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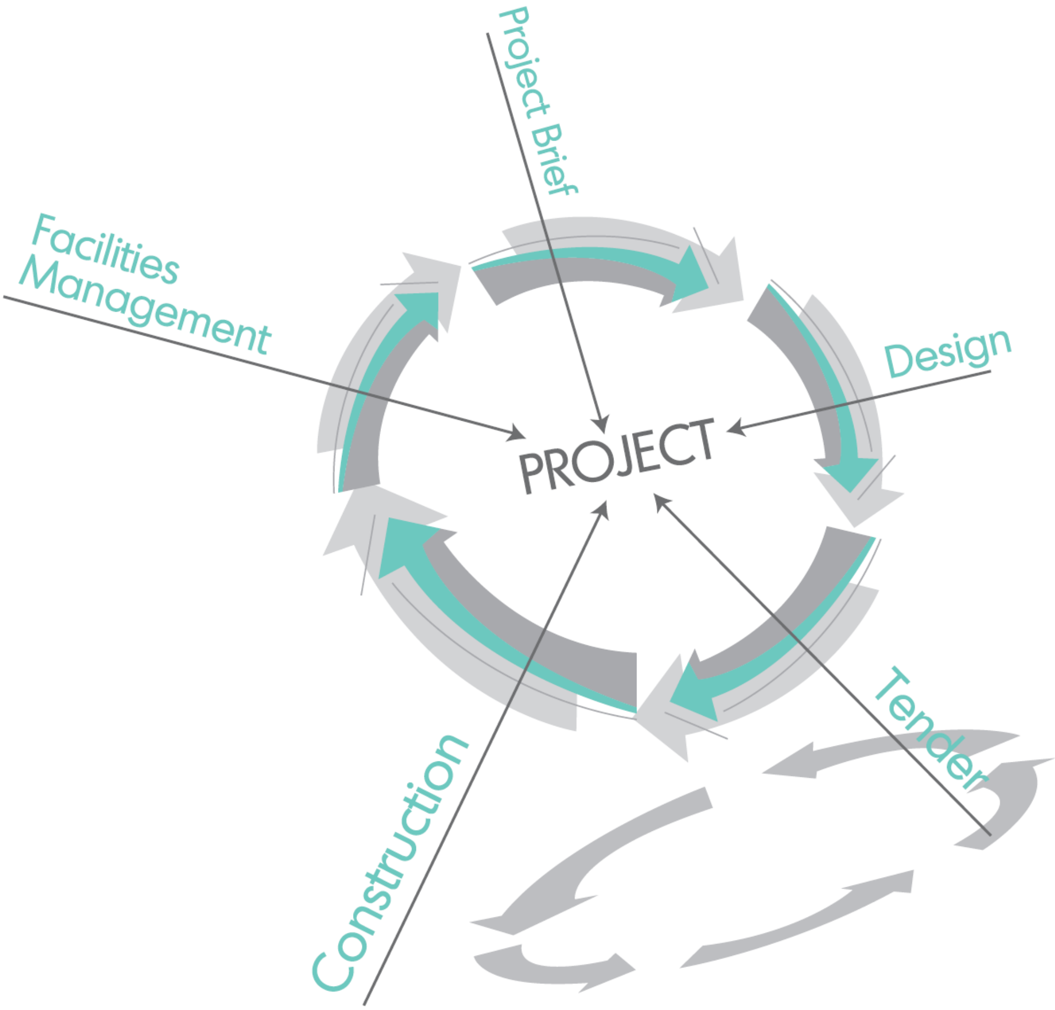

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Contents

Editorial Advisory Board

Editorial

Welcome from the Editors

Welcome to the twenty-third (23rd) issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include six papers that cover wide range of research area in construction industry. The editorial team would like to express our sincere gratitude to all contributing authors and reviewers for their contributions, continuous support and comments.

In this issue:

Siti Noor Linda Taib et al., studied on strength evaluation of stabilized tropical fibrous peat samples under short and long-term performance conditions. The cement stabilized peat samples were prepared and tested to study their shear strength characteristics by performing triaxial compression tests in isotropic consolidated undrained (CIU) and isotropic consolidated drained (CID). The reduction factor for the effective friction angle of cement stabilized peat ranged from 0.81 to 0.97; while the ratio between CID and CIU tests results for effective cohesion of cement stabilized peat has an average additional factor of 2.44.

