII	Rank	RII	Rank
F01	Delay of progress payments	0.521	11	0.517	6	0.674	5
F02	Delay of retention payment	0.625	7	0.455	9	0.659	6
F03	Increased project financing	0.676	3	0.378	14	0.538	14
F04	Increased reworks and demolition works	0.529	10	0.484	8	0.754	2
F05	Decrease in contractor reputation	0.407	16	0.524	4	0.578	10
F06	Poor contractor relationship with the client	0.449	14	0.626	1	0.659	7
F07	Loss of opportunity for new projects	0.649	5	0.411	12	0.552	11
F08	Increased contractor overhead expenses	0.647	6	0.544	3	0.587	9
F09	Increased site logistics requirements	0.674	4	0.33	15	0.608	8
F10	Increased project re-planning	0.746	1	0.621	2	0.781	1
F11	Loss of efficiency due to work interruption	0.606	8	0.505	7	0.721	4
F12	Loss of efficiency due to lack of equipment	0.531	9	0.404	13	0.541	13
F13	Increased in project management efforts	0.685	2	0.524	5	0.734	3
F14	Increased material unit prices	0.426	15	0.417	11	0.487	15
F15	Decreased project health and safety levels	0.467	13	0.326	16	0.485	16
F16	Decreased project quality levels	0.487	12	0.444	10	0.551	12

Moreover, the participants were requested to rake the impact of each change order types (additional works, omission works and substitution works) on construction project performance. The results can be seen in Table 2.

RII Values results and change orders initial ranking are listed in Table 3. These values used later on to give the relative weights of AHP analysis.

Table 3. RII results and ranking for types of change orders

ID	Types of change orders	RII	Rank
T01	Additional works	0.710	2
T02	Omission works	0.513	3
T03	Substitution (change) works	0.743	1

These RII values are used for Spearman’s Rank Correlation and assign relative weights of AHP analysis later on.

4.2. Correlation Test (Spearman's Rank Correlation Test)

The accuracy and the precision of data were assessed using Spearman test by analyzing different factors by the following formula.

$$\rho = 1 - 6 * \sum d_i^2 / n(n^2 - 1),$$

where ρ = Spearman correlation coefficient; d_i = difference between parties rank assigned to each factor; n = the impact factors total number (16 in this study).

Spearman's test was utilized to analyze and compare different classifications. The ranks were obtained using relative importance index. Spearman's coefficient is between -1 and $+1$, where positive sign shows positive correlation and negative sign represents negative correlation.

Table 4 provides a summary for Spearman's correlation values for different comparison cases.

Table 4. Spearman's rank correlation values

Comparison criteria	Additional works	Omission works	Substitution works
Contractor vs others	0.93	0.92	0.78
Contractor vs owner	0.85	0.94	0.74
Owner vs others	0.89	0.96	0.83
Less vs more than 10 years' experience	0.77	0.73	0.75

A brief calculation of "Less vs more than 10 years' Experience" for "omission works" with a value of 0.73 in Table 4 is shown in Table 5 as a reference.

Table 5. Spearman's correlation test – Less vs more than 10 years' experience – Omission works

ID	Factors	Less than 10 year	More than 10 year	(Difference) ²
F01	Delay of progress payments	7	4	9
F02	Delay of retention payment	10	8	4
F03	Increased project financing	13	14	1
F04	Increased reworks and demolition works	9	6	9
F05	Decrease in contractor reputation	3	10	49
F06	Poor contractor relationship with the client	1	1	0
F07	Loss of opportunity for new projects	11	12	1
F08	Increased contractor overhead expenses	4	7	9
F09	Increased site logistics requirements	15	15	0
F10	Increased project re-planning	2	2	0
F11	Loss of efficiency due to work interruption	8	5	9
F12	Loss of efficiency due to lack of equipment	14	11	9
F13	Increased in project management efforts	6	3	9
F14	Increased material unit prices	12	9	9
F15	Decrease in project health and safety	16	16	0
F16	Decrease in project quality	5	13	64
			Spearman value	0.73

4.3. Analytical Hierarchy Process (AHP)

The impact factors were initially ranked using RII. An overall impact ranking of change order types was obtained using AHP. The AHP was founded by (Saaty & Vargas, 1979). AHP was used successfully in many past research as a multi-criteria decision making tool to rank factors. AHP engages pairwise relative importance comparisons for each criteria. Improper conceptualization of data-hierarchy may result in inconsistency in pairwise comparisons. It measures how consistent the decisions have been made relative to large samples of purely random decisions. The consistency ratio needs to be lower than 0.1, otherwise, the matrix for pairwise comparison needs to be changed (Hadidi & Khater, 2015; Doloi, 2008). AHP organize the decision problem into multi-level hierarchical structures. The criteria was three change order types and the alternatives are the impact factors. SuperDecision software was utilized to obtain the consistency ratio (CR) and to prioritize each element. Figure 2 shows a screenshot from the software.

