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A Structural Equation Model to Investigate the Risk of Change Orders in Residential Building

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Key words: Change orders, construction industry, structural equation model, second-order factor model, residential buildings

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Abstract: Change orders have become a common phenomenon, especially in developing countries which requires a continuous and systematic analysis of the causes of change orders depending on the probability and impact of each factor. An initial list of causes for change orders was suggested from previous research and the final list was developed using Delphi technology. The 200 questionnaires were collected to investigate the proposed model which includes a second-order model to predict the overall change orders on residential projects. Six factors were eliminated to match the model with the recommended measurements. The main factors affecting change orders were the different site conditions and changes in design requests. The final structural equation model provides insight into the effect of measured and latent factors that are not clear in conventional equations. The results of this research are expected to improve the performance of building projects in Egypt by identifying the main causes of change order risks, hence, a risk response plan can be developed.

INTRODUCTION

Change orders are common phenomena in construction projects especially in developing countries such as Egypt where almost infrastructure projects suffer from them. In the event of any variation, A change order is issued[1]. The variation is described as any modification in specification or design which affects the amount or quality of the work[2]. Fisk classified the changes into two types directed and constructive changes[3]. The client's request from the contractor to add works undefined in the original contract is considered direct changes. Whereas Informal amendments to a contract due to a special procedure are considered constructive changes. Ruben classified the changes into two kinds; useful change and harmful change. A useful change is a change to improve quality, lower cost or schedule, or overcome a technical problem within the project. The harmful change is defined as any modification having an adverse influence on project performance or stakeholder satisfaction[4].

Literature review: Construction projects contain many complex processes that cannot be identified accurately in the early stages of the project. One of the main problems facing construction projects is the change orders during the construction phase. Jawad *et al*.[5] noted that most of the change orders in large construction projects were related to structural issues. The larger the project, the greater the probability of change orders[6]. Change orders may lead to differences in the amount in the contract, consequently, it is essential to restrain the variation in projects[7].

The causes of change orders: The main causes of change orders in highway projects in Jordan identified by Msallam *et al*.[8] were changes in scope, changes in the schedule, obscure and complex design, contract differences, sociocultural factors, poor coordination, employer financial problems, safety and health requirements, changes in design and changes in the policies of the government. Another study for identifying the causes of change orders in Indonesia found that the key causes were errors in design, differing site conditions, estimation errors, insufficient studies, incomplete contract documents, safety requirements, ambiguous contract conditions, Force Majeure and administrative changes. The main causes identified by Hansen *et al*.[9] in Indonesia were design/specification changes, scope changes, site condition changes, schedule changes, policy changes and imported materials. Halwatura and Ranasinghe[10] identified 55 reasons for change orders in Sri Lanka's road construction projects. The top factors were the misjudgment, unforeseen site condition, political pressure during the construction phase, poor on-site investigations and changes initiated by the client[10]. The effect of change orders on the project cost depends on the reason for the change. They found that the additional work factor has the highest impact on the cost, followed by a change in quality, then a change in the level or dimension and the omission of work[12].

The effect of change orders: The effects of change orders on construction projects include additional payments to the contractors, increased overhead, delayed schedule, rework and demolition[13]. The impacts of the change orders in the Sultanate of Oman were delays in schedule, disputes and cost overruns[1]. Bhadmus *et al*.[14] observed that the increase in project cost, delayed work progress, cash flow crises, reduction of the contractor profits, project abandonment, deterioration of quality, logistical delays, re-work and project demolition were the most impacts of change orders in the construction industry in Nigeria. Bello and Saka[15] declared that the impacts of change orders were the deterioration of quality, increased project cost, delayed project time, logistical delays, re-work, demolition, loss of productivity and delayed procurement.