Nikolai V. Lyubomirskiy et al., presents a study of the structuring of composite systems based on lime harden through carbonation and secondary limestone raw materials. It has been revealed that limestone aggregate enters into active chemical interaction with calcium carbonate produced in the carbonation process, forming strong cohesive coalescence contacts, characterizing high mechanical strength and durability of carbonized material. The resulting calcium carbonate 'duplicates' to a certain extent the properties of the limestone aggregate introduced into the raw mix, whereby the strength and water resistance of the carbonized samples on a marbleized aggregate are higher than the same properties of the samples produced based on limestone aggregates of sedimentary origin.

Through analysis by using Rasch model, **Hairuddin Mohammad et al.,** outlaid several perspectives that represent the current knowledge on construction concepts which are considered important to be equipped by the construction manager: (i) Knowledge of Lean Construction; (ii) Knowledge of Constructability; and (iii) Knowledge of Value Engineering. The findings may act as a reference for the construction manager's competency profile.

Yati Md Lasa et al., explore the sources of financing available for Private Finance Initiative (PFI) projects and the critical factors affecting financing requirements for PFI projects in Malaysia through questionnaire survey. They show that the two financing options available in Malaysia are conventional and Islamic financing, and most financing facilities offered are term loan and Istisna respectively. Project risks, project viability, and the company's financial strength are among the most critical factors that the financiers consider before granting any financing for the PFI projects.

Through desk research focuses on preliminaries and their pricing for construction works of residential buildings, **Khairuddin Abdul Rashid** and **Samer Shahedza Khairuddin** found that there is no specific format for the presentation of preliminaries items in the bills of quantities and no specific pattern of pricing the items by the tenderers, preliminaries form between 4.40% and 8.73% of the contract sum and for residential buildings' projects the study has identified the top ten preliminaries items. The findings are deemed significant to clients, quantity surveyors and contractors as they may be incorporated into their estimating and tendering strategies respectively.

Khairuddin Abdul Rashid and **Samer Shahedza Khairuddin** reported a study on the systems of construction procurement in use in Malaysia. In particular, the authors (i) identify the systems of construction procurement in use, (ii) assess whether the systems used matched the criteria as proposed by the theory on procurement systems; and (iii) identify clients' top priority in procurement and whether their objectives were met or otherwise. The findings suggested that the traditional design-bid-build (DBB) system of procurement remained Malaysia's most dominant system of procurement, clients' top priority in procurement is speed of completion and in terms of meeting the clients' overall objectives on time, cost and quality, these objectives, combined together and in most projects, they were not met. In addition, problems that caused delays and constraining the processes of procurement were identified, the top two being contractors' related (lack of expertise and time overrun) and local authorities' related (delay in obtaining approvals).

Prasad Kudrekodlu Venkatesh and Vasugi Venkatesan, reviewed fifty-three research articles to identify the critical causes of delays and mitigation strategies globally as well as the gaps in literature. From this study, it was indicated that the causes of delays vary among countries and the top ten causes of construction project delay in both developing and developed countries are identified. This paper also presents the scope for future research work to improve the construction project delivery.

Editorial Committee

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DRAINED AND UNDRAINED TRIAXIAL COMPRESSION TESTS ON CEMENT STABILIZED TROPICAL FIBROUS PEAT OF SARAWAK

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Abstract
Peat is classified as one of the major type of problematic soils due to its high water content, high compressibility and low shear strength characteristics. The research site investigated in this paper is in Matang, Kuching. Studies have been carried out on strength evaluation of stabilized tropical fibrous peat samples under short and long-term performance conditions. Ordinary Portland cement (OPC) was used as the stabilizing agent. Cement stabilized peat samples were prepared with cement content of 25% and 50% by weight of dry soil and cured for 7 and 28 days. These stabilized samples were tested to study their shear strength characteristics by performing triaxial compression tests in isotropic consolidated undrained (CIU) and isotropic consolidated drained (CID). Reduction factor for the effective friction angle of cement stabilized peat that was obtained in CIU and CID tests were in the range of 0.81 to 0.97. The effective drained cohesion of the untreated peat has a reduction factor of 0.5 from the undrained cohesion. While the ratio between CID and CIU tests results for effective cohesion of cement stabilized peat has an average additional factor of 2.44. Relationship between the secant modulus of elasticity (E50) and peak shear strength (q) from CIU and CID tests is also established in this study. Values of reduction factor highlighted in this work may be used to estimate values of effective friction angle and cohesion from undrained test performed on cement stabilized peat. This is an interesting work for researchers and practitioners to understand the engineering behaviour of cemented tropical peat.

