ANALYSING TYPICAL FACTORS FOR THE EARLY PREDICTION OF VARIATIONS

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Within the standard forms of construction contracts, there are provisions allowing the client to make changes. In practice, in the construction phase, many problems can occur following the issue of variations resulting in delays, disruption, additional expenses and potential disputes. Therefore it was considered important to develop a methodology enabling the early prediction of unexpected variations that would allow the parties involved to take any necessary actions in anticipation of these events. This paper aims to identify and analyse the typical project factors that could be used as indicators for the early prediction of variations occurring in construction projects. The typical project factors were identified and developed from a literature research and a pilot questionnaire which was sent to a representative samples of practitioners. These typical project factors will be discussed and analysed as an initial finding in order to develop a methodology for the early prediction of variations.

Keywords: early prediction, model, variations.

INTRODUCTION

Variations have become an almost inevitable part of the construction process. Even for construction projects that are carefully planned and try to adapt a high degree of consistency in their initial agreements, it is almost impossible to construct the project totally identical to the original design used for tender (Thomas 2001). In many cases, variations can lead to conflict between the parties involved. Conflicts can be managed, however these conflicts can easily result in disputes (Fenn *et al.* 1997). When disputes come into place, resolutions will be required. If the disputes can not be resolved by the involved parties, then intervention by a third party, such as adjudicator, will be necessary for a decision (Latham 1994). Third parties will also need to consider involve additional direct and indirect costs derived from the delays; any time and expense incurred in preparing the delay claims document it self could be substantial (Alkas *et al.* 1996). Furthermore in another construction area, it has been reported that change orders (variations) have significantly reduced the labour efficiency by up to 15.24% on electrical works (Hanna *et al.* 1999b) and between 5-8% on mechanical construction projects (Hanna *et al.* 1999a.).Therefore, it is considered crucial to identify potential variations as early as possible in order to minimise the unnecessary additional cost which can occur from conflicts, disputes, delays and even decreasing efficiency of the labour during the project execution.

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VARIATIONS

A variation was defined as an agreed alteration or modification by the parties of a pre-existing contract (Wallace 1995). The range of this alteration or modification was considered being subject to certain extras, additions, deductions, enlargements, deviations, alterations, substitutions and omissions by the New South Wales Court of Appeal in *Arcos Industries v. Elect Commissions of New South Wales* (1973) case.

There are two types of variations; namely, variations expressly authorised under the term of the contract and variations to the terms of the contract itself (Chappel 2000). However, this paper narrows the discussion to all variations related to the contracts and expressly authorised under the terms of contract that are necessary for the completion of the original scope of works. It will not include additional works that may not be relevant and require a separate contract. Variations can also be considered in the case of mistakes in the tender documents, or waivers by owners and the promise to pay (Wallace 1995) and also by a contractor's proposal in the case of emergency works regarding safety and/or compliance with statutory regulations (Twort & Rees 1995) or simply for a contractor's own benefits i.e. cheaper solutions and/or impracticality (Hibberd 1986).

In order to determine whether a particular work can be treated as a variation or should be included in the original scope of works, it is very obvious that it will depend on the clauses contained in the contract documents. Standard forms of contracts have been designed to standardise the duties of contractors, employers and engineers and to distribute the risks fairly (Abrahamson 1956). Therefore, it is considered crucial to assess the treatment of variation events under these standard forms.

This paper concentrates on variations occurring within the traditional procurement system with lump sum contracts since the traditional system is still one of the most widely used procurement systems. This is supported also by the necessity to deal with variations in lump sump contracts as using lump sum contracts can create conflicts where circumstances require flexibility and change (Nahapiet & Nahapiet 1985).

AIM AND METHODOLOGY

The aim of this paper is to identify typical project factors leading to variations in construction projects and discuss these project factors as an initial finding in developing a methodology for the early prediction of the variations. The methodology applied in this paper is firstly to identify several typical project factors that might influence the occurrence of variations by literature research from previous studies and cases. In the next step, these typical project factors are confronted to a representative group of respondents representing practitioners from the real world in a pilot questionnaire. The results from this pilot questionnaire are discussed including the extent of these findings in order to develop the methodology. The methodology for the early prediction of the variations will be expected to be a useful tool in order to predict the likelihood of the occurrence of variations. This can be applied at an early stage in the construction project cycle based on a model developed from an organisation's own database of previous projects.

THE PILOT QUESTIONNAIRE

The pilot questionnaire was submitted to 111 respondents at 8 February 2002 and the closing date of the responds was established 1 March 2002, giving the total period of 3 weeks. One respondent was not taken into account since the address was not valid and the questionnaire was sent back to the sender, leaving 110 potential respondents. The pilot questionnaires were sent to practitioners from all over United Kingdom i.e. England, Scotland, Wales and Northern Ireland. The returned and completed pilot questionnaires received were 55 questionnaires which give: 55/110 = 50 % as the response rate. These respondents' experience ranged from 10 – 40 years with a mean of 31.39 years and mode 30 years experience. Their occupations varied from Quantity Surveying Manager, Building Finance Manager, Project Manager, Contractual Manager and Director of Contract, Building Economist, Project Co-ordinator to Head of Construction Management.