Sunday *et al*.[16] believed that change orders lead to 25-78% of cost overruns and 27-68% of project time overruns. There is a 42% probability that a project will incur cost overruns due to change orders. These overruns range between 3-49%[16]. The change orders in construction projects increase the cost between 10% to 15% of the contract value and reduce productivity from 10-20%[17]. Mhando *et al*.[18] announced that the increase in construction cost due to change orders in Tanzania ranged between 6-10% of the original contract cost.

Although, there is a lot of research that defines the causes of change orders in construction projects, there is a gap in research that focuses on the causes of change orders in residential projects, especially. In addition, to this, the above-mentioned researches were identifying the causes of change orders based on the impact of the change orders only but they do not consider the probability while this study investigates the causes as risk factors taking both probability and impact into consideration. This research aims to explore the measured and latent variables that cause change orders in residential projects and to develop a model for total change orders.

MATERIALS AND METHODS

Methodology of research: The methodology of this research consists of four parts. The first part concerns the previous studies including three elements. The first element includes the review of the literature to recognize the impact of change orders on the project performance and to identify the root causes for change orders in residential projects. While the second element concerns the interviews with experts to obtain consensus about the key factors that cause change orders and the third element for developing a theoretical structural equation model extracted from the literature review. The second part relates to data collection and includes three elements. The first element includes preparing a questionnaire to determine the probability and impact of each factor on a five-point scale. The second element is to determine the required sample size based on the number of construction engineers in Egypt. While the third element concerns collecting data from employers, consultants and contractors. The third part concerns the analysis of data and consists of four elements. The first element is the analysis of data using AMOS 24. The second element for checking the reliability of constructs. The third element about determining the risk score for each factor. The fourth element to propose the overall change orders equation based on the measured and latent variables. In the last part, the results of the study were discussed with the results of the previous studies followed by a conclusion.

Selection of the key factors: The main causes of change orders in residential projects were classified into four main groups; Employer (EM), Consultant (CS), Contractor (CN) and External (EX). The employer's group contains nine factors; change in scope, delay the decision-making process, lack of strategic planning, change in specifications by the employer, employer's financial problems, employer intervention, inadequate project objectives, desired profitability and obstinate nature of the employer[19-29]. The consultant's group consists of eight factors; change in design request, the complexity of the design, lack of consultant's knowledge of available materials and equipment, change in specification by the consultant, errors and omissions in design, conflicts among contract documents, poor drawings and inadequate design[25, 30-33]. The contractor's group consists of eleven factors; unavailability of equipment, fast-track construction, long-lead procurement, lack of communication between the parties, value engineering, bad sub-contractor or supplier, contractor's financial difficulties, health and safety requirements, lack of involvement of the contractor in design, unavailability of skills and unfamiliarity with local conditions[2, 3, 11, 25, 31, 34, 35]. The external group contains six factors; weather conditions, change in economic conditions, force majeure, unforeseen problems, differing site condition and sociocultural factors[3, 8, 9, 11, 19, 31, 34,, 36-38].

Questionnaire design: Ten experts who have at least 15 years of experience in residential projects were selected. The Delphi technique was used to achieve consensus among experts on the causes of the change orders in residential projects. The initial list of factors was sent to the experts then the expert's opinions were summarized and redistributed for further comments. In this research, the consensus on the most important causes for change orders in residential projects was reached among the experts after four rounds. Hence, these causes constitute the final list of orders for change in residential projects in Egypt.

In this study, a qualitative approach was chosen to investigate the conceptual model in the context of residential construction in Egypt. For gathering the data on the identified characteristics, a structured questionnaire was developed. The respondents assessed the probability and impact of each factor in the final list by selecting one of the residential projects in which they had participated. A five-point Likert scale was adopted to assess the probability and impact where refers to a very low category, represents a low category, indicates a medium category, represents a high category and denotes a very high category.

Respondent's profiles: Participants in this research were selected from specialists working in the construction sector in Egypt including the employers, consultants or contractors. The detailed statistics of the respondent's profiles and their classifications according to their experience in the construction sector and their professional roles are presented in Table 1.