Keywords: *Tropical peat, Cement stabilized peat, Shear strength, Triaxial compression test, Soil improvement.*

INTRODUCTION

Peat is classified as one of the major soil types in Malaysia. Mutalib et al. (1991) stated that Sarawak has the largest peat land area in Malaysia which is 16500 km^2 or 13% of the state (Figure 1). Peat consists of high organic content mainly vegetable tissue under various stages of decomposition and is accumulated under excessive moisture conditions. It is extremely soft and considered as problematic soil due to its high water content, high compressibility and low shear strength (Huat, 2004). Hence, it is unsuitable for supporting foundations in its natural state.

There are several pioneering studies on geotechnical improvement for construction on peat. According to Edil (2003), the improvement methods available are avoidance, excavation-displacement or replacement, ground improvement, stage construction, preloading, deep in situ mixing method and reduce driving forces by light-weight fill. Many researchers had studied the stabilization of soft soils by using chemical stabilization method (Azman et al., 1994; Uddin et al., 1997; Eriktius et al., 2001; Huat et al., 2005; and Kolay et al., 2011, Boobathiraja et al., 2014, Rahgozar and Saberian, 2016). They found that the physical and geotechnical properties of the stabilized soft soil could be improved.

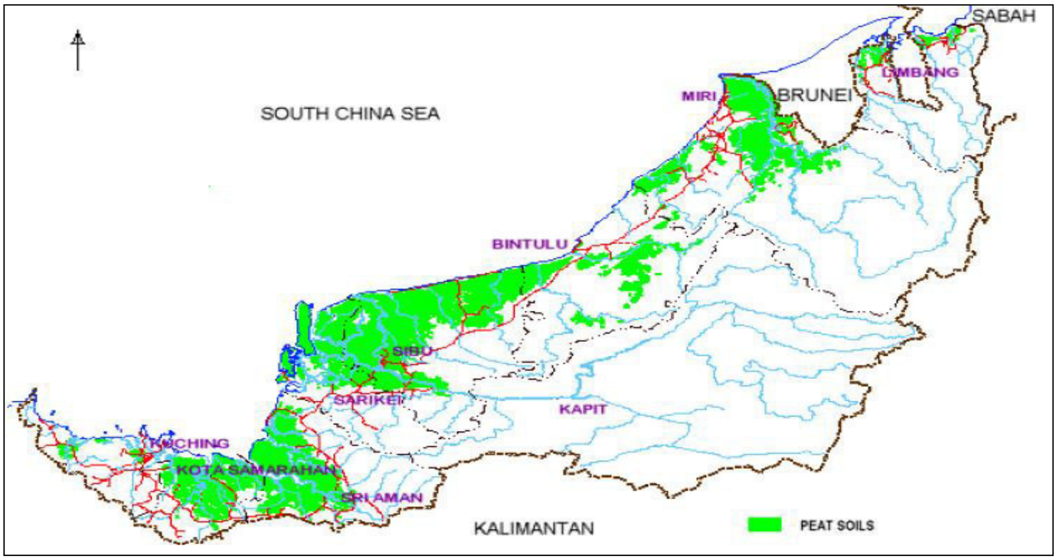


Figure 1. Distribution of Peat in Sarawak (Lee, 1991)

The shear strength of soil is an important property to be evaluated in geotechnical engineering. In this study, peat is stabilized with ordinary Portland cement (OPC). The shear strength test would be carried out by triaxial compression (TC) tests under isotropic consolidated undrained (CIU) and isotropic consolidated drained (CID) conditions to understand the short and long-term performances of the stabilized soil. The objective of this study is to compare the index properties and shear strength characteristics of untreated and treated Sarawak tropical peat.

SOIL PROPERTIES

The chosen peat for the study was collected from Matang, Sarawak in which peat at the depth of 0.25 to 0.6 m from the ground surface were extracted. Ground water table was found to be around 0.25 m from the ground surface. Figure 2 shows the vicinity of study area. Visual observation shows that the soil was dark brown in colour and further descriptions of the soil agreed well with the Von Post classification of H_4. Table 1 presents the properties of Matang peat. All the tests were carried out according to BS or ASTM standard. According to ASTM D 4427-92, if the peat has more than 67% fibre content, it is classified as fibrous peat. Matang peat is a fibrous peat and is also an acidic soil based on its pH test. Shear strength parameters are determined based on the maximum principle stress ratio (σ_1'/σ_3') as a failure criterion.

a) b)