The respondents were asked to:

- Express their degree of agreement to the identified project factors from the literature study on a Likert scale from 1 to 5 (strongly disagree-disagree-neutral-agree-strongly agree). This was to show how the identified project factors were relevant in the real world. As the data are ordinal, it is established that the project factor will be considered acceptable if the mode is at least = 3 which means majority of the respondents have failed to deny the project factor as a significant factor in the occurrence of variations.
- Add other project factors according to their own experience. All of these additional factors are counter-checked to further literature study and will be considered if there are literature supports for these factors.
- Rank all the project factors. The ranking of the project factors is crucial in order to test whether there are any differences in perception of these respondents towards the rank/degree of importance for these project factors using a non-parametric statistical analysis (Friedman test).
- Group the approximate value of contingency and actual variations based on their experience in order to determine an approximate variation percentage that is anticipated and has occurred on actual construction projects.
- Give their additional comments and/or feed back.

THE TYPICAL PROJECT FACTORS

Previous research in variations and in several different areas, were studied in order to identify the typical project factors. Typical project factors are specific project characteristics that may distinguish one project from other project.

There are two starting points for this paper. It has been argued that variations may occur due to the complexity of the project, ground conditions variability and the employer's initiative (Potts 1995) And previously there was a study on variations which revealed that the source of variations are: designer, client, contractor, defects in design, inadequate considerations of design, incorrect assessment of brief, defects in documentation, unnecessary and unforeseen works (Hibberd 1982).

Project Complexity

Akinsola *et al.* (1997) concluded from a survey result that variations will be increased as the project complexity is increased. Project complexity factors can be determined by identifying the following:

Number of activities
The number of activities is selected as one indicator of the project complexity. The more activities involved, the more complex the project will be. The number of activities will depend on how the related parties break down the project activities. However, the number of the activities can be derived from the construction schedule. And as a general rule, a bar chart should contain less than 100 activities (Callahan *et al.* 1992) and a network diagram normally contains 50-150 activities (Fisk 1978).

The response from the pilot questionnaire has shown that the mode for this project factor is 4. This shows that the most frequent response for this particular project factor is 4 (=agree) on the Likert scale.

Number of Sub Contracts
It has been argued that several factors need to be considered in determining the optimum number of sub contractors and/or suppliers involved in a particular project. The fewer the number of sub contractors, the less will be the co-ordination and potential interface problems. On the other hand, as it can also be argued that smaller units of workers will provide better a commitment, fewer sub contractors may result in a larger work force for each sub contractor and/or supplier, with result in loss of productivity. After considering all of these factors, Weeks (1991) proposed 150 workers as optimum number of work force under each sub contractor.

The response from the pilot questionnaires has shown that the mode for this project factor is 4.

Project value
The project value is determined by the investment required to complete the project. Following the previous research by Akinsola *et al.* (1997), it was found that the value of the project has a strong correlation between its parameters, namely the magnitude and the frequency of variations.

The response from the pilot questionnaires has shown that the mode for this project factor is 3. This shows that the most frequent response for this particular project factor is 3 (=neutral) on the Likert scale.

Project duration
Still in close relation to the previous research by Akinsola *et al.* (1997), the project duration was considered a significant factor since this particular factor also has a quite strong correlation between its magnitude and frequency of variations.

Again the response from the pilot questionnaires has shown that the mode for this project factor is 3 on the Likert scale.

Project cost rate
Project cost rate measures the project value per square metre in £. This project factors was applied by Nahapiet & Nahapiet (1985) when they tried to classify some construction projects in USA and UK. The intention of using this factor in this paper is to complement the project value factors that project cost rate can better represent the intensity of capital utilised in a particular project. In other words, it will cover the possibilities of having a construction project with a high value but not cost intensive that may mislead the observation.

The value will be calculated by:

$$Pct = Pv / Pa$$

Pct is Project cost rate (in £/square metre)

Pv is Project total value (in £)

Pa is Project total area

Again the response from the pilot questionnaires has shown that the mode for this project factor is 3 on the Likert scale.

Project speed rate
Project speed rate measures the project area in square metre executed per-week. Again, this project factor was suggested by Nahapiet & Nahapiet (1985) and included here with the intention of complementing the project duration factors. The project speed rate can better represent the intensity of work executed in a given period of time. In other words, it will cover the possibilities of having a construction project with a short period but not work intensive and vice versa (short period but in low speed or long period but in high speed) that may also mislead the observation.