The target population in this research are residential engineers who represent a very large number and therefore the sample size can be calculated using Eq. 1. To reach the 5% confidence interval at the 95% confidence level, the target number of questionnaires was 246. The 270 questionnaires were sent. Despite numerous attempts to obtain a larger sample for research, only 200 valid questionnaires were received from 70 companies which means that the confidence interval was 5.54% at the 95% confidence level:

$$n = \frac{Z^2 * p * (1-p)}{C^2} \tag{1}$$

where, n represents the sample size, Z equal to 1.96 according to the 95% confidence level, p is the percentage of picking a choice expressed as a decimal which was 0.2 as there is five choose from very low to very high and C is the confidence interval expressed as a decimal.

Responses to the questionnaires were highly reliable due to the experience of respondents and the understanding of the questionnaire as well as the personal contact with respondents[39]. The highest portion of respondents participating in the questionnaire was from the contractors involved in residential projects by 66%, followed by the consultants with 23% while the respondents from the employers were about 11%. The average experience of the respondents was nearly 10 years while 34% of them had >15 year's experience in residential projects as shown from Table 1.

Theoretical framework: Hughes *et al*.[40] reported that the sources of the changes were the employers or designers or external factors and changes in legislation. Employers can change their mind about what they have requested before the work is completed. While the designers may not have completed all design and specifications before awarding the contract. Whereas

Table 1: The profiles of the respondents

	Experience (Years)						
Role of the profession (%)	3-5	5-10	10-15	15-20	>20	Total	Role (%)
Employer	8	4	3	3	4	22	11
Consultant	9	11	7	11	7	45	23
Contractor	41	28	23	25	16	133	66
Total	58	43	33	39	27		
Experience (%)	29	22	17	20	14		