Figure 2. (a) Location of Study Area (b) Peat in Study

Table 1. Properties of the Natural Peat

Parameters	Standard Specifications	Average values
Degree of humification (Von post scale)	Von Post	H_4
Moisture content (%)	BS 1377-1990: part 2	715.21
Organic content (%)	ASTM D 2974	91.14
Liquid limit (%)	BS 1377-1990: part 2	144.8
Linear shrinkage (%)	BS 1377-1990: part 2	6.4
Specific gravity	BS 1377-1990: part 2	1.265
pH	BS 1377-1990: part 2	3.91
Fibre content (%)	ASTM D 1997	76.86
$\rho_{d(max)}$ (g/cm^3) Optimum moisture content (%)	BS 1377-1990: part 4	0.513 101.5
CIU test (remoulded) c_{cu}' (kPa) ϕ_{cu}' (˚)	ASTM D 4767	 10.6 40.8
CID test (remoulded) c_{cd}' (kPa) ϕ_{cd}' (˚)	ASTM D 4767	 5.76 39.7

TEST MATERIALS

Stabilized Soil Specimen Preparation

In this study, disturbed original peat sample was presented as a control sample. Admixture which was used to stabilize peat is Ordinary Portland Cement (OPC). Prior to mixing the soil with cement, the soil was first sun dried, grinded and then sieved through 1.18 mm sieve to remove large pieces of woody debris contained within the samples. The stabilizing agent percentage which was used in this research is shown in Table 2. For compaction tests, the amounts of OPC used in the study were based on the total dry mass of the mixed sample. For shear strength tests, optimum moisture content and maximum dry density obtained in the compaction tests were maintained in the samples. Cement content of 25% and 50% of the total dry weight was mixed with peat until a uniform mix was obtained. The peat admixture was then compacted by hand with 10 constant full thumb pressures for approximately 10 seconds on each layer. This method is used in Sweden as described by Axelsson et al (2002). The periods of curing day were designated at 7 and 28 days. For the shear strength tests, after a curing period, specimens were removed from the mould and trimmed to height of 76mm and diameter of 38mm.

Table 2. Percentage of Total Dry Mass of Admixtures and Peat

Admixtures	Amount (% of total dry mass)	
	OPC content	Peat soil content
Pt + 25% OPC	25	75
Pt + 50% OPC	50	50

Triaxial Compression (TC) Test

The triaxial compression apparatus used for laboratory testing is fully automated stress path triaxial. There are two conditions of triaxial compression test, the CIU and CID conditions, which were carried out in accordance with ASTM D4767. Four phases (Initialization, Saturation, Consolidation/B and Shear phases) are required in order to run triaxial compression testing in both CIU and CID conditions. The saturation ratio (B) value of all the tested specimens was generally kept at above 0.9. The confining pressure values used to test the specimen until failure were 50, 100 and 200 kPa. In this paper, only 50 and 200 kPa confining stresses discussed. Shearing was carried out at a constant rate of strain of 0.1% per minute and 0.005% per minute for CIU test and CID tests respectively as suggested by Bishop and Henkel (1962) and Head (1981).

RESULTS AND DISCUSSION

Specific Gravity

Figure 3 shows the effect of curing time with different percentage of cement content on the specific gravity of the sample where untreated peat is a control sample. Cement content caused significant increase in specific gravity if compared with untreated peat due to the filling of the cement particle in the pores of peat. Similar observation was obtained by Chin (2006) on cemented clay. However, specific gravity showed decrement with longer curing time. This is supported by Uddin et al. (1997), Chin (2006) and Xiao and Lee (2009).

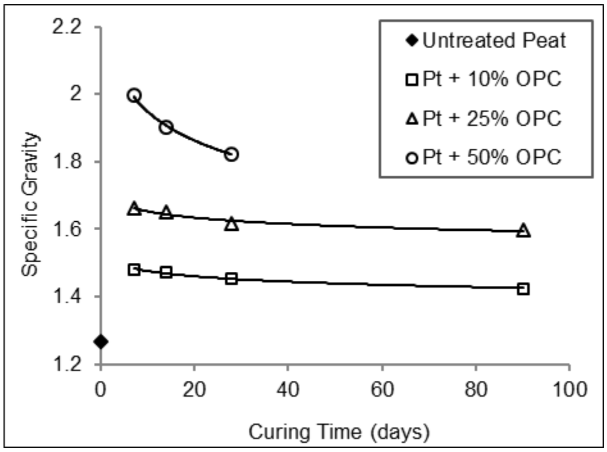


Figure 3. Specific Gravity – Curing Time Curve

pH test

Figure 4 shows that the pH of cement stabilized peat samples increased to values higher than 7 which depict a change from acidic to alkaline state after curing. This indicates that peat which is naturally acidic can be neutralized by adding cement to above 10% after the hydration of cement. The pH of the treated peat was increasing slightly with curing time. The curing time of stabilized samples does not have much effect on pH value, but the pH value will be affected by increase in cement content. The trend obtained was similar to the finding of Eriktius et al. (2001).

