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A STUDY ON VARIATIONS IN SEWERAGE CONSTRUCTION PROJECTS

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Abstract. Variations in construction have long been a debatable issue among the different participants involved in construction projects. However, only a few formal studies have been carried out to analyse its causes and effects. This study is focused on the frequency and severity of various factors causing variations in sewerage networks construction projects. It is important for a company not only to know the variation costs, but also to identify the most likely areas on which to focus in order to reduce these costs for the future projects. All the necessary data and information are obtained from archival files of thirteen projects and verified through interviews. These data are categorised to analyse the frequency and severity of factors. Tables and charts are presented to show the research findings. From the analysis, differing site conditions appear to be the major factors contributing to variations. They average 49.3% of the total number of variations, 56.2% of the total variation costs and 3.8% of the total project costs. Two project characteristics i.e. contract award value and the contractor's registration grade with the Construction Industry Development Board (which represents the contractor's specialisation, financial and other resources standing) [1] show certain causal relationships with variations.

Key words: variation, frequency, severity, sewerage, network, specialisation

Abstrak. Perubahan dalam pembinaan telah lama menjadi isu pertikaian antara pelbagai pihak yang terlibat dalam projek pembinaan. Namun, hanya sejumlah kecil kajian yang rasmi telah dijalankan untuk menganalisis sebab-sebab dan kesan-kesannya. Kajian ini tertumpu kepada analisis kekerapan dan keterukan berbagai-bagai faktor yang mengakibatkan perubahan dalam projek pembinaan rangkaian pembetungan. Adalah penting bagi sesebuah syarikat bukan sahaja mengetahui kos perubahan, tetapi juga mengenal pasti perkara-perkara yang perlu diberi perhatian untuk mengurangkan kos-kos sedemikian dalam projek akan datang. Kesemua data dan maklumat yang diperlukan diperolehi dari fail-fail arkib bagi tiga belas projek dan disahkan melalui temubual. Data-data dikategori untuk menganalisis kekerapan dan keterukan faktor-faktor. Jadual dan carta digunakan untuk menunjukkan hasil-hasil kajian. Daripada hasil analisis, keadaan tapak yang berbeza merupakan faktor utama yang mengakibatkan perubahan. Faktor-faktor ini menyumbangkan 49.3% daripada jumlah bilangan perubahan, 56.2% daripada jumlah kos perubahan dan 3.8% daripada jumlah kos projek. Dua ciri projek, iaitu nilai anugerah kontrak dan gred pendaftaran kontraktor dengan Lembaga Pembangunan Industri Pembinaan (mewakili pengkhususan, kedudukan kewangan dan sumber-sumber lain kontraktor) menunjukkan hubungan penyebab yang tertentu dengan perubahan.

Kata kunci: perubahan, kekerapan, keterukan, pembetungan, rangkaian, pengkhususan

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1.0 INTRODUCTION

One of the most significant challenges in construction management is the management of variations. Burati *et al.,* [2] said that variation in construction includes changes to the requirements that result in rework, as well as products or results that do not conform to all specification requirements, but do not require rework. The Institution of Engineers, Malaysia provides a detailed definition of variation. The clause 23(a) in the "I.E.M. Conditions of Contract for Works Mainly of Civil Engineering Construction [3]" defines variation as an increase or decrease in the quantity of any work included in the contract, omission of any such work, change in the character or quality or kind of any such work, change in the levels lines position and dimensions of any part of the works or execution of additional work of any kind necessary for the completion of the works. In short, variation occurs whenever there is any change or variance from what are originally stated in the contract documents. It may be a result of a number of reasons such as site constraints, design omissions, changes of construction method and owner's requirements. Since variations are always associated with cost overruns and extension of time, they are very sensitive and need adequate attention by the parties involved.