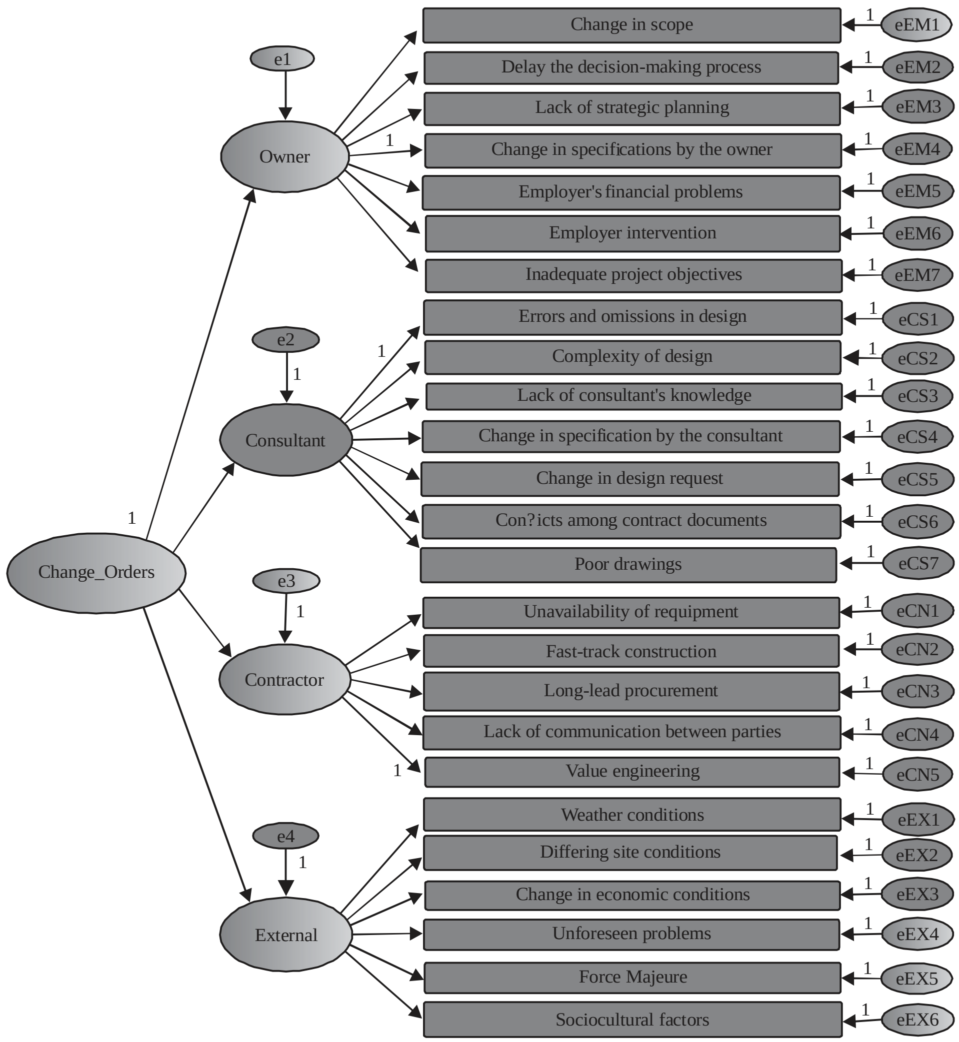

Fig. 1: The initial structural equation model

changes in legislation and other external factors may impose changes on the project. The previous researches supply with a theoretical fundamental to develop the theoretical framework in this research. It is hypothesized that there are four latent variables; the employer (EM), the consultant (CS), the contractor (CN) and the external (EX) which causes the change orders in residential projects. To estimate the effect of these latent variables on change orders in residential projects, four hypothesis were sat out in this study as follows:

Hypothesis 1: The frequency of occurrence of factors caused by the Employer (EM) affects the overall impact on change orders (CO) in residential projects.

Hypothesis 2: The frequency of occurrence of factors caused by the consultant (CS) affects the overall impact on change orders (CO) in residential projects.

Hypothesis 3: The frequency of occurrence of factors caused by the contractor (CN) affects the overall impact on change orders (CO) in residential projects.

Hypothesis 4: The frequency of occurrence of factors caused by the External to the project (EX) affects the overall impact on change orders (CO) in residential projects.

The theoretical framework was developed using the second-order factor model. The initial framework for the causes of change orders in residential projects was presented as a philosophical chart of the structural model in Fig. 1. The arrow indicates the path of the proposed effect on the structural model.

Model specification and refinements: The primary proposed structural model was analyzed using AMOS 24.0. The initial structural equation model based on

Table 2: The causes of change orders

I.D.	Primary questionnaire	Final questionnaire	Final structural equation modeling
EM1	Change in scope	Change in scope	Change in scope
EM2	Delay the decision-making process	Delay the decision-making process	Delay the decision-making process
EM3	Lack of strategic planning	Lack of strategic planning	----
EM4	Change in specifications by the employer	Change in specifications by the employer	Change in specifications by the employer
EM5	Employer's financial problems	Employer's financial problems	Employer's financial problems
EM6	Employer intervention	Employer intervention	Employer intervention
EM7	Inadequate project objectives	Inadequate project objectives	Inadequate project objectives
EM8	Desired profitability	----	----
EM9	Obstinate nature of employer	----	----
CS1	Change in a design request	Change in a design request	Change in a design request
CS2	The complexity of the design	The complexity of the design	The complexity of the design
CS3	Lack of consultant's knowledge of available materials and equipment	Lack of consultant's knowledge of available materials and equipment	----
CS4	Change in specification by the consultant	Change in specification by the consultant	Change in specification by the consultant
CS5	Errors and omissions in design	Errors and omissions in design	Errors and omissions in design
CS6	Conflicts among contract documents	Conflicts among contract documents	Conflicts among contract documents
CS7	Poor drawings	Poor drawings	----
CS8	inadequate design	----	----
CN1	Unavailability of equipment	Unavailability of equipment	Unavailability of equipment
CN2	Fast-track construction	Fast-track construction	Fast-track construction
CN3	Long-lead procurement	Long-lead procurement	Long-lead procurement
CN4	Lack of communication between parties	Lack of communication between parties	----
CN5	Value engineering	Value engineering	Value engineering
CN6	Bad sub-contractor or supplier	----	----
CN7	Contractor's financial difficulties	----	----
CN8	Health and safety requirements	----	----
CN9	Lack of involvement of the contractor in the design	----	----
CN10	Unavailability of skills	----	----
CN11	Unfamiliarity with local conditions	----	----
EX1	Weather conditions	Weather conditions	----
EX2	Differing site conditions	Differing site conditions	Differing site conditions
EX3	Change in economic conditions	Change in economic conditions	Change in economic conditions
EX4	Unforeseen problems	Unforeseen problems	Unforeseen problems
EX5	Force Majeure	Force Majeure	Force Majeure
EX6	Sociocultural factors	Sociocultural factors	----