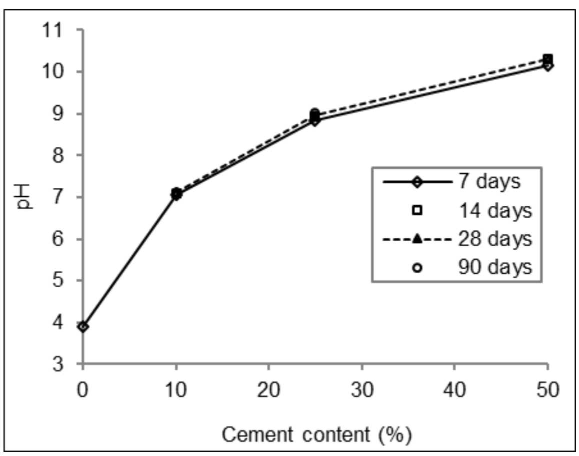


Figure 4. pH values versus Cement Content

Compaction test

In order to find the moisture-density relation, compaction tests were conducted on original peat and the mixture of peat with different amounts of OPC. From moisture-density curves, optimum moisture content and maximum dry density were obtained for each set of peat mixtures as shown in Figure 5. The original peat sample is presented as a control sample. As the cement content of the mixture is increased, the optimum moisture content decreases while the maximum dry density increases. This particular finding is agreeable to findings by Huat et al. (2005) and Kalantari and Huat (2009).

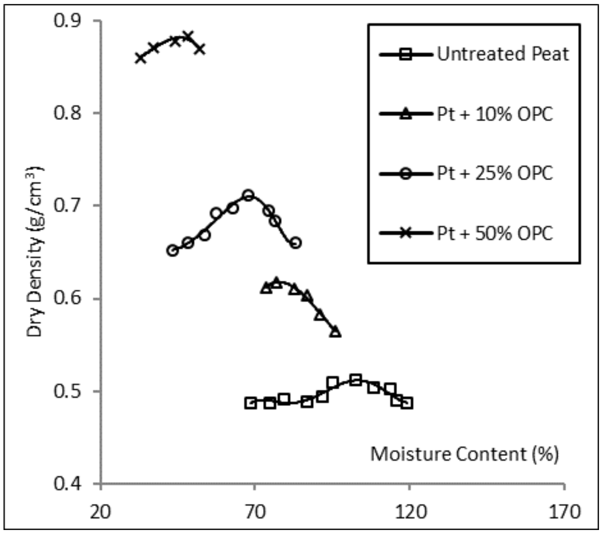


Figure 5. Moisture-Density Relationship Curves of Natural Peat and Peat with Different Percentages of Cement

Comparison between CIU and CID Triaxial Compression Tests

Stress-Strain Relationship and Volumetric Strain – Strain Relationship

The results of the untreated and cement stabilized peat (25% OPC and 50% OPC) were performed for comparison. The stress – strain variation from CIU and CID triaxial compression tests is shown in Figure 6. Stress-strain curves for CIU test showed ductile behaviour. While, the trends for the CID test were exhibiting brittle behaviour. Figure 7 shows the changes on vertical strain and volume change at different curing time for CID samples at different cement contents and confining pressures. From the figure, an increase in curing time caused a decrease in vertical strain at undrained and drained peak conditions at different effective confining pressures. However, the vertical strain at drained peak condition increased slightly with an increase in curing time when high effective confining pressure (200 kPa) was applied. It is also found, at both effective confining pressures the specimens behaved in a dilative manner in which increase of the volume is observed in CID test upon failure.

