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FACTORS CAUSING DESIGN CHANGES IN VIETNAMESE RESIDENTIAL CONSTRUCTION PROJECTS: AN EVALUATION AND COMPARISON

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Abstract

Most of the construction projects in Vietnam are suffering from the design changes during the implementation phase. These changes have a significant impact on the time and cost of the project. The primary purpose of this study is to explore factors causing the design change of residential construction projects from the Vietnamese perspective. This study has used a questionnaire to collect data for the occurrence and effect of these factors on project performance. Based on the literature review, there are a total of 28 initial factors filtered. These factors were classified into four cases: environment, clients, consultants, and contractors. The results of the analysis showed that there is almost no difference in mean between groups of respondents, and there is a relatively high consensus in ranking the factors between project parties. Based on factor analysis, there are four principal components extracted from all initial factors, with total variance explained of nearly 65.2%. In addition, an evaluation sheet for the overall impact of factors on project performance is proposed. The result indicated that the level of impact is 70.7 per the scale of 100. Eventually, a comparison with other construction project types has been made to understand generally the factors of design changes in the construction industry.

Keywords: design change; residential building; construction management; Vietnam.

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1. Introduction

Designing is an activity in the field of investment and construction, describing the client's requirements for the prospective construction project in relation to architectural forms, technical contents, and financial characteristics. Changes and delays in design often create delays in the schedule of project performance, thus affecting project cost [1]. Hanna et al. [2] claimed that most project changes are derived from the problems related to defects, errors, and omissions in design and planning. Until now, a design change has been a critical problem in construction projects around the world [3]. Actually, project changes during the design phase are easily controlled, whereas changes during the construction phase are complex, and they often harm the project performance [4].

Extensive studies have been undertaken in design change of construction projects in the past around twenty years. These research works can be grouped in, but be not limited to, the following topics: (1) Concept and classification [5–7]; (2) Cause of change [4, 6, 8–11]; (3) Effect of design

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change [2, 6, 8, 10, 12–22] ; (4) Evaluation of design change [23, 24] and (5) Solutions for preventing design change [7, 8, 25, 26].

In Malaysia, Yap and Skitmore [27] have indicated the five most significant causes for design changes in residential building projects, including lack of coordination among various professional consultants, change of requirements/specification, addition/omission of scope, erroneous/discrepancies in design documents and unforeseen ground conditions. In addition, Mohamad et al. [3] have stated that modifications to the original design, addition of new work/scope, and unclear initial design brief are three major causes of design changes attributable to the client in the view of contractors, consultants, and clients. Design changes will inevitably cause negative effects on project efficiency [3]. That is why Yap and Skitmore [27] have concluded that time–cost overruns of 5–20% due to design changes in residential building projects. In Vietnam, design changes in construction projects in general and in residential projects are one of the main causes leading to many injuries, such as slow progress and increased costs [12, 13]. Unfortunately, a lot of adverse changes made by the clients and contractors during the implementation phase in the initial design of a residential project have occurred. These changes have resulted in a distortion in form and a conversion in utility that causes inconvenience for living [28].

Compared to other projects, a residential project has different characteristics in terms of scope, quality, design, construction, and operation. Therefore, there are differences among the main factors causing design changes within the delivery phase of Vietnamese residential projects, other residential projects, and other construction projects over the world. Moreover, identifying the source and impact of each design change in the project lifecycle could help manage all of the design changes associated with a residential building [3]. That is why further studies on reasons for design change of a residential project during the construction phase is necessary. As a result, this study aims to: (1) analyze and summarize factors causing design changes in construction projects based on the literature review and expert's opinion; (2) identify the influence level of factors of a design change on the project performance during the construction stage under the viewpoint of project parties; (3) build a principal component-based model for the design change problems; and (4) make a brief comparison of the main factors causing design changes in residential projects and other construction projects in Vietnam and some selected countries. It is kindly noted that, in this study, a design change is defined as changes that occurred with the project specification and drawings during the construction phase.

2. Literature review

Design changes in construction are a complicated matter. Currently, there is no standard definition of design change in construction projects. Most previous studies have defined design changes based on their manner and consequences. Because a construction project has many constraints, there is no perfect design in reality. Thus, design changes are unavoidable [8]. The performance of construction projects is significantly influenced by design changes [9]. Even they often occur during construction in the United States because there are many differences between the design criteria and the realities of design and build projects [22]. Moreover, Wan et al. [29] investigated the errors in the design of electrical and mechanical works in Hong Kong. The results indicated that poor coordination and design change are the main reasons for variations and issues of a change order, thus leading to rework. Causes for design changes in high-rise projects include lack of scrutiny of the site investigation, the incompleteness of working drawings, and unpredicted situations during the execution phase. As a result, design changes during the construction phase probably bring about adverse variations in cost or time compared with the original expectation of the clients [17]. Based on a questionnaire survey, Tin [4] indicated that there are three significant causes of project adjustment during construction, including additional works, financial change, and poor drawing quality.