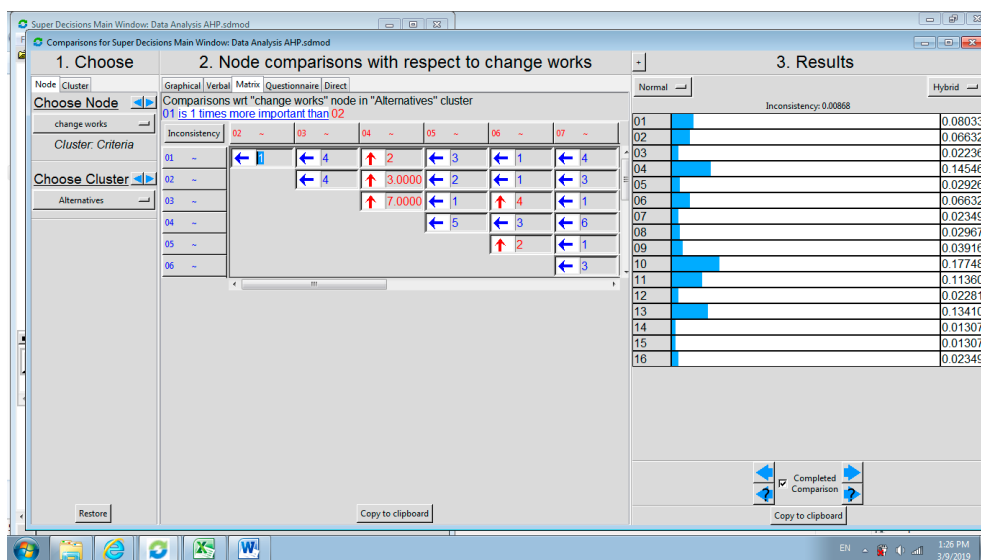


Figure 2. SuperDecision software screenshot

The AHP hierarchical structure is presented in Figure 3 with three levels. First level represents the alternatives, which are the impact factors. Second level represents the selection criteria, which are the types of change orders and the last level, represent the analysis goal, which is the final ranking.

The steps for the AHP process in steps are:

1. Identify the problem objective.
2. Identify the problem criteria.
3. Assign relative weights for each criterion.
4. Develop the AHP multiple level hierarchical structure.

- Develop pairwise matrices for comparison. The formula for developing pairwise matrix is as follows:

$$[A_{ij}], \text{ where } i, j = 1, 2, \dots, \tag{1}$$

where A = pairwise comparison value; i = impact factors ($i = 16$); j = change order types ($j = 3$).

Pairwise comparison matrices were developed according to the formula above. It requires a square size matrix of $m \times m$.

A total of $m(m-1)/2$ comparisons were assessed.

- Check consistency ration, pairwise comparison matrix needs revision if the ratio is less than 0.1. SuperDecision software was used to perform this step.