theoretical projections and previous empirical results is initially acceptable even without the achievement of standard indicators. The final model must achieve the recommended measures for the Goodness-Of-Fit (GOF). Hence, the model that meets theoretical expectations and the GOF requirements will be investigated[41]. To achieve the GOF indices, modifications to the model were made to improve its suitability to the accepted levels. The GOF metrics of the fourth model achieved the recommended indices therefore it was adopted as the final SEM in this research. In the final SEM, six factors were eliminated because of their low impact in SEM[42]. The eliminated factors were Lack of strategic planning (EM3). Lack of consultant's knowledge of available materials and equipment (CS3), Poor drawings (CS7), Lack of communication between the parties (CN4), Weather conditions (EX1) and sociocultural factors (EX6). The final structural equation model was illustrated in Fig. 2. Table 2 shows the causes of the change orders which were included in the primary questionnaire in the final questionnaire and final structural equation model.

The Chi-square (χ^2) can be estimated from Eq. 2, thus the result of the Chi-square test will be dependent on the sample size. In the large samples, the results will be significant hence, it should be rejected. Therefore, the researchers sought alternative indicators to assess the fitness of the model. The normed Chi-square ($N\chi^2$) is a good indicator as the sample size is not taken into consideration[43]. The normed Chi-square can be estimated using Eq. 3. The recommended value of the normed Chi-square between 1.0-2.0[44]:

$$\chi^2 = (N\text{-}1)^* F_{ML} \quad (2)$$

Where:

χ^2 = The Chi-square
N = The sample size which was 200 in this research
F_{ML} = The maximum likelihood estimation function which was 0.918

Hence, the Chi-square value is 183:

$$NX^2 = X^2/df \quad (3)$$

Where:

NX^2 = The normed Chi-square
X^2 = The Chi-square value
df = The degree of freedom which was 145