Many studies have been conducted to mainly examine the impact of design changes on the effectiveness of construction projects. Some of them can be listed as follows:

- Burati et al. [5] noted that design changes are related not only to matters by the provision of the contract but also changes to the work conditions.

- Kaming et al. [17] demonstrated that volume and duration of work are the subjects for design changes during the construction projects' performance after the contract has been signed

- Ibbs [16] conducted a study on the size of the change and its impact on the project. The results showed that the amount of change is negatively associated with productivity but positively associated with total project cost, whether within the design phase or construction phase.

- Hanna et al. [2, 18] concluded that design changes from the owners hurt the labor efficiency of electrical and mechanical construction, respectively.

- Love and Li [19] stated that a lack of attention to work quality, especially during the design period, is the leading cause of reworks. The cost for these reworks is estimated at up to 12.4% of total project costs.

- Aibinu and Jagboro [25] verified that design changes have harmful impacts on most projects, such as extra work, time loss, design revisions, and increased costs.

- Love et al. [26] expressed that changes that happened during construction may have unpredictable effects on its organization and management.

- Josephson et al. [7] found that in some of the observed projects, the cost of reworks is 3.2% of the total project cost, while the cost of design changes is 6.0% of that one.

- Park and Peña-Mora [15] claimed that construction changes usually resulted from differences in work quality and conditions, scope changes, or uncertainties that make construction dynamic and unstable.

- Wu et al. [8] indicated several different impacts of design changes, including low motivation, quality differences, and legal arguments.

- Love and Edwards [30], and Yap et al. [20] stated that there is a strong positive relationship between design changes and reworks.

- Sun and Meng [6] stated that delays of start and finish of tasks, deletion, and addition of works, and variation of resource inputs are typical changes in construction projects.

- Chang et al. [31] reported that design changes have resulted in an increased redesign cost of 2.1% to 21.5% and, on average, 8.5% of the construction change cost.

- Ibbs [21] identified that design changes might cause an adjustment to the contract price or contract time of a design or construction project.

- Kaming et al. [17], Wu et al. [8], Assaf and Hejji [9], Motawa et al. [32], Le-Hoai et al. [13], Alnuaimi et al. [14], Hai [12] and Yap et al. [20] found that design changes often lead to the time delay or cost overruns in construction projects.

- Memon et al. [10] showed that design changes are the leading cause of excusable delays in construction projects.

- Ngan [33] proved that the variation of work quantity due to design changes cause conflicts between project parties during construction.

When a design change is made, a change order is issued on the construction site to provide the revised requirements and method for related works [3, 4, 8]. Hsieh et al. [34] constructed a hierarchy of thirty-six causes of change orders with three levels of detail in metropolitan public works. This hierarchy consists of two major groups: (1) construction needs group that is related to planning and design, underground conditions, safety considerations, and natural incident; and (2) administration needs group that is related to changes of work regulations, changes of decision-making authority, commissioning and ownership transfer, neighborhood pleading, and miscellaneous causes. Also, Wu et al. [8] divided thirty-five reasons for change orders in a highway project into two main groups: (i) external group that pertains to policy, environment, and thirty parties; and (ii) internal group that relates to owners, design consultants, contractors, and others. Based on the field investigation of thirty-three practical cases of work packages and contracts, Moselhi et al. [35] claimed that change order is a cause leading to the decrease of productivity, and the excess of time and cost in construction projects. Furthermore, Assaf and Al-Hejji [9] concluded that change order is the most common cause of delay determined by project parties. Moreover, Hanna et al. [2] also identified that change orders are considered as one of the main sources of controversies between owners and contractors. In detail, the contractors are expected to execute these change orders with a corresponding financial compensation, whereas the owner often claims that they only impact on the specific work, this does not recognize the possible effects on other related works. Most recently, Alnuaimi et al. [14] ranked twenty-four change order causes in the Oman construction industry. They discovered the five most important causes of change orders for every party of the project. It is worth to mention that design-related causes almost appear among them.

3. Research methodology

A total of 28 factors causing design changes in residential construction projects were collected based on the literature review (12 factors) and experts' opinion (16 factors), as shown in Table 1. The surveying projects are in Ho Chi Minh city because this city is the biggest city in Vietnam with several residential projects that have been performed in the last years to provide accommodation to citizens, not only the current ones but also novel habitants who came to work there. These factors have been classified into four groups: (1) environment-related group; (2) client-related group; (3) consultant-related group; and (4) contractor-related group. It can be seen that the factors causing design changes are also related to contractors, as suggested by experts. This finding is entirely possible. In reality, contractors are also a direct participant of the project. They are even primarily responsible for the result of the construction performance. If this result is wrong or needs further improvement, design changes for the next tasks highly occur. For example, the contractor proposes better alternatives for construction or performs the work with many defects during the implementation phase. These actions can cause a change in the current design to guarantee the outcomes of the project.