The value will be calculated as follow:

Psr = Pa / Pd

Psr is Project speed rate

Pa is project total area

Pd is project total duration

The response from the pilot questionnaires has shown that the mode for this project factor is 4. This shows that the most frequent respond for this particular project factor is 4 (=agree) on the Likert scale.

Ground works

It has been argued that in engineering terms, the ground conditions are recognised to carry potential high risk and uncertainty (Whyte & Tonks1994). Further in this paper, the effect of the potential high risk and uncertainty are measured by the proportion of ground works involve in a construction project and the extent and quality of its initial site investigation.

Proportion of ground works in the construction project
Following the argument above by Whyte & Tonks (1994), it can also be argued that the ground conditions could lead the project into variations. Therefore, the more the proportion of ground works in a project, the more risk and uncertainty involved the more the possibility of variations occurring.

The response from the pilot questionnaires has shown that the mode for this project factor is 4.

The quality of the site investigation
Furthermore, it has been proposed by Alhalaby & Whyte (1994) that the degree of ground uncertainty can be determined by the extent and quality of the site investigation. The relationship is described as follows,

Ground uncertainty	Quality of site investigation
10%	Very good
20%	Good
30%	Moderate
40%	Poor
50%	Very poor

The response from the pilot questionnaires has shown that the mode for this project factor is 5.

The Role of Employers and Related Parties

As mentioned early, the employers hold a prominent role in initiating variations. It is true that in the forms of contract it is mentioned that the engineer/architect will give the instruction for variations. However, the employers, through the engineer, can obtain the result wished if their ideas and desires have altered since the employers awarded the contracts (Twort & Rees 1995).

Experience of the employers

A research in optimising building cost by Winstanley (1978) revealed that when a systematic series of the same work was introduced, the condition can be considered as in a learning situation. Therefore, Winstanley proposed the learning effect, as in the learning curve, should be applied. In other words, when facing a series of systematic and similar works, people will learn to do the work in a better manner. This is related to the study of client experience regarding variations. It has been proven that variations occurred relatively more often when the client/employer is inexperienced (Akinsola *et al.* 1997). So, the more the employer has experience, especially with similar projects, it can be argued that the employer will know better about their requirements and needs. Therefore, it may reduce the number of variations initiated by them during the project execution.

The response from the pilot questionnaires has shown that the mode for this project factor is 4.

Experience of the quantity surveyors

As also mentioned earlier, variations can also occur due to mistakes in tender documents. These mistakes may occur in the bill of quantities, specifications or drawings. In this respect, we can recognise the role of other related parties which are the designer and quantity surveyors. The quantity surveyor, together with the designer, is responsible for preparing the bill of quantities for tender (Seeley 1984). So, it can also be argued that the experience of quantity surveyor and designer may affect the occurrence of variations due to any mistakes.

The response from the pilot questionnaires has shown that the mode for this project factor is 3 on the Likert scale.

Experience of the designers

Moreover, it is obvious that the experience of the designer may affect their competencies to reduce or recognise design errors prior to tender stage. Cornes (1994) argued that the architect (designer) has both the right and the duty to check their initial design as work proceeds and to correct it whenever necessary. Cornes (1994) also acknowledged that design errors often can not be discovered until after construction has begun.

The response from the pilot questionnaires is very strong with the mode of 5 for this project factor.

Information at Pre-tender Stage

Design Completion

Cornes (1994) also mentioned that in many cases, employers put considerable pressure on the designer to shorten the period of design in order to secure early tenders from contractors. This is argued, may result in an incomplete design, even at the stage of the contractor's selection and commencement of the project. This may cause modifications in the ongoing design and/or may be related to the established design which is being constructed.

The response from the pilot questionnaires is very strong, in fact this project factor appeared to have most of the agreement from respondents, with a mode of 5.

RANKING OF THE PROJECT FACTOR

As mentioned earlier, another outcome from the pilot questionnaire is the ranking of the project factors and the test of difference in perception of the respondents in terms of the degree of importance. This analysis is included in order to complement the questionnaire results mentioned above by determining the differences between factors with the same mode.

Since the data are ordinal with rankings and consist of a single factor of interest *k* levels with the sample data organised into blocks, the non-parametric Friedman test provides a correct method of testing for differences in location for the *k* factor-level populations (Kvanli *et al.* 2000).