Research performed by Hibberd [4] revealed that the two major causes of variations in building construction projects were inadequate consideration of design and those initiated by the designer. Inadequate consideration of design accounted for 25% of total variation, whereas the designer initiated another 19% of total variation. Diekmann and Nelson [5] stated that design errors accounted for 46% of the total number of additive claims and 40% of the total compensation. However, according to Halligan, *et al*., [6] who focused their research on highway construction projects, differing site conditions accounted for only 20% of all claims, but categorised by root cause, they were responsible for approximately 35% of the total amount paid to contractors for claims. This was the major factor contributing to claims in construction projects.

These findings appear to be in conflict. Some indicated that design deviations are the main causes of variations in construction projects, while others indicated that differing site conditions are the major sources. Anyway, since the area of focus for each of these studies is not the same, a conclusion could not simply be drawn for general construction projects from these studies. Therefore, there is a need to identify and analyse the causes and effects of variations for a specific area of construction, which in this study, is the construction of sewerage works.

The aims of this research are to identify the factors contributing to variations, to analyse the frequency and severity of various factors causing variations, and to establish causal relationships between variations and some characteristics of sewerage construction projects.

2.0 METHODS OF INVESTIGATION

The aims were achieved through identification of factors from literature, and validation and analysis of the data obtained. All the data and information were supplied by a sewerage facilities construction company. Whenever primary data was unclear or ambiguous, further explanation or information was obtained through interviews with relevant project representatives. This was intended to maximise clarity and gain adequate understanding of the data for its use in analysis.

In order to provide a more meaningful comparison among projects, all the projects chosen for the analysis of variations were comprised of only one type of construction project, i.e. sewerage networks construction projects. The study was based on projects with minimum worth of RM500,000. As such, data obtained from thirteen projects have been studied and used for analysis in this research. These projects were fully completed and their accounts have been finalised and closed. Table 1 shows a brief description of the projects studied.

Table 1 Description of projects studied

Project	Completion Year	Type of Project	Location	Contract Award Value (× RM1,000)
A	1996	Networks	Negeri Sembilan	4 515.0
B	1996	Networks	Kedah	4 460.8
C	1996	Networks	Kuala Lumpur	737.1
D	1997	Networks	Negeri Sembilan	13 406.7
E	1997	Networks	Negeri Sembilan	14 029.3
F	1997	Networks	Negeri Sembilan	8 688.2
G	1997	Networks	Kedah	8 891.0
H	1997	Networks	Selangor	607.0
I	1997	Networks	Selangor	2 626.0
J	1997	Networks	Kuala Lumpur	583.7
K	1997	Networks	Kuala Lumpur	1 585.6
L	1998	Networks	Negeri Sembilan	5 801.5
M	1998	Networks	Penang	690.0

3.0 RESULTS AND DISCUSSION

3.1 Categories of Variation Factor

The data obtained were summarised and classified into five categories to identify the factors causing variations along with their frequency and severity. These categories are differing site conditions, owner initiated variations, design deviations, deviations due to authority and others. Table 2 shows a description of the variation categories used. These categories are chosen because there are mutually exclusive and most of the data can be grouped into one of them without ambiguity.

Table 2 Description of variation categories

Variation Category	Description
1. Differing Site Conditions	Variations required when differences exist between physical conditions in the field and those shown on the plans or specifications. A variation caused by the absence of any indication on plans reasonably expected by the contractor also falls in this category.
2. Owner Initiated Variations	Variations due to changes, errors or omissions caused by the owner.
3. Design Deviations	Variations due to errors or omissions occurring at the design stage or by the designer. These include flaws and ambiguities found in the plans or specifications.
4. Deviations due to Authority	Variations due to changes or requirements by the local authority or other relevant authorities, which are unforeseen during the tendering stage.
5. Others	Other factors exclusive from the above categories are placed under this category.

3.2 Data on Variations

Table 3 shows information on variations for the thirteen projects studied. It depicts the frequency of variations, contract award values and the variation costs for each of the projects.

The frequency of variations is taken as the number of variation occurring in each project. For a single variation order, which contains several different variations, each variation is treated separately.