Data were collected by a structured questionnaire, which consists of two sections: (1) assessment of the level of impact of each factor on causes of design changes, and (2) personal information of respondents including project parties, work positions, and year of experience. A five-point Likert scale was employed with a value being 1 for 'no effect' and 5 for 'extreme effect'. The preliminary questionnaire was made based on the literature review. A pilot test for this questionnaire was performed through five experts. All of them have the following characteristics: (1) years of experience is more than fifteen years, and (2) position of work is a project manager or above. Their valuable comments were adopted to revise the questionnaire. Then, the questionnaire was re-sent to these experts to get their confirmation on the revisions. At this time, no more comments were received from them; hence the questionnaire was ready for mass survey. The respondents are engineers and managers who work for the clients, consultants, and contractors of private-funded projects. The non-probability sampling method was applied to collect data because of several specific difficulties. The statistical analysis tools include scale reliability test, normality test, variance analysis, rank correlation test, and factor analysis.

Table 1. Twenty-eight factors causing design changes in residential construction projects

Group	#	Factors	Source
Environment	F1	Adverse weather	[17]
	F2	Unforeseeable soil condition	[17, 27, 29, 34]
	F3	Changes in governmental policies	Expert
	F4	Difference between design standard and reality	[15]
	F5	Complex local culture	Expert
	F7	The appearance of new materials	Expert
Clients	F8	Unclear requirements during the design phase	[3, 4]
	F9	Changes in the scope of work during construction	[3, 4]
	F10	Unstable financial capacity	[4]
	F11	Low knowledge about the construction field	Expert
	F12	Inappropriate project duration	Expert
	F13	Lack of supervision	Expert
	F14	Indifference to consultants' opinion	Expert
Consultants	F15	Errors in drawings and specification	[8, 9, 15, 27, 29]
	F16	Low understanding of client's requirements	[9]
	F17	Changes to suit with the previously completed projects	Expert
	F18	Application of inappropriate standards	[4]
	F19	Complex project characteristics	[9]
	F20	Poor design experience	[9]
	F21	Lack of survey on an on-site investigation	[17, 29, 34]
Contractors	F22	Low quality of completed work	Expert
	F23	Difficulties in the construction method	Expert
	F24	Rational change suggestion	Expert
	F25	Poor construction experience	Expert
	F26	Mistakes during the construction stage	Expert
	F27	Using a new method to speed up the construction progress	Expert
	F28	Inappropriate materials	Expert

4. Analysis results

4.1. Characteristics of respondents

Tabachnick and Fidell [36] concluded that the size of the data sample necessary for reflecting the research problem is calculated based on the following formula: $n \geq 104 + m$. Where n is a number of questionnaires, and m is a number of factors. In this study, $m = 28$; thus, $n \geq 132$. There were a total of 203 questionnaires sent to the respondents. After more than one month of the survey, there were 146 feedbacks collected. However, only 135 of them were found to be valid for this study because 11 feedbacks were not filled fully. First of all, the characteristics of the respondents involved in the survey should be investigated. The summary of the analysis on aspects of the respondents is presented in Table 2. The results show that the questionnaires have been distributed widely to clients, consultants, and contractors. In addition, most of the respondents are project engineers. It would be better if the proportion of top and functional managers is more significant than the proportion of project engineers. The reason for this requirement is due to the manager's opinions can correctly reflect the practical problem. Moreover, the results indicate that most of the respondents have between 3 and 9 years of experience. It would be better if the percentage of respondents with experiences of more than nine years or more could be increased. In general, the respondents are professionals who have demand changes in project designs if necessary. Therefore, they must be the ones who best know the causes of design changes in the project construction phase.

Table 2. Characteristics of respondents

Profile	Frequency	Percent
Project party	135	100.0
Clients	26	19.3
Consultants (design and supervision)	64	47.4
Contractors	45	33.3
Work position	135	100.0
Directors/ vice directors	10	7.4
Department managers	27	20.0
Project managers	7	5.2
Project engineers	85	63.0
Others	6	4.4
Year of experience	135	100.0
< 3 years	15	11.0
3-6 years	43	31.9
6-9 years	43	31.9
> 9 years	34	25.2

4.2. Test of suitability

Cronbach's alpha test was used to check the reliability of the scale in the questionnaire. There were three times of performing this test. The result of the analysis shows that the factor F1 'Adverse weather' and F5 'Complex local culture' were removed for the first time because their coefficient of corrected item-total correlation is less than 0.3. Similarly, the factor F3 'Changes in governmental policies' and F7 'The appearance of new materials' was also removed in the second time. In the third time, the overall ratio of this test for all factors is 0.926. Based on the commonly accepted rule of thumb, the internal consistency of the collected data is perfect because the coefficient is more than 0.9. Next, because the numbers of data sets are greater than 50, the Kolmogorov-Smirnov test was used to check the hypothesis on a normal distribution (significance level of 0.05).