The hypotheses:

Ho: the *k* populations have identical probability distributions

Ha: at least two of the populations differ in location

The Friedman test is:

$$FR = \frac{12}{bk(k+1)} \sum_{i=1}^{k} T_i^2 - 3b(k+1)$$

k = populations, b = blocks, T_i = total of ranks for the i^{th} population

The null hypothesis is rejected if :

$$FR > X^2_{\alpha.df}$$

For this test we use significance level of 0.05

Using the KGP Data Analysis this Friedman test was performed using the data from the questionnaire (refined from outliers) with following result:

Friedman Test	k = 12	b = 25
Computed chi-square	113.0923	Average Rank
ρ-value	.0000	
Group	Sum of Ranks	
1	248.0	9.92
2	220.0	8.80
3	215.0	8.60
4	183.0	7.32
5	171.0	6.84
6	176.0	7.04
7	108.0	4.32
8	151.0	6.04
9	144.0	5.76
10	188.0	7.52
11	109.0	4.36
12	37.0	1.48

From the result, it is very obvious that the ρ-value is very small which is strongly suggest us to reject *Ho*.

Alternatively we can use chi-square table, using $k - 1 = 11$ df and right tail area = 0.05 the test procedure is to reject *Ho* if FR > 19.6751.

Since 113.0923 > 19.6751, we reject *Ho* and conclude that there is a difference in the perceived degree of importance. As shown in the average rank, for instance the group 12 (Design Completion factor) is ranked between 1 and 2 by most respondents and far outranked other factors, therefore is considered as the most important factor among others.

OTHER RESULTS

Several additional project factors were suggested by the respondents. The main consideration was the time provided in pre-tender period to complete the design and to better understand the project by all parties. The most interesting additional feed back on this issue is the sharing of one previous study that the time provided has an optimum value, which means up to a point the longer time will no longer give a positive impact to reduce variations. Furthermore, time is also considered essential in determining the adequacy of a client's brief. In a further literature review, Barrett & Stanley (1999) stated that the briefing process is seen as both critical to successful construction yet problematic in its effectiveness that for instance may result in re-designing many aspects of the work as the project progressed. Several respondents also suggested the nature of the works with a special attention on refurbishment works which can contain a high degree of uncertainty.

Another issue raised by several respondents is the experience of the contractors which is not originally considered in the questionnaire. After a further literature review, it is found that a previous survey and case studies by Hibberd (1982) has proved the contractors as one source of variations.

In the pre-execution stage, an experienced contractor has a duty to warn and a duty of care to inform of any errors and/or defects in the design (Cornes, 1994). This will allow all necessary revisions to the contract documents which will minimise the occurrence of variations. In contrary at the construction stage, the contractor with his experience may just find defects/errors in the design, or difficulties in execution, or found a cheaper solution for his and the employer's benefits (Twort & Rees, 1995). Thus, the experience of the contractor can have a bearing on the occurrence of variations.

Respondents were also asked to state from their experience the approximate percentage (of original project value) of variations anticipated and actual happened. As the result, 98% of the respondent agreed that the *anticipated* percentage of variations, represented in the pre-budget contingency, was up to 10% of the original project value. Furthermore, 96% agreed that the *actual* percentage of variations occurring was also up to 10% from the original project value. This result suggests that the practitioners generally incorporate sufficient contingency for the anticipated variations with a maximum value 10%.

CONCLUSIONS

Typical project factors were derived from a literature study and forwarded to a representative sample of practitioners in a pilot questionnaire to obtain their opinions. The results were analysed and studied with the summary of findings as follow,

All typical project factors forwarded in the questionnaire, namely:

1. Number of activities
2. Number of sub-contract
3. Project value
4. Project duration
5. Project cost rate
6. Project speed rate
7. Proportion of ground works
8. Quality of site investigation
9. Employer experience
10. Designer experience
11. QS experience
12. Design completion

were accepted with additional factors to be considered:

1. Time available in pre-tender stage
2. Adequacy of client briefing
3. Nature of works whether the project is a refurbishment or a new one
4. Contractor experience

These factors are considered as key factors for further study in order to develop a model for the early prediction of variations.

Based on a quantitative analysis, namely the Friedman test, it was found that the difference in the perceived degree of importance of the project factors is recognised. This showed that the factors are not perceived as equally important and there are certain factors that considered more important than other factors.

The current anticipation for variations represented in the *contingency* percentage is perceived sufficient to cover the *actual* variations which is approximately up to 10% of the original project value.

RECOMMENDATIONS

Further analysis of an organisation's own database of previous projects to develop a model that determine the likelihood of new projects can be started using the key factors resulted above. Both qualitative and quantitative analyses are recommended.

Qualitative analysis will have to make a comparison analysis for each key factor between the previous projects and next projects, especially for key factors with high degree of importance such as Design Completion factor.

For quantitative analysis, the key factors within the database of previous projects should be classified and analysed using applicable statistical tools that will classify the projects. One group includes projects with variations level anticipated by the contingency percentage (i.e. 10%) and the other group includes projects with variation levels beyond the anticipated. When the statistical model is established, the key factors of new projects can be inputted to the model to determine the potential impact of variation on these new projects.

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