Meanwhile, the variation costs mean the direct costs associated with each variation. This variation costs are also expressed in terms of percentage of original total project costs (contract award value) to show its severity for the thirteen projects. In order to

Table 3 Data on variations

Project	Frequency of Variation	Contract Award Value (× RM1000)	Variation Costs (× RM1000)	Variation Costs (% of Contract Award Value)
A	6	4 515.0	265.6	5.9
B	4	4 460.8	81.7	1.8
C	0	737.1	0.0	0.0
D	8	13 406.7	548.7	4.1
E	13	14 029.3	550.5	3.9
F	4	8 688.2	108.8	1.3
G	16	8 891.0	967.6	10.9
H	4	607.0	665.1	109.6
I	4	2 626.0	262.6	10.0
J	5	583.7	143.9	24.7
K	3	1 585.6	368.7	23.3
L	7	5 801.5	535.2	9.2
M	1	690.0	11.9	1.7
Total	**75**	**66 621.9**	**4510.3**	
Mean	**6**			**6.8**

provide a clearer view, variation costs and its value as the percentage of original total project costs is presented in the form of a bar-line chart as shown in Figure 1.

Out of the thirteen projects studied, there were variations in twelve of them. This finding shows that variations were commonly taking place in sewerage networks construction projects. There were 75 variations all together in the thirteen projects. On average, there were 6 variations for each project.

For the twelve projects with variations, the associated variation costs ranged from RM11,900 to RM967,600, resulting in a total variation costs of RM4,510,300. When the severity of the variation costs were considered in terms of the percentage of total project costs, it ranged from 1.3% to 109.6%. It was found that the large amount of variation costs does not mean that its value as percentage of total project costs is necessarily high, and vice versa.

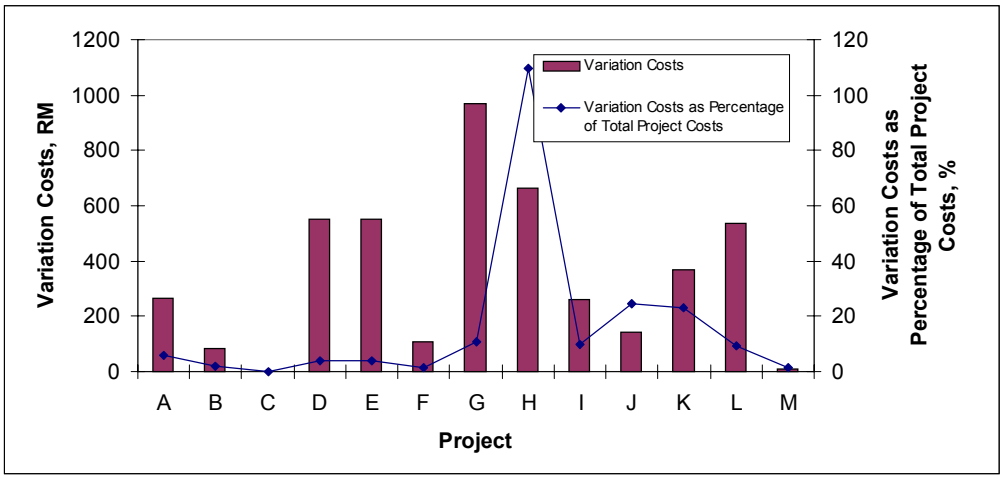

Figure 1 Variation costs and its value as percentage of total project costs for the thirteen projects

In order to avoid from being affected by extreme values, the mean value of variation costs as percentage of total project costs is taken directly as the total variations costs (RM) divided by the total contract award value (RM) for all projects (column 4 divided by column 3), but not as the average of variations costs as percentage of total project costs (%) for all projects (column 5). Thus, variation costs made up 6.8% of the total project costs generally.

3.3 Frequency of Variations

The analysis of frequency is intended to indicate the number of variations according to the factors causing them. With this analysis, the factors could be ranked with respect to their numbers of occurrence. The analysis is presented in Table 4, where the finding has been summarised in Figure 2.