The hypothesis is stated as follows:

- Null hypothesis (H_0): the data is normally distributed.
- Alternative hypothesis (H_A): the data is not normally distributed.

The result indicates that all the p-values of the test are higher than 0.05. It means that the alternative hypothesis is rejected; thus, this study can use parametric tests for prospective analyses.

4.3. Analysis of mean

One-way analysis of variance (ANOVA) was used to analyze the difference between group means and their associated trend as well. Because multiple two-sample t-tests could result in an increased chance of committing a statistical type I error, ANOVA is useful in testing three or more means. The results show that very few factors have a statistical significance level of less than 0.05 (see Table 3). In detail, they include F22 and F25 for project party; F18, F25, and F27 for work position; and F19, F22, F24, and F27 for years of experience. It could be concluded that F22, F24, and F27 almost have the difference in mean between groups in each characteristic. These factors were then detected by the Tukey HSD posthoc test with a significance level of 0.05. The purpose of this test is to check the mean difference for groups in homogeneous subsets. The results demonstrate that all the significance level of the Tukey test is higher than 0.05. It means that these factors can be remaining. In addition, Levene's test is also employed to verify the assumption of equal variances across samples. The results indicate that most of the values of significance level are higher than 0.05. The factors with a value of less than 0.05 are F4, F8, F17, and F21 for project party; F6, F24, and F27 for work position; and F11 for years of experience. Generally, it can be accepted that the samples have equal variances.

Table 3. Significance level of Levene's and ANOVA test

Factor	Project party		Work position		Year of experience	
	Levene's	ANOVA	Levene's	ANOVA	Levene's	ANOVA
F2	0.058	0.118	0.673	0.095	0.476	0.346
F4	0.041	0.846	0.428	0.706	0.687	0.122
F6	0.926	0.976	0.008	0.748	0.397	0.789
F8	0.029	0.132	0.761	0.678	0.446	0.400
F9	0.084	0.370	0.659	0.051	0.530	0.164
F10	0.390	0.097	0.698	0.376	0.837	0.331
F11	0.079	0.066	0.764	0.114	0.034	0.278
F12	0.104	0.158	0.175	0.062	0.229	0.187
F13	0.766	0.843	0.156	0.608	0.867	0.381
F14	0.093	0.108	0.836	0.343	0.203	0.634
F15	0.124	0.320	0.322	0.269	0.342	0.149
F16	0.812	0.530	0.199	0.845	0.577	0.648
F17	0.027	0.279	0.955	0.723	0.056	0.915
F18	0.070	0.787	0.650	0.048 (0.058)	0.075	0.412
F19	0.646	0.997	0.580	0.115	0.471	0.021 (0.190)
F20	0.357	0.533	0.726	0.464	0.700	0.643
F21	0.036	0.784	0.129	0.704	0.748	0.694
F22	0.613	0.044 (0.137)	0.868	0.367	0.393	0.018 (0.079)
F23	0.594	0.263	0.205	0.577	0.226	0.674
F24	0.102	0.057	0.032	0.343	0.916	0.014 (0.119)
F25	0.101	0.018 (0.092)	0.702	0.048 (0.209)	0.153	0.054
F26	0.142	0.865	0.629	0.974	0.049	0.150
F27	0.502	0.704	0.041	0.017 (0.297)	0.176	0.001 (0.098)
F28	0.198	0.780	0.383	0.334	0.637	0.354

Note: value in parentheses is the significance level of Tukey HSD post-hoc test

The mean of the respondent's rating values was analyzed to rank the impact level of factors under the viewpoint of project parties (see Table 4). Based on the results of the analysis, it can be said that there is a high consensus in the ranking of three top influential factors between parties. These factors are F8 (mean = 3.22), F2 (mean = 3.21), and F10 (mean = 3.07); and three lowest influential factors, i.e., F13 (mean = 2.58), F12 (mean = 2.53), and F27 (mean = 2.44).