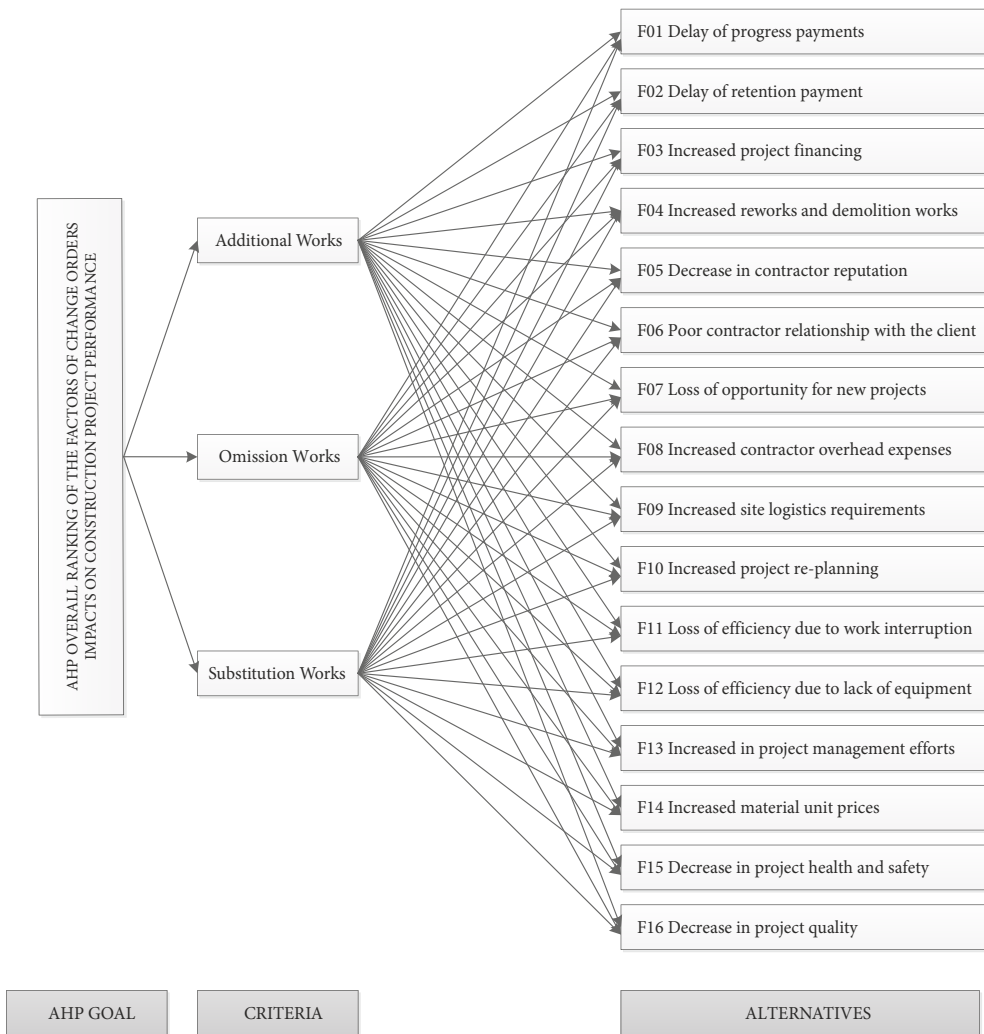


Figure 3. Model for AHP overall ranking (All 3 change types)

7. Calculate priority values to generate the alternatives overall ranking. The summation of each column for each pairwise comparison matrix was calculated and normalized with sum of each columns.

The above steps and their sample calculations are provided in this section. A size of 16*16 matrices was developed. As a sample, Table 6 shows “Additional works with priority values and consistency ratio” normalized pairwise comparisons.

Table 6. Additional works – AHP normalized pairwise comparisons

ID	F01	F02	F03	F04	F05	F06	F07	F08	F09	F10	F11	F12	F13	F14	F15	F16	Priority Value
F01	0.03	0.03	0.02	0.03	0.04	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.05	0.02	0.02	0.030
F02	0.09	0.08	0.10	0.09	0.09	0.09	0.08	0.08	0.10	0.07	0.06	0.06	0.05	0.08	0.08	0.09	0.080
F03	0.11	0.08	0.10	0.12	0.10	0.11	0.08	0.08	0.10	0.10	0.12	0.12	0.10	0.11	0.12	0.11	0.104
F04	0.03	0.03	0.02	0.03	0.04	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.05	0.04	0.02	0.031
F05	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.013
F06	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.01	0.01	0.02	0.02	0.02	0.02	0.017
F07	0.09	0.08	0.10	0.09	0.09	0.09	0.08	0.08	0.10	0.07	0.06	0.09	0.10	0.09	0.10	0.09	0.087
F08	0.09	0.08	0.10	0.09	0.09	0.09	0.08	0.08	0.10	0.07	0.06	0.09	0.10	0.09	0.10	0.09	0.087
F09	0.11	0.08	0.10	0.12	0.10	0.11	0.08	0.08	0.10	0.10	0.12	0.12	0.10	0.11	0.10	0.11	0.103
F10	0.17	0.23	0.20	0.17	0.13	0.14	0.25	0.25	0.20	0.20	0.24	0.18	0.21	0.12	0.14	0.16	0.187
F11	0.06	0.08	0.05	0.06	0.07	0.07	0.08	0.08	0.05	0.05	0.06	0.06	0.05	0.08	0.08	0.07	0.065
F12	0.03	0.04	0.02	0.03	0.04	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.05	0.04	0.02	0.032
F13	0.11	0.15	0.10	0.12	0.10	0.11	0.08	0.08	0.10	0.10	0.12	0.12	0.10	0.11	0.12	0.11	0.108
F14	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.02	0.02	0.02	0.015
F15	0.03	0.02	0.02	0.01	0.03	0.02	0.02	0.02	0.02	0.03	0.01	0.01	0.02	0.02	0.02	0.02	0.019
F16	0.03	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.023
Summation	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Consistency ratio = 0.00917 < 0.1																	