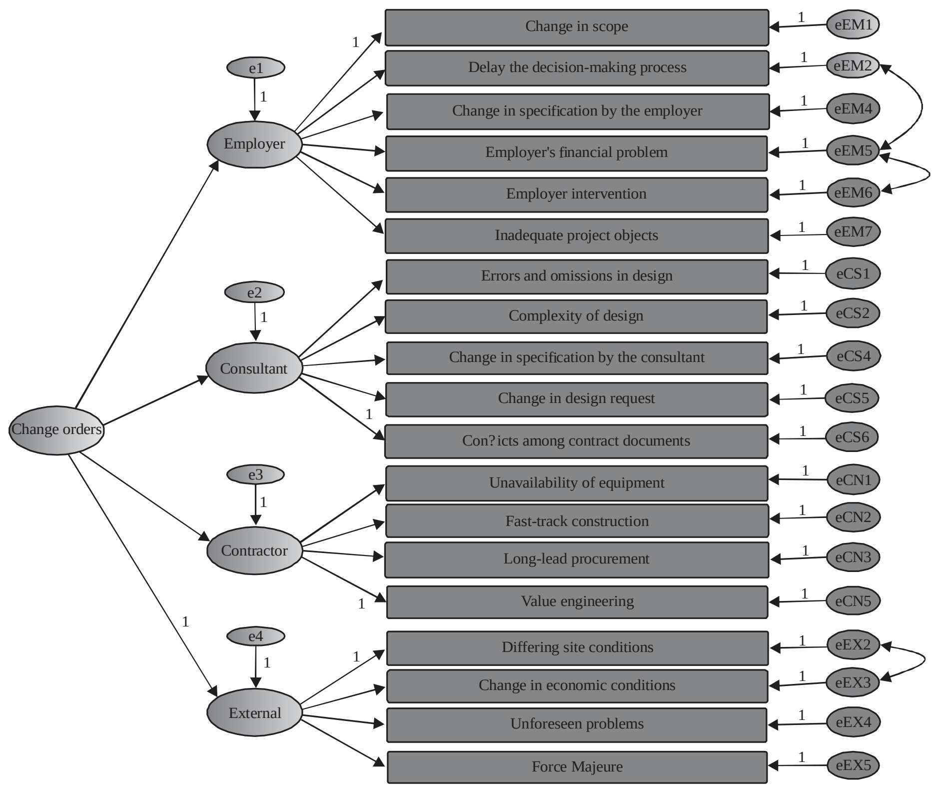

Fig. 2: The final proposed structural equation model

Hence, the value of normed Chi-square was 1.26 which is accepted. The Root Mean Square Error of Approximation (RMSEA) shows the appropriateness of a model having optimally selected for unknown variables with the population variance matrix[45]. RMSEA index becomes one of the most important fit indices, due to its allergy to the determined variables in the model. RMSEA values between 0.05 and 0.08 represent an indication of good fitness of the model and values above 0.08 indicate poor fitness of the model[42]. Whereas, the upper limit of RMSEA which satisfy the consensus among the experts is 0.07[46]. The Root Mean Square Error of Approximation (RMSEA) was calculated using Eq. 4. In this study, the value of RMSEA was 0.036:

$$\text{RMSEA} = \sqrt{\frac{\text{Max}(0, X^2_{ML}\text{-df}_{ML})}{\text{df}_{ML}\text{*(N-1)}}} \quad (4)$$

Incremental fit indices compare the chi-square value in the default model with its value in the null model[47]. The null model is the worst situation as all measured parameters are not interrelated. Normed Fit Index (NFI) evaluates the model by matching the value of Chi-square of the default model to the value of Chi-square of the null model. The range of the NFI is between 0 and 1. To obtain a good fit model, Bentler and Bonett advised the NFI values should be >0.90[48] while Hu and Bentler[49] mentioned that NFI should not be <0.95. The comparative compatibility index (CFI) can be considered as the second generation of NFI where the sample size is taken into consideration. CFI performance is considered better than NFI especially if the sample size is relatively small[44]. The CFI values range from 0.0 to 1.0 and the closer the values to 1.0, the more appropriate the model. The recommend CFI values should >0.95 and should not be <0.90 in all cases[49]. CFI can be calculated using Eq. 5:

$$\text{CFI} = \frac{\text{Max}(0, X^2_M\text{-df}_M)}{\text{Max}(0, X^2_B\text{-df}_B)} \quad (5)$$

Where:
X^2_M = The Chi-square
df_M = The degree of freedom for the default model
X^2_M = The Chi-square
df_M = The degree of freedom for the null model

In this research, CFI was 0.95 which means that this model is 95% better than the baseline model which assumes no relationship between variables.