Table 4. Mean of respondent's rating value and its ranking

Factor	Overall		Clients		Consultants	Contractors		
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
F8	3.22	1	3.00	2	3.38	1	3.27	2
F2	3.21	2	3.33	1	3.20	2	3.30	1
F10	3.07	3	2.78	11	3.14	4	3.23	3
F22	2.99	4	2.96	5	3.18	3	267	15
F16	2.98	5	2.89	7	3.03	5	3.00	6
F15	2.98	6	3.00	2	2.92	9	3.03	5
F6	2.93	7	3.00	2	2.89	10	2.83	8
F20	2.89	8	2.85	9	2.95	7	2.77	10
F23	2.89	8	2.93	6	3.00	6	2.60	17
F17	2.84	10	2.89	7	2.87	11	2.73	12
F21	2.82	11	2.67	13	2.80	15	2.93	7
F28	2.80	12	2.70	12	2.85	12	2.77	10
F11	2.79	13	2.30	22	2.82	14	3.07	4
F9	2.78	14	2.60	16	2.95	7	2.57	19
F4	2.76	15	2.63	15	2.71	18	2.83	8
F26	2.71	16	2.52	18	2.78	16	2.63	10
F18	2.68	17	2.52	18	2.74	17	2.70	13
F25	2.67	18	2.81	10	2.85	12	2.07	24
F19	2.64	19	2.67	13	2.63	22	2.70	13
F14	2.63	20	2.37	21	2.68	21	2.60	17
F24	2.62	21	2.52	18	2.71	18	2.50	20
F13	2.58	22	2.56	17	2.69	20	2.50	20
F12	2.53	23	2.19	24	2.57	23	2.50	20
F27	2.44	24	2.22	23	2.52	24	2.43	23

4.4. *Factor analysis*

Exploratory factor analysis (EFA) technique was employed to sort out the main factors of design changes. The extraction method is principal component analysis. The rotation method is varimax with Kaiser Normalization. Barlett's test and Kaiser-Meyer-Olkin (KMO) test are adopted to check the suitability of data before applying the factor analysis technique. The required criteria of this technique include: the value of communality errors is higher than 0.5, the KMO coefficient is between 0.5 and 1.0, the significance level of Bartlett's test is less than 0.05, and the explained variance after rotation is greater than 50%.

The analysis has been performed three times. For the first time, factor F4, F8, F13, F21, and F28 were removed because they do not have factor loading values. At the second time, factor F6, F9, F11, and F16 were also removed because their factor loading value simultaneously appears in two components. At the third time, no more factors were removed. There are four principal components (PCs) extracted with eigenvalues greater than 1.0, which are abbreviated as PC1, PC2, PC3, and PC4. The Barlett's test of sphericity having significance at 0.000 indicates that the correlation matrix is not an identity matrix. The KMO coefficient proves that the sampling adequacy is high, with a value of 0.866. These two values justify that factor analysis can be applied in this study. The scree plot of twenty-eight items is drawn in Fig. 1. The value of explained variance before and after rotation is shown in Table 5. The result indicates that the total explained variance of four extracted components is 65.192% greater than 50%. It means that these components can represent the initial design change factors. Table 6 presents four loading coefficients obtained from factor analysis except for loading values less than 0.5.

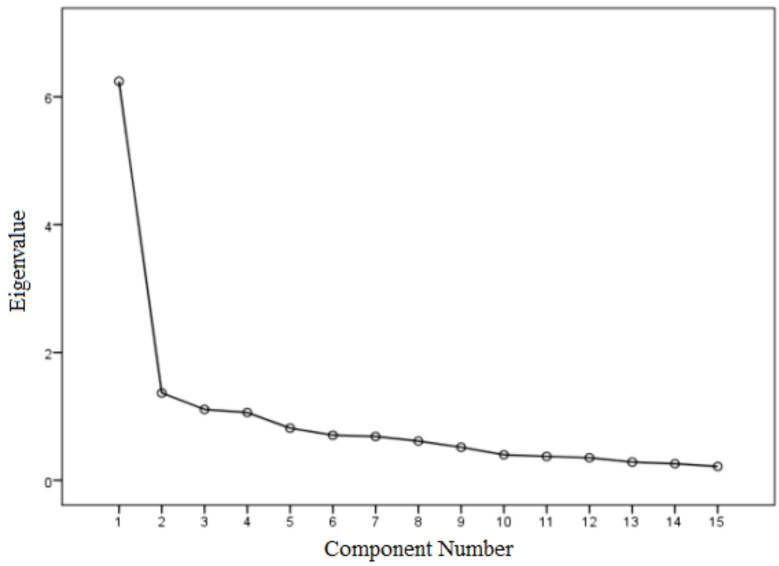

Figure 1. Scree plot of twenty-eight design change factors

Table 5. Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.243	41.621	41.621	6.243	41.621	41.621
2	1.366	9.105	50.727	1.366	9.105	50.727
3	1.109	7.396	58.123	1.109	7.396	58.123
4	1.060	7.070	65.192	1.060	7.070	65.192
5	0.816	5.441	70.634			
6	0.705	4.703	75.336			
7	0.685	4.567	79.903			
8	0.613	4.089	83.992			
9	0.517	3.444	87.436			
10	0.399	2.660	90.096			
11	0.373	2.486	92.582			
12	0.352	2.348	94.930			
13	0.285	1.898	96.828			
14	0.260	1.730	98.558			
15	0.216	1.442	100.000			