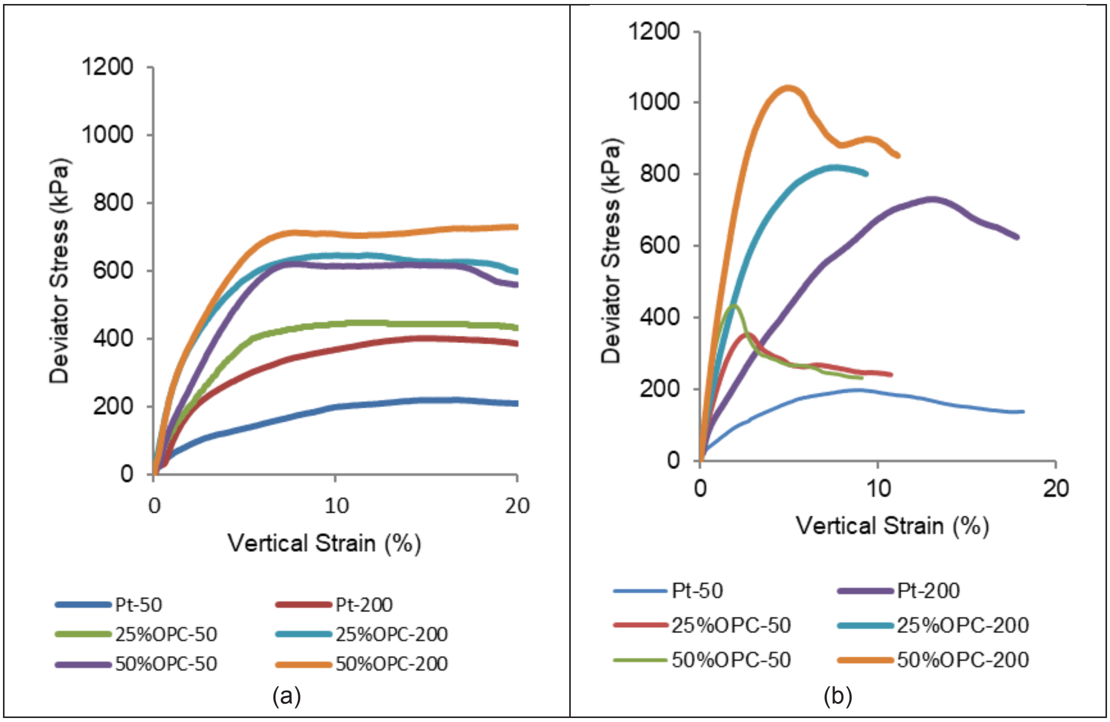
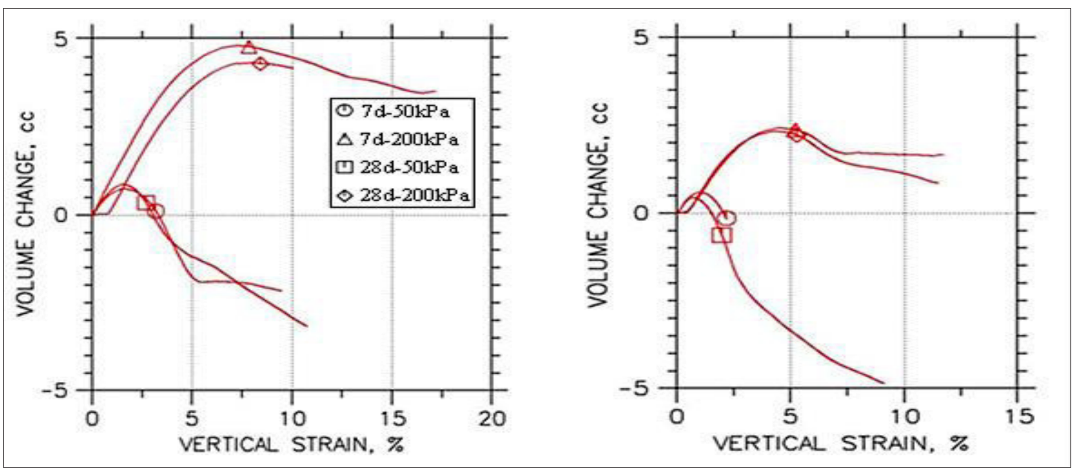


Figure 6. Deviator Stress – Vertical Strain Curves for a) CIU test and b) CID test at 28 days



a) Pt + 25% OPC b) Pt + 50% OPC

Figure 7. Relationship Between Volume Change and Vertical Strain for CID Test at Different Curing Time for a) 25% OPC, b) 50% OPC

Excess Pore Water Pressure

Figure 8 shows development of pore pressure of the stabilized peat with 25% and 50% OPC at curing time of 28 days in CIU test. Development of negative pore pressure is observed in CIU test upon failure at lower confining pressure as compared to the higher confining pressure. This shows that significant dilative behaviour is shown by samples in lower confining pressure. Figure 9 shows the effective and total Mohr Circles for samples treated with 25% OPC in CIU and CID tests. The total and effective Mohr circles for specimens tested by CID test results were the same due to no change of pore pressure. The diameters of the Mohr circles for CID test results were greater than CIU test results because the sample volume was reduced during axial loading and soils became stiffer. Thus, the deviator stress was increasing. Production of positive excess pore pressure in untreated peat and cement stabilized peat caused a lower effective strength in undrained conditions than in drained condition as shown in Figure 6 and Figure 8. In Figure 8, it is also shown that the pore pressure change increased with degree of cementation.