Moreover, a matrix for change order types with 3*3 size was developed for the AHP analysis in Table 7. These matrices were normalized by dividing the values of each column with the column summation and priority values (the average value of each row) were calculated.

Table 7. Change order types priority values matrix

ID	T01	T02	T03	Priority value
T01 Additional works	0.32	0.41	0.31	0.347
T02 Omission works	0.05	0.06	0.07	0.058
T03 Substitution works	0.64	0.53	0.62	0.595
Summation =	1.00	1.00	1.00	1.00
Consistency ratio = 0.02089 < 0.1				

At the end, the priority matrix was multiplied by the change order type matrix to calculate the final ranking of factors as shown in Figure 4.

	T01	T02	T03				Overall	
F01	0.030	0.073	0.081			F01	0.063	
F02	0.080	0.041	0.066			F02	0.069	
F03	0.104	0.021	0.023			F03	0.051	
F04	0.031	0.056	0.145			F04	0.100	
F05	0.013	0.076	0.029			F05	0.027	
F06	0.017	0.180	0.066			F06	0.056	
F07	0.087	0.025	0.024	T01	0.347	F07	0.046	
F08	0.087	0.092	0.030	X	T02 0.058	=	F08	0.053
F09	0.103	0.014	0.040		T03 0.595		F09	0.060
F10	0.187	0.176	0.176			F10	0.180	
F11	0.065	0.068	0.114			F11	0.094	
F12	0.032	0.024	0.023			F12	0.026	
F13	0.108	0.074	0.134			F13	0.122	
F14	0.015	0.029	0.013			F14	0.015	
F15	0.019	0.017	0.013			F15	0.016	
F16	0.023	0.036	0.024			F16	0.024	

Figure 4. Priority values matrices multiplication and result of overall ranking

Table 8 shows ranking for each change order type.

Table 8. Factors ranking using AHP for each change order type and overall ranking

ID	Factors	Additional works		Omission works		Substitution works	
		Priority	Rank	Priority	Rank	Priority	Rank
F01	Delay of progress payments	0.030	11	0.073	6	0.081	5
F02	Delay of retention payment	0.080	7	0.041	9	0.066	7
F03	Increased project financing	0.104	3	0.021	14	0.023	14
F04	Increased reworks and demolition works	0.031	10	0.056	8	0.145	2
F05	Decrease in contractor reputation	0.013	16	0.076	4	0.029	10
F06	Poor contractor relationship with the client	0.017	14	0.180	1	0.066	6
F07	Loss of opportunity for new projects	0.087	5	0.025	12	0.024	11
F08	Increased contractor overhead expenses	0.087	6	0.092	3	0.030	9
F09	Increased site logistics requirements	0.103	4	0.014	16	0.040	8
F10	Increased project re-planning	0.187	1	0.176	2	0.176	1
F11	Loss of efficiency due to work interruption	0.065	8	0.068	7	0.114	4
F12	Loss of efficiency due to lack of equipment	0.032	9	0.024	13	0.023	13
F13	Increased in project management efforts	0.108	2	0.074	5	0.134	3
F14	Increased material unit prices	0.015	15	0.029	11	0.013	15
F15	Decreased project health and safety levels	0.019	13	0.017	15	0.013	16
F16	Decreased project quality levels	0.023	12	0.036	10	0.024	12

The Table 9 presents the factors overall ranking using AHP method.