Extraction method: Principal component analysis

Table 6. Factor loading results

Factor	Content	Factor loading	Eigenvalue	% of variance	Cumulative %
	PC1		6.234	22.065	22.065
F25	Poor construction experience	0.842			
F23	Difficulties in the construction method	0.770			
F22	Low quality of completed work	0.767			
F24	Rational change suggestion	0.696			
F26	Mistakes during the construction stage	0.597			
	PC2		1.366	17.025	39.090
F19	Complex project characteristics	0.789			
F18	Application of inappropriate standards	0.677			
F27	Using a new method to speed up the construction progress	0.577			
F12	Inappropriate project completion duration	0.550			
F20	Poor design experience	0.507			
	PC3		1.109	13.887	52.977
F2	Unforeseeable soil condition	0.787			
F10	Unstable financial capacity	0.762			
F14	Indifference to consultants' opinion	0.582			
	PC4		1.060	12.215	65.192
F17	Changes to suit with the previously completed projects	0.808			
F15	Errors in drawings and specification	0.665			

Extraction method: Principal component analysis.
Rotation method: Varimax with Kaiser Normalization.
Rotation converged in 8 iterations.

PC1 consists of five initial factors that are all related to the contractor. Factor F25 'Poor construction experience' is a general cause for design changes. In the bidding stage, the client has selected the appropriate contractor for his project. However, in the construction stage, the experience and qualifications of this contractor are lower than expected. Therefore, this contractor did work with many defects or errors. It leads to a rework if these defects and errors are likely to be corrected. If not, the current design of the successive activities needs to be changed to fit the reality of the predecessive activities. Factor F23 'Difficulties in the construction method' means that the contractor does not almost, or even can not, propose a construction method for an activity because of its constraints of cost and time. The main construction methods have been, of course, stated before implementation; however, some of them were found as low feasibility based on actual working conditions. In this context, the client or the consultants need to make their decision causing a change of design. Factor F22 'Low quality of completed work' is a cause for a design change in the project. The underlying reason may be that the work requirements are very complicated, but the contractors have not considered them carefully before a performance. As a result, the quality of the completed work is lower than expected. If the project contains many repetitive works, the design changes are very efficient for the next time to improve the quality of completed works. Factor F24 'Rational change suggestion' is a cause that regularly occurs in reality both the construction stage and the design stage. During construction, the contractor found that there is a conflict between design drawings; thus, this contractor proposed an appropriate suggestion to change the design. Factor F26 'Mistakes during the construction stage' is the main reason for the significant repairs on the construction site. Typically, construction errors are derived from the indifference of the supervisors in their works. Many of those errors cannot be solved because it is impossible to propose a suitable solution. Therefore, the related party will require several changes in the initial design.

PC2 also includes five factors: F19 'Complex project characteristics', F18 'Application of inappropriate standards', F27 'Using a new method to speed up the construction progress', F12 'Inappropriate project completion duration', and F20 'Poor design experience'. Regarding factor F19, the contractors have to propose appropriate construction methods to face the complex characteristics of the project. If these methods require a lot of cost and time, the project client will not choose them. As a result, the design consultants are responsible for making changes in their drawings as much as they can. Regarding factor F18, using inappropriate standards of the designer is always a critical problem even though it has a low probability of occurrence. Of course, if it is found before construction, it is no problem, whereas if it is in the construction stage, it leads to mistakes in the contractor's completed works due to the wrong design. Regarding factor F27, the construction schedule is always accelerated by the owner. To do this acceleration, the contractor must use a better construction method; therefore, the design may be changed significantly. Regarding factor F12, any investor in the construction sector expects the project to be completed as soon as possible. In this case, the designers have to select an appropriate alternative for their design. For example, in order to execute a construction project quickly, the designers should change their design from an in-situ casted structure to an assemble structure. Regarding factor F20, poor experience in designing of the designer is a very general cause for the design change problem a construction project. It may not meet all the requirements of the owner before and during construction. The project scope is often modified due to a lack of design experience. That is why the design of the project is also changed.

PC3 contains three factors: F2 'Unforeseeable soil condition', F10 'Unstable financial capacity', and F14 'Indifference to consultant's opinion'. In terms of factor F2, soil condition is always unforeseeable in the construction stage even though its properties have been clearly explained in the geotechnical investigation report. One of many consequences due to adverse soil conditions is that the pile cannot reach for the permitted load capacity. It causes a change in the design of foundation and basement work. In terms of factor F10, the owner's financial ability is also a direct cause of the change in design. Because the business market fluctuates irregularly and negatively, the clients have not enough money to continue to perform the project; thus, the clients have decided to change the project scope or materials during construction. It can be said that this is a cause that frequently happens in the current construction industry. In terms of factor F14, the indifference of the owners to the opinions of consultants or other parties commonly causes a big problem to the project because it leads to poor design or low efficiency.