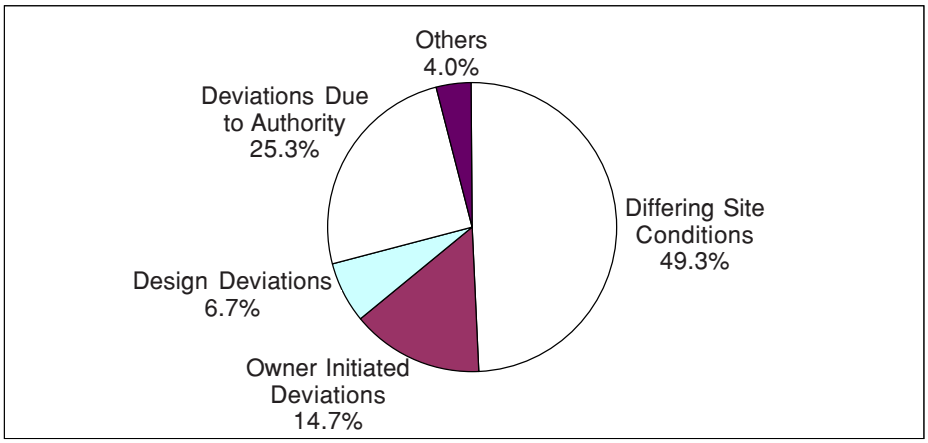

Figure 2 Frequency of various factors causing variations

Table 4 Frequency of various factors causing variations

Project	Differing Site Conditions		Owner Initiated Deviations		Design Deviations		Deviations Due to Authority		Others	
	α	β(%)	α	β(%)	α	β(%)	α	β(%)	α	β(%)
A	2	*33.3*	2	*33.3*	0	*0.0*	1	*16.7*	1	*16.7*
B	3	*75.0*	1	*25.0*	0	*0.0*	0	*0.0*	0	*0.0*
C	0	*0.0*	0	*0.0*	0	*0.0*	0	*0.0*	0	*0.0*
D	4	*50.0*	2	*25.0*	0	*0.0*	2	*25.0*	0	*0.0*
E	7	*53.7*	3	*23.1*	0	*0.0*	3	*23.1*	0	*0.0*
F	4	*100.0*	0	*0.0*	0	*0.0*	0	*0.0*	0	*0.0*
G	4	*25.0*	2	*12.5*	3	*18.8*	5	*31.2*	2	*12.5*
H	2	*50.0*	0	*0.0*	1	*25.0*	1	*25.0*	0	*0.0*
I	2	*50.0*	0	*0.0*	1	*25.0*	1	*25.0*	0	*0.0*
J	2	*40.0*	0	*0.0*	0	*0.0*	3	*60.0*	0	*0.0*
K	2	*66.7*	0	*0.0*	0	*0.0*	1	*33.3*	0	*0.0*
L	5	*71.4*	0	*0.0*	0	*0.0*	2	*28.6*	0	*0.0*
M	0	*0.0*	1	*100.0*	0	*0.0*	0	*0.0*	0	*0.0*
Total	**37**		**11**		**5**		**19**		**3**	
Average		***49.3***		***14.7***		***6.7***		***25.3***		***4.0***

Note:
α is the number of variations for each project.
β is the number of variations as percentage of total number of variations for each project.
The average is obtained by dividing the total number of variations in each category by the total number of variations of all projects.

Differing site conditions were the major factors that caused variations in the projects studied. Out of the twelve projects with variations, there were variations caused by differing site conditions in eleven projects. It contributed 49.3% of the total number of variations, followed by deviations due to authority (25.3%) and owner initiated deviations (14.7%).

The ranking of factors causing variations according to their frequency in descending order is as follows:

- differing site conditions,
- deviations due to authority,
- owner initiated deviations,
- design deviations, and
- others.

3.4 Severity of Variations

The analysis of severity is intended to show the seriousness of various factors causing variations. It is presented in two forms, i.e. variation costs as percentage of total project variation costs, and variation costs as percentage of total project costs. Table 5 and Figure 3 show the former, whereas Table 6 and Figure 4 show the latter.

From Table 5 and Figure 3, it is found that differing site conditions were the factors that contributed most to the total variation costs. It resulted in RM2,532,600 or 56.2% of the total variation costs (RM4,510,300).