In the final model, the normed Chi-squared was 1.26, the goodness of fit index value was 0.92, the Comparative Fit Index (CFI) value was 0.95, the Tucker-Lewis (TLI) value was 0.94 and the Incremental Fit Index (IFI) value was 0.95 which indicate strong evidence that the SEM model is acceptable. The value of the Root Mean Square

Error of Approximation (RMSEA) was 0.036 indicating that the final model was accepted with a high confidence level[50-52].

Reliability of constructs: The reliability of the constructed test was conducted to estimate the competence of the model in concern with the relationships between the measured and the latent variables[53]. Most researches that used SEM still applied alpha Cronbach rather than using the SEM-based reliability coefficients. Reliability analysis demonstrates the accuracy of measuring latent variables using a subjective scale. The Alpha cronbach reliability test was performed to evaluate the reliability of the default model for use in SEM[51]. The threshold value for Alpha cronbach representing the acceptable level is 0.7. Alpha cronbach was 0.861 for the final questionnaire. Cho suggested a formula for estimating the reliability coefficients in the second-order factor model which is represented in Eq. 6[54]:

$$\rho'_{SOF} = \frac{\left(\sum_{p=1}^{m} \sum_{i=1}^{k} \lambda_{ip} * \Upsilon_p\right)^2 + \sum_{p=1}^{m} \left(\sum_{i=1}^{k} \lambda_{ip} * \left(1-\Upsilon_p^2\right)^{1/2}\right)^2}{\sigma_x^2} \quad (6)$$

where, ρ'_{SOF} represents the reliability coefficient of the second-order factor model, m represents the number of key latent factors which was four in this research, k number of factors in the group, λ_{ip} represents the factor loading in the group, γ_p represents the factor loading for the key latent factor and σ_x represents the average covariance between items. In this research, the reliability coefficient of the second-order factor model was 0.835 which indicates good reliability of the final SEM.

RESULTS AND DISCUSSION

The factor score for each variable can be calculated using Eq. 7. The overall score for each factor and their ranking were shown in Table 3:

$$FS = IGS*GS \quad (7)$$

Where:
FS = The factor score
IGS = The in-group factor's score and the group score

The top causes for change orders were differing site conditions, change in design request, the complexity of the design, Force Majeure and errors and omissions in design and (Table 2). While the lowest influence factors were fast track construction, long-lead procurement, unavailability of equipment, conflicts among contract documents and employer intervention. The most important factor was differing site conditions which have the highest score of 1.0, followed by the change in design request which has a score of 0.88. The complexity of the design factor ranked third with a score value of 0.88. The factor errors and omissions in the design ranked fourth with a factor score of 0.86.

Table 3: Ranking of causes of change orders

Causes of change orders	GS	IGS	FS	Ranks
Differing site conditions	1.00	1.00	1.00	1
Change in design request	1.00	0.88	0.88	2
The complexity of the design	1.00	0.88	0.88	3
Errors and omissions in design	0.98	0.88	0.86	4
Force majeure	0.83	1.00	0.83	5
Change in scope	1.00	0.79	0.79	6
Change in economic conditions	0.77	1.00	0.77	7
Employer's financial problems	0.96	0.79	0.76	8
Delay the decision-making process	0.94	0.79	0.74	9
Change in specifications by the employer	0.94	0.79	0.74	10
Change in specification by the consultant	0.83	0.88	0.73	11
Value engineering	1.00	0.72	0.72	12
Unforeseen problems	0.70	1.00	0.70	13
Inadequate project objectives	0.87	0.79	0.68	14
Employer intervention	0.84	0.79	0.66	15
Conflicts among contract documents	0.75	0.88	0.66	16
Unavailability of equipment	0.77	0.72	0.55	17
Long-lead procurement	0.70	0.72	0.50	18
Fast-track construction	0.52	0.72	0.37	19