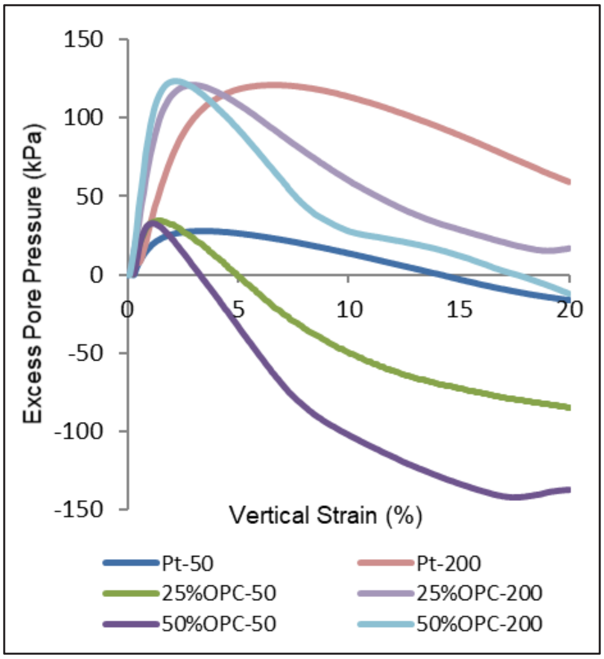
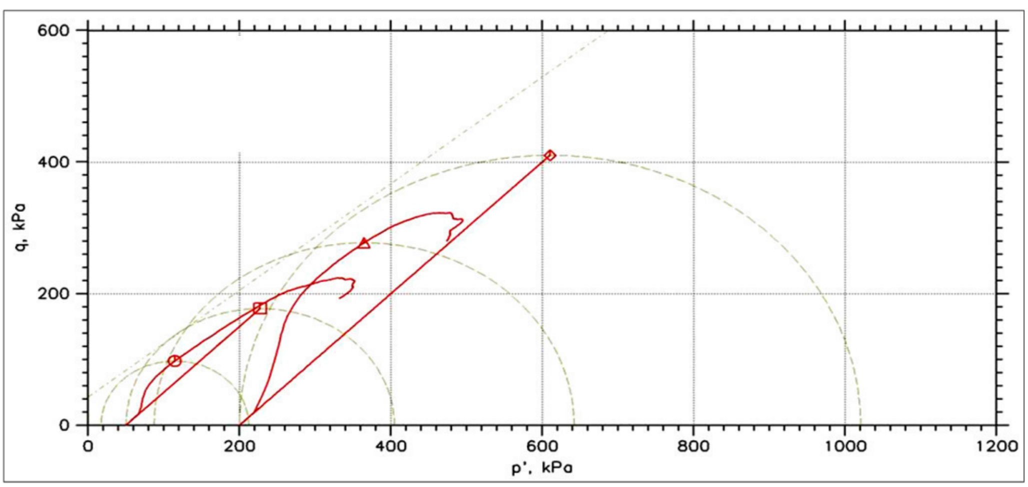
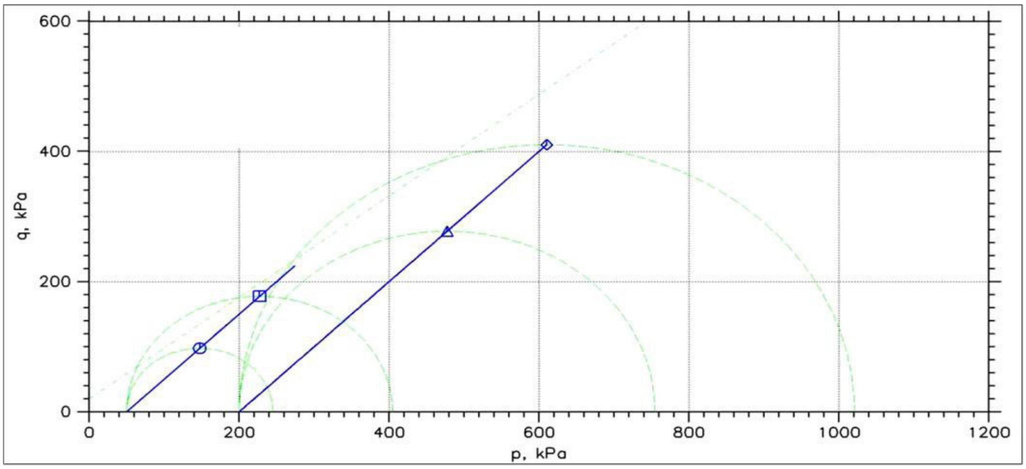