The ranking of factors causing variations according to their severity in descending order is as follows:

- differing site conditions,
- design deviations,
- deviations due to authority,
- owner initiated deviations, and
- others.

The positions of several factors in this ranking is not the same as the ranking according to the frequency. These factors are design deviations, deviations due to authority,

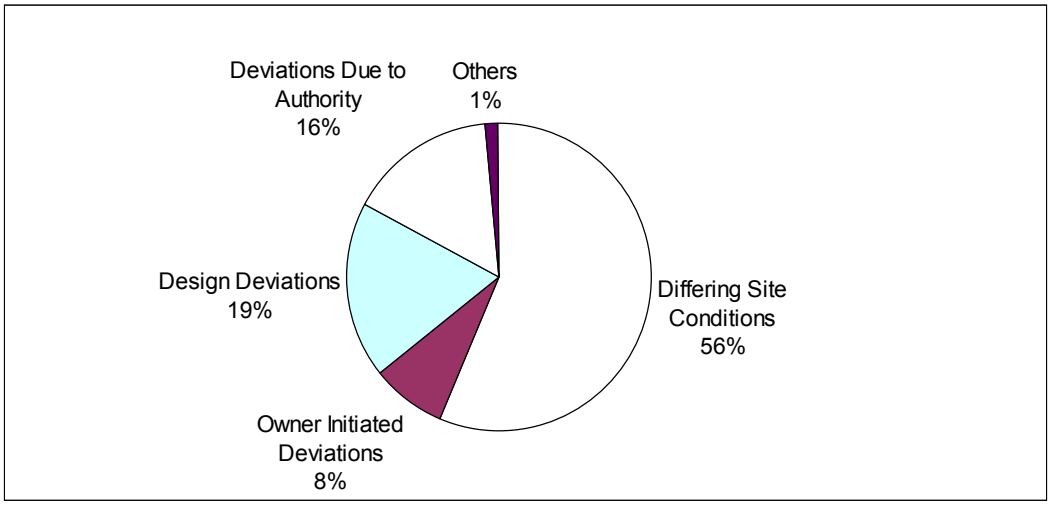

Figure 3 Variation costs as percentage of total project variation costs

Table 5 Severity of various factors causing variations: Variation costs as percentage of total project variation costs

Project	Differing Site Conditions		Owner Initiated Deviations		Design Deviations		Deviations Due to Authority		Others	
	α	β(%)	α	β(%)	α	β(%)	α	β(%)	α	β(%)
A	66.0	*24.8*	55.3	*20.8*	0.0	*0.0*	106.7	*40.2*	37.6	*14.2*
B	79.3	*97.1*	2.4	*2.9*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*
C	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*
D	423.0	*77.1*	72.4	*13.2*	0.0	*0.0*	53.3	*9.7*	0.0	*0.0*
E	435.8	*79.2*	89.3	*16.2*	0.0	*0.0*	25.4	*4.6*	0.0	*0.0*
F	108.8	*100.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*
G	192.4	*19.9*	133.0	*13.7*	568.9	*58.8*	48.9	*5.1*	24.4	*2.5*
H	443.6	*66.7*	0.0	*0.0*	162.1	*24.4*	59.4	*8.9*	0.0	*0.0*
I	69.1	*26.3*	0.0	*0.0*	110.8	*42.2*	82.7	*31.5*	0.0	*0.0*
J	132.6	*92.1*	0.0	*0.0*	0.0	*0.0*	11.3	*7.9*	0.0	*0.0*
K	81.6	*22.1*	0.0	*0.0*	0.0	*0.0*	287.1	*77.9*	0.0	*0.0*
L	500.4	*93.5*	0.0	*0.0*	0.0	*0.0*	34.8	*6.5*	0.0	*0.0*
M	0.0	*0.0*	11.9	*100.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*
Total	**2532.6**		**364.3**		**841.8**		**709.6**		**62.0**	
Average		***56.2***		***8.1***		***18.6***		***15.7***		***1.4***

Note:
α is the variation costs for each category in a project (in RM1000).
β is the variation costs as percentage of total project variation costs for each project.
The average is obtained by dividing the total variation costs in each category by the total variation costs of all projects.

and owner initiated deviations. Amongst the most significant, the position of design deviations have been changed from the forth to the second. These findings show that even though design deviations did not occur frequently (6.7%), but its effect in term of costs was quite high (18.6%). At the same time, although deviations due to authority happened frequently (25.3%), its effect was not that bad (15.7%).