From the final SEM, the estimated values of the latent factors of the employer, consultant, contractor, external and overall change orders factors were presented in the equations 8-12, respectively:

$$EM = EM_1 + 0.94*EM_2 + 0.94*EM_4 + 0.96*EM_5 + 0.84*EM_6 + 0.87*EM_7 \quad (8)$$

$$CS = 0.98*CS_1 + CS_2 + 0.83*CS_4 + CS_5 + 0.75*CS_6 \quad (9)$$

$$CN = 0.77*CN_1 + 0.52*CN_2 + 0.70*CN_3 + CN_5 \quad (10)$$

$$EX = EX_2 + 0.77*EX_{32} + 0.70*EX_{42} + 0.83*EX_5 \quad (11)$$

$$OCO = 0.789*O + 0.878*S + 0.721*C + EX \quad (12)$$

Where:
EM = The employer latent variable
CS = The consultant latent variable
CN = The contractor latent variable
EX = The external latent factor
OCO = The overall change order latent variable

The external latent factor has the maximum effect on the change orders with a group score of 1.0, followed by the consultant latent factor which has a group score of 0.88. The employer latent factor was come in third place with a group score of 0.79 while the contractor latent factor was ranked last with a group score of 0.72. Ibn-Homaid *et al*.[55] revealed that consultants are mostly responsible for the change orders. Enshassi *et al*.[32]

studied 64 reasons for change orders in construction projects in Gaza and found that the reasons for change orders resulting from the consultant are more important than the reasons related to the employer. Although, the score of the consultant group was higher than the score of the employer group in this research, the external group was the highest score.

The most important factor in this study was the differing site condition factor and ranked second in the study of Senouci *et al*.[20] in Qatar, ranked sixth in the study of Muhammad *et al*.[35] in Nigeriaand identified as one of the key causes in the study of Hansen *et al*.[10] in Indonesia. The most effective factor in the group of the consultant is the change in design request which was ranked second in this study while this factor was one of the key factors in the study of Hansen *et al*.[10] in Indonesia, ranked second in the study of Halwatura and Ranasinghe[11] and ranked fourth in the study of Muhammad *et al*.[35] in Nigeria. The most important factor in the employer group is the change in scope which was ranked sixth in this study. It is worth mentioning it was one of the key factors in the studies of Hansen *et al*.[10] in Indonesia, Senouci *et al*.[20] in Qatar, Msallam *et al*.[8] in Jordan, Muhammad *et al*.[35] in Nigeria and Arain and Pheng[56] in Singapore.

Simple summary: Frequently, changes occur in housing projects, especially in developing countries such as Egypt which may lead to an increase in the cost and the total time of the project. The causes of change orders are categorized depending on the source into four groups; owner, consultant, contractor and external. The 200 valid questionnaires were received. A theoretical framework was developed based on a second-order model including the four major latent variables in the first order and the overall change orders in a second order. The results of the SEM model show that the different site conditions factor was ranked first followed by the change in design request while the fast track factor was ranked last.

CONCLUSION

Residential projects suffer from the increase in time and cost, especially in developing countries such as Egypt. One of the most causes of these problems is the change orders which may happen several times in the same project. The causes were classified according to the source into four groups; employer, consultant, contractor and external. This research considered the causes of change orders as risk factors. Hence, this study investigated the effect of each factor based on its probability and impact. Based on the previous studies, a primary list of causes was constructed. The final list was developed with the assistance of ten experts using the Delphi technique. A structured questionnaire was developed to determine the probability and impact of each factor and 200 valid questionnaires were received.

A theoretical frame was developed depending on a second-order model including the four key latent factors in the first order and the change orders latent factor as a second order. To fit the model with the recommended indices six factors were eliminated. In the final SEM, the normed Chi-squared was 1.26, the value of the Root Mean Square Error of Approximation (RMSEA) was 0.036 and the other values of indices achieve the recommended values which indicate strong evidence that the SEM Model is acceptable. The results of the SEM Model show that the factor of differing site conditions was ranked the first cause for change orders followed by the change in design request while the factor fast track construction was ranked last.

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