Table 9. Factors overall ranking using AHP

ID	Factors	Priority	Rank
F10	Increased project re-planning	0.181	1
F13	Increased in project management efforts	0.122	2
F04	Increased reworks and demolition works	0.101	3
F11	Loss of efficiency due to work interruption	0.094	4
F02	Delay of retention payment	0.069	5
F01	Delay of progress payments	0.062	6
F09	Increased site logistics requirements	0.060	7
F06	Poor contractor relationship with the client	0.056	8
F08	Increased contractor overhead expenses	0.053	9
F03	Increased project financing	0.050	10
F07	Loss of opportunity for new projects	0.045	11
F05	Decrease in contractor reputation	0.026	12
F12	Loss of efficiency due to lack of equipment	0.026	13
F16	Decreased project quality levels	0.024	14
F15	Decreased project health and safety levels	0.015	15
F14	Increased material unit prices	0.015	16

5. Discussion of results

“Increase project re-planning” is the highest ranked factor for additional works. The project needs to be planned again when there is additional works. This situation could change the sequence of the works and may affect the continuing works. “Increased in project management efforts” is the second highest rank factor. Increased project financing, increased site logistics requirements and poor contractor relationship with the client are the next three highest ranked factors.

“Poor contractor relationship with the client” is the highest ranked factor for omission works. When there is omission work, the contractor may already did some procurement for that part of the work. This would lead to problems with poor relationship with the client. “Increased project re-planning” is the second highest rank factor. Increased contractor overhead expenses, decrease in contractor reputation and increased in project management efforts are the next three highest ranked factors.

“Increased project re-planning” is the highest ranked factor for substitutional works. Additional works require restructuring and re-planning. “Increased reworks and demolition works” is the second highest rank factor. Increased in project management efforts, loss of efficiency due to work interruption and delay of progress payments are the next three highest ranked factors.

Increased project re-planning is the highest ranked factor overall (first ranked for additional and substitutional works and second highest ranked for omission works). Each time there is a change to the project, the project needs to be planned again, which requires a lot of efforts.

“Increased in project management efforts” is the second highest ranked factor overall. Change orders disturb the work sequence and this disruption requires a lot of efforts to eliminate the negative impact on project performance.

“Increased reworks and demolition works” is the third highest ranked factor overall. This factor impacts the project significantly, as it may require revised methodology and additional resources.

“Loss of efficiency due to work interruption” is the fourth highest ranked factor overall. Change orders impact the regular progress and this would cause productivity losses due to disruption of regular progress and learning curve.

“Delay of payments” is the fifth highest ranked factor overall. Delay of payments may interrupt ongoing progress and generate delays. The contractors and subcontractors depend on the progress payment to pay material suppliers. Delay of payments negatively affect the payment schedule of contractors and this situation would lead to poor cash management and project efficiency.

Conclusions

This paper studied the effect of change order factors on three types using relative importance index and AHP. The construction industry experts would use the rankings to better manage changes. Impact of the change order factors for three types (additional, omission and substitutional) were quantified through a questionnaire. The effect of additional, omission or substitutional types were analyzed separately and together with AHP.

The most highly ranked factors are increased project re-planning, increased in project management efforts, increased reworks/demolition works, loss of efficiency due to work interruption and delay of payment. This study differs from other past studies by studying change order impact factors on three different change order types namely additional, omission and substitutional works.

This article proposes a general ranking that could help experts understand the effects of change order. Construction industry experts need to comprehend and mitigate the effects of change orders. Improved communication between members of the project team could decrease the adverse effects of change orders and decrease conflicts. Contractor’s early engagement at the project design level would decrease changes and lead to better project specifications. Finally, as a future research, the impact factors listed in this paper could be studied as a case study in a construction project.

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*Please evaluate the following factors based on how much is the impact of change orders on each factor.

*on a rating scale of 1–9 (1: Very Low impact, 5: medium impact, 9: Very High impact).

Example:

Q – What is the impact of “Additional works” change orders on the “Delay of progress payments” in construction projects?

Q – What is the impact of “Omission works” change orders on the “Delay of progress payments” in construction projects?

Q – What is the impact of “Substitution works” change orders on the “Delay of progress payments” in construction projects?

	Additional works	Omission works	Substitution (change) works
Delay of progress payments			
Delay of retention payment			
Increased project financing			
Increased reworks and demolition works			
Decrease in contractor reputation			
Poor contractor relationship with the client			
Loss of opportunity for new projects			
Increased contractor overhead expenses			
Increased site logistics requirements			
Increased project re-planning			
Loss of efficiency due to work interruption			
Loss of efficiency due to lack of equipment			
Increased in project management efforts			
Increased material unit prices			
Decrease in project health and safety			
Decrease in project quality			