Table 6 and Figure 4 depict the variation costs caused by various factors as compared to the total project costs. On average, total variation costs accounted for 6.8% of total project costs (contract award value) for the projects concerned.

Table 6 Severity of various factors causing variations: Variation costs as percentage of total project costs

Project	Differing Site Conditions	Owner Initiated Deviations	Design Deviations	Deviations Due to Authority	Others	Total
	β(%)	β(%)	β(%)	β(%)	β(%)	β(%)
A	*1.5*	*1.2*	*0.0*	*2.4*	*0.8*	***5.9***
B	*1.8*	*0.1*	*0.0*	*0.0*	*0.0*	***1.8***
C	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	***0.0***
D	*3.2*	*0.5*	*0.0*	*4.4*	*0.0*	***4.1***
E	*3.1*	*0.6*	*0.0*	*0.2*	*0.0*	***3.9***
F	*1.3*	*0.0*	*0.0*	*0.0*	*0.0*	***1.3***
G	*2.2*	*1.5*	*6.4*	*0.6*	*0.3*	***10.9***
H	*73.2*	*0.0*	*26.7*	*9.8*	*0.0*	***109.6***
I	*2.6*	*0.0*	*4.2*	*3.2*	*0.0*	***10.0***
J	*22.7*	*0.0*	*0.0*	*1.9*	*0.0*	***24.7***
K	*5.2*	*0.0*	*0.0*	*18.0*	*0.0*	***23.3***
L	*8.6*	*0.0*	*0.0*	*0.6*	*0.0*	***9.2***
M	*0*	*1.7*	*0.0*	*0.0*	*0.0*	***1.7***
Average	***3.8***	***0.5***	***1.3***	***1.1***	***0.1***	***6.8***

Note:
β is the variation costs as percentage of total project costs for each project.
The average is obtained by dividing the total variation costs in each category by the total costs of all projects.

The five categories of factors contributed to variation costs with a range from 0.1% to 3.8% of total project costs. Differing site conditions contributed the most (3.8%), followed by design deviations (1.3%), deviations due to authority (1.1%), owner initiated deviations (0.5%) and others (0.1%).

3.5 Establishment of Causal Relationship

This analysis examines whether there exists any causal relationship between variations and some project characteristics. Three project characteristics used in this analysis are the contract award value, the contractor's registration grade with Construction