Finally, PC4 comprises two factors: F17 'Changes to suit with the previously completed projects', and F15 'Errors in drawings and specification'. For factor F17, this is a particular reason for a design change in construction projects. In the construction phase, the clients and consultants found that there are conflicts with the previously completed project; hence the current plan must be changed so that it can be synchronous with the previous one. For factor F15, errors in drawings or specifications directly affect design changes of a project. This error is the cause that frequently happens in the construction phase, and the designer is, of course, the party who is mainly responsible for this problem.

4.5. Evaluation of overall impact of factors

The main results of factor analysis were adopted to evaluate the overall impact of initial factors on design changes. The steps to do the analysis include:

- Step 1: Define the correlation coefficient of each PC.
- Step 2: Define the weight of each component based on the coefficient above.
- Step 3: Define the eigenvalue of each factor for each component based on the factor loading values.
- Step 4: Propose an evaluation sheet for the overall impact of factors.

Based on the correlation analysis results, all coefficients are positive, with a significance level of 0.01 (see Table 7). Correlation strength has been adopted to define the individual weight of PCs. The rationale to employ the correlation coefficient as a weighting criterion is that a more correlative power of a factor has the highest effect on the overall level of design changes. The weight of each component is calculated by dividing its value of correlation coefficient by total value of all coefficients (see Table 8). Hence, an evaluation formula created from four PCs and their weight indices are written as follows:

$$\text{Overall Impact Index} = 0.259 \times PC1 + 0.258 \times PC2 + 0.246 \times PC3 + 0.237 \times PC4$$

Table 7. A correlation coefficient of the PCs

Component	PC1	PC2	PC3	PC4
PC1	1.000	0.640	0.488	0.462
PC2	0.640	1.000	0.505	0.438
PC3	0.488	0.505	1.000	0.465
PC4	0.462	0.438	0.465	1.000

Correlation is significant at 0.01 level (2-tailed)

Table 8. Weight of the PCs

Component	Sum of coefficients	Average coefficient	Weight
PC1	2.590	0.648	0.259
PC2	2.583	0.646	0.258
PC3	2.458	0.615	0.246
PC4	2.365	0.591	0.237
Total	-	2.499	1.000

Because four PCs are self-explanatory criteria of design changes, the weight of elements in each component has been defined based on loading results. It is determined according to the element's loading proportion in a particular component (see Table 9). The criterion used in this study to evaluate the overall impact of initial factors on the design changes includes five levels: (1) very low, (2) fairly low, (3) moderate, (4) fairly high, and (5) very high. The results of the evaluation show that the overall impact is 70.7 per the scale of 100. It means that the initial factors have a fairly high impact on the design changes (see Table 10).

Table 9. Weight of each element in the PCs

Factor	Content	Factor loading	Eigenvalue
	PC1	3.672	1.000
F25	Poor construction experience	0.842	0.229
F23	Difficulties in the construction method	0.770	0.210
F22	Low quality of completed work	0.767	0.209
F24	Rational change suggestion	0.696	0.190
F26	Mistakes during the construction stage	0.597	0.163
	PC2	3.100	1.000
F19	Complex project characteristics	0.789	0.255
F18	Application of inappropriate standards	0.677	0.218
F27	Using a new method to speed up the construction progress	0.577	0.186
F12	Inappropriate project completion duration	0.550	0.177
F20	Poor design experience	0.507	0.164
	PC3	2.131	1.000
F2	Unforeseeable soil condition	0.787	0.369
F10	Unstable financial capacity	0.762	0.358
F14	Indifference to consultants' opinion	0.582	0.273
	PC4	1.473	1.000
F17	Changes to suit with the previously completed projects	0.808	0.549
F15	Errors in drawings and specification	0.665	0.451

Table 10. Evaluation sheet for the overall impact of factors causing design changes on residential construction projects