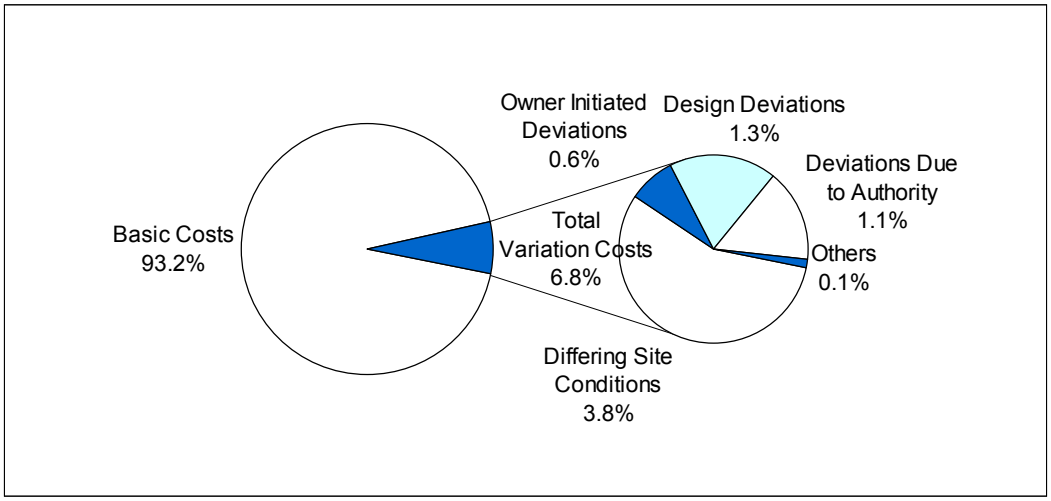

Figure 4 Total variation costs as percentage of total project costs

Industry Development Board (which represents the contractor's specialisation, financial and other resources standing), and the contractual project duration.

3.5.1 Contract Award Value versus Deviations

The variation data obtained has been classified in accordance with the size of project, which was represented by the contract award value. The projects have been divided into three categories, namely small (contract award value equal or less than RM1,000,000), mid-sized (more than RM1,000,000 to RM5,000,000) and large (more than RM5,000,000). Table 7 shows the findings.

From Table 7, it was found that project size had an influence on the frequency of variations. Both the total number of variations and the number of variations per project increased when the contract award value was larger, and vice versa.

As for the severity of variations, even though the total variation costs changed positively with the contract award value, its values as percentage of total project costs changed inversely. Figure 5 displays the change of variation costs according to the size of project.

3.5.2 Contractor's CIDB Grade versus Deviations

Variation data for the thirteen projects studied has been classified into three groups according to the contractor's CIDB grade. The thirteen contractors possessed either Grade 7, Grade 6 or Grade 4. The contractors with Grade 7 were then further subdivided according to the possession of specialisation code CE19 (specialisation in contruction of sewerage works). The findings are presented in Table 8.

Table 7 Contract award value versus variations

Contract Award Value	Number of Projects	Total Project Costs	Variations				
			Frequency		Severity		
		RM 1000	no	Per project	RM 1000	per project	%
Small (RM1,000,000 or less)	4	2618	10	2	821	205	**31.4**
Mid-sized (> RM1,000,000 to RM5,000,000)	4	13188	17	4	979	245	**7.4**
Large (More than RM5,000,000)	5	50816	48	10	2711	542	**5.3**

Note:
% is the variation costs as percentage of the total project costs.

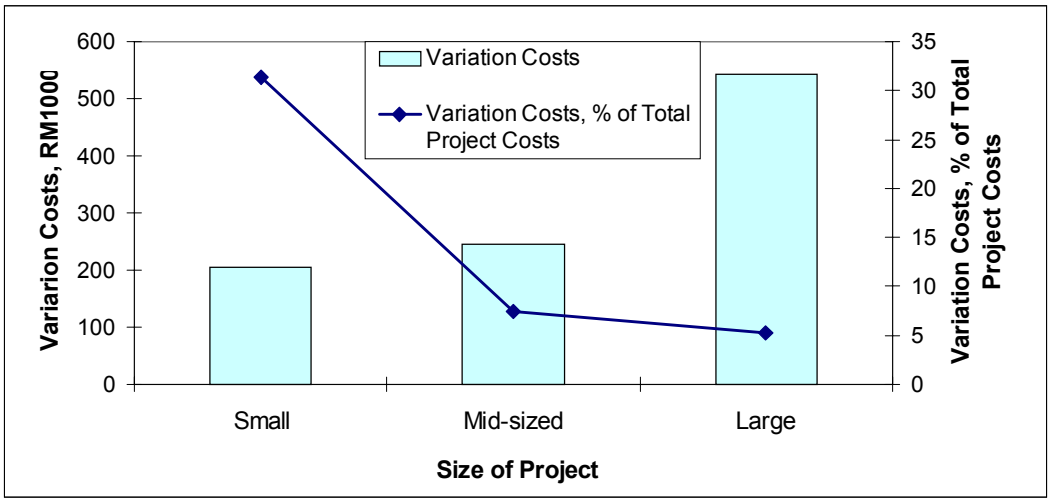

Figure 5 Variation costs according to the size of project

Table 8 Contractor's CIDB grade versus variations

Contractor's CIDB Grade	**No. of Project**	**Total Project Costs**	**Variations**			
			Frequency		**Severity**	
			No.	Per project	RM1000	%
Grade 7						
-with C19	5	34841	41	8	2555	7.3
-without C19	5	23810	19	5	908	3.8
Total	10	58651	60	6	3463	**5.9**
Grade 6	2	7387	10	5	904	**12.2**
Grade 4	1	584	5	5	144	**24.7**
Mean						**6.8**