#	Factor	Principal components	Weight	Mean	Field score (3) × (4)	Overall score (3) × (5)
(0)	(1)	(2)	(3)	(4)	(5)	(6)
		PC1	0.259	-	2.78	0.72
1	F25	Poor construction experience	0.229	2.67	0.61	
2	F23	Difficulties in the construction method	0.210	2.89	0.61	
3	F22	Low quality of completed work	0.209	2.99	0.62	
4	F24	Rational change suggestion	0.190	2.62	0.50	
5	F26	Mistakes during the construction stage	0.163	2.71	0.44	
		PC2	0.258	-	2.63	0.68
1	F19	Complex project characteristics	0.255	2.64	0.67	
2	F18	Application of inappropriate standards	0.218	2.68	0.58	
3	F27	Using a new method to speed up the construction progress	0.186	2.44	0.45	
4	F12	Inappropriate project completion duration	0.177	2.53	0.45	
5	F20	Poor design experience	0.164	2.89	0.47	
		PC3	0.246	-	3.00	0.74
1	F2	Unforeseeable soil condition	0.369	3.21	1.18	
2	F10	Unstable financial capacity	0.358	3.07	1.10	
3	F14	Indifference to consultants' opinion	0.273	2.63	0.72	
		PC4	0.237	-	2.90	0.69
1	F17	Changes to suit with the previously completed projects	0.549	2.84	1.56	
2	F15	Errors in drawings and specification	0.451	2.98	1.34	
		GRAND TOTAL				
		In the 5-point scale:				2.83
		Total percentage:				70.70
		RESULT OF EVALUATION				Fairly high

5. Comparison with other construction projects

The design changes happen in all types of construction projects. However, this study has only identified the main factors causing design changes in Vietnamese residential construction projects. It is kindly noted that numerous past studies have been conducted to discover the problems of design changes. The majority of these studies are related to the effect of design changes, change order, or project variation. A few studies are related to the identification of the root causes of the design changes. The results of the comparison (see Table 11) illustrated that most of the causes of design changes in construction projects come from the clients and consultants.

Table 11. Comparison with other construction projects

Author	Project type	Three common causes for design changes in construction projects		
		1	2	3
1. For residential projects				
This study(*)	Residential	Unclear requirements during the design phase(1)	Unforeseeable soil condition(4)	Unstable financial capacity(1)
Mohamad et al. [3]	Residential	Lack of coordination among various professional consultants(2)	Change of requirements/ specification(1)	Addition/ omission of scope(1)
Yap and Skitmore [27]	Residential	Modifications to the original design(1)	Addition of new work/scope(1)	Unclear initial design brief(1)
2. For other projects				
Tin [4](*)	All	Change order(1)	Change on project finance(1)	Poor design drawings(2)
Hsieh et al. [34](**)	Metropolitan public	Unforeseeable conditions(4)	Lack of design experience(2)	Complicated method(4)
Enshassi et al. [11](**)	All	Financial problem(1)	Lack of consultant's knowledge of available materials(2)	Conflicts between contract documents(4)
Memon et al. [10](**)	Public works	Unavailability of equipment(3)	Poor workmanship(3)	Design complexity(2)
Sun and Meng [6](**)	All	Change order(1)	Lack of construction experience(3)	Low qualification(2)

Note: (1), (2), (3) and (4) mean clients, consultants, contractors, and others; (*) and (**) mean domestic and oversea.

6. Conclusions and recommendation

Many studies on factors affecting the design changes have been made around the world in recent years. Design changes have regularly occurred during the construction phase, even though the project has been carefully prepared at all. In order to contribute to the whole picture of the design change problem of the construction sector in the world, this study was conducted to understand the design changes in residential construction projects. Compared with [3, 27], the practically significant difference of this study is that the overall impact of factors causing design changes on the project performance is evaluated through a proposed calculation sheet.

Based on 135 valid data sets, the factors causing design changes have been examined. First, the result indicated that 25/28 factors have the mean of respondent's feedback values higher than the mean of the scale. It means that these factors have a substantial impact on the occurrence of the design changes in residential construction projects. Among them, the three highest-ranking factors are 'unclear requirements during the design phase', 'unforeseeable soil condition', and 'unstable financial capacity'. In addition, there is no difference in mean between the respondent groups. Second, there are four PCs extracted from the initial factors with total variance explained of nearly 61.2%, and the overall impact of the factors is then evaluated as 70.7 per the scale of 100 based on these PCs. Finally, a valuable comparison on the most occurred factors of design changes in construction projects, in general, and in residential projects, in particular, has been made and discussed.

This study has some specific limitations, including: (1) the number of data samples is quite small and in one city of Vietnam; (2) sampling method is based on non-probability sampling; (3) some factors are grouped into a PC without considering the relationship on the content between them. It is recommended that all project parties should clearly understand their responsibility in preventing and controlling the design changes during construction. Clients need to focus on giving their requirements to the consultants clearly and thoroughly. Moreover, clients also need to prepare the finance of the project well before construction. Consultants, especially designers, should focus on the investigation of soil condition, prediction of market demand, analysis of material price variation, and issue of proper design drawings and specification to ensure that the project can be completed according to all client's requirements. Contractors should actively collaborate with the clients and consultants in the construction phase of the project to reduce mistakes or errors in the completed works.

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