Note:
C19 is the specialisation code in sewerage works under CIDB grading.
% is the variation costs as percentage of total project costs.

From Table 8, it was found that the frequency of variations was not much affected by the contractor's CIDB grade. The number of variations per project for each group of contractors was almost the same. However, the severity of variations was greatly influenced by the contractor's CIDB grade.

The variation costs as percentage of total project costs increased drastically as the grade became lower. This result means that the issue of variations was more serious when the contractor's financial and other resources standing were poorer.

Among the three grades, the contractors with Grade 6 and Grade 4 caused more variations than the average value for the thirteen projects studied. Only contractors with Grade 7 managed to control the deviations and hence, produced variation costs below the average value. The distribution of variation costs according to the contractor's grade is presented in Figure 6.

Findings in Table 8 also indicate that the specialisation code CE19 did not play a significant role in the matter of deviations. Possessing a code CE19 does not necessarily mean that a contractor is more capable of controlling deviation problems in sewerage works. Findings in Table 8 even shows that the contractors without code CE19 caused lesser deviations as compared to the contractors with CE19.

4.0 CONCLUSIONS

The major factors contributing to variations were differing site conditions. They averaged 49.3% of the total number of variations, 56.2% of the total variation costs and 3.8% of the total project costs. The frequency of variations increased, but the variation costs

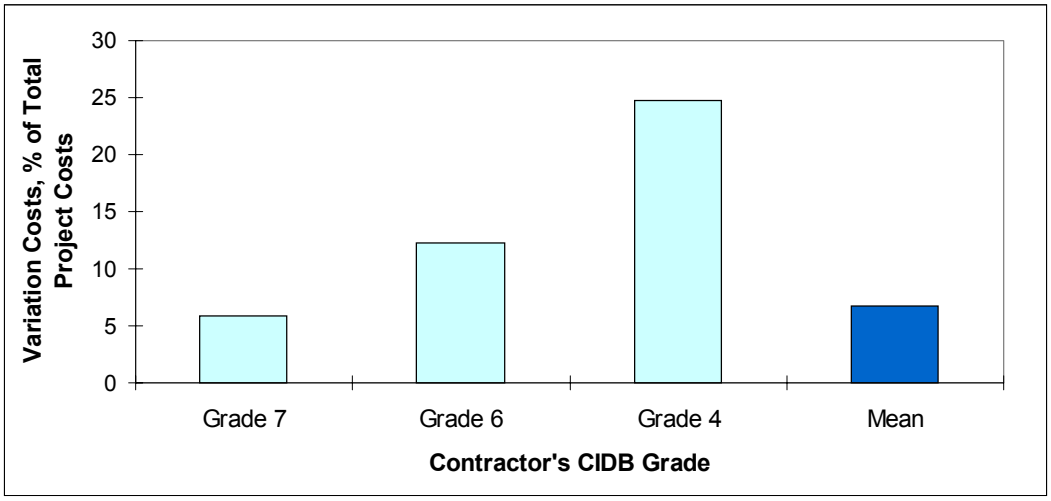

Figure 6 Variation costs according to contractor's CIDB grade

as percentage of the total project costs decreased when the contract award value of project was larger. As the contractor's CIDB grade was lower, the variation costs as percentage of total project costs increased drastically.

This paper demonstrates how the historical data can be categorised to identify the frequency and severity of various factors causing variations. It does identify not only the variation costs, but also the most likely areas on which to focus to reduce these costs on the future projects.

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