Figure 8. Excess Pore Pressure – Vertical Strain Curves (28 days)



(a)



(b)

Symbol	○	△	□	◇
Sample No.	CU-25C	CU-25C	CD-25C	CD-25C
Test No.	28d-50	28d-200	28d-50	28d-200

Figure 9. (a) Effective and (b) Total Mohr Circles for Samples Treated with 25% OPC in CIU and CID tests

Stress Ratio – Vertical Strain Relationship

Figure 10 shows the stress ratio for untreated peat and treated peat with 25% OPC obtained from CIU and CID tests. The peak stress ratio decreased with increasing of the effective confining pressure. An increase of cement content caused the peak stress ratio to increase as well. When the volumetric strains were prevented in CIU test, a higher stress ratio can be obtained.

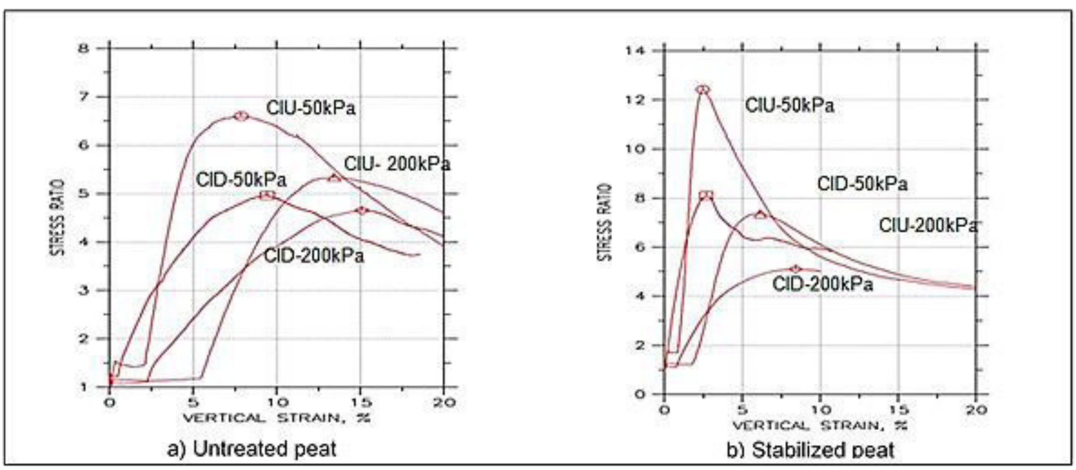


Figure 10. Examples of a) untreated peat and b) stabilized peat (25%OPC; 28 days) performed in CIU and CID tests with effective confining pressure of 50 kPa and 200 kPa

Shear Strength Parameters

Comparison is made between undrained (CIU test) and drained (CID test) shear strength parameters for untreated and cement stabilized peat and is presented in Table 3. Matang peat has low cohesion and high friction angle and this finding is in line with other peat types reported by Edil and Dhowian (1981), Yamaguchi et al. (1985), Sarac et al. (1997), Huat (2004) and Cola and Cortellazo (2005). It is interesting to know that the results of the effective undrained shear strength parameters (CIU test) of untreated peat were higher than the results obtained from effective drained shear strength parameters (CID test). This similar observation had obtained by Asmaa (2010) who had done a comparison between CU and CD tests for residual soils. However, for cement stabilized peat samples, the undrained cohesion (c_{cu}') were found to be lower than drained cohesion (c_{cd}') and the undrained friction angle (ϕ_{cu}') is marginally higher than drained friction angle (ϕ_{cd}'). The higher value of c_{cd}' than c_{cu}' of the cement stabilized soil was proven by Engan (2003). Ratio between CID and CIU tests results for the friction angle of the untreated and cement stabilized peat ranged from 0.81 to 0.97. This ratio can be used as a reduction factor to obtain CID test results from CIU test results in term of friction angle. However, the difference in friction angle of the cement stabilized peat for CIU and CID tests between 7 and 28 days samples was not significant. This same observation was reported by Balmer (1985), Clough et al. (1981) and Banks et al. (2001). In addition, the c_{cd}' result of the untreated peat was found to have a reduction factor of 0.5 from the c_{cu}'. While, for cement stabilized peat, the observation is in the opposite trend where the c_{cd}' has an average factor of 2.44 as shown in Figure 11.

Table 3: The Shear Strength Parameters for CIU and CID tests

Samples	Curing Time (days)	CIU		CID	
		c_{cu}' (kPa)	ϕ_{cu}' (°)	c_{cd}' (kPa)	ϕ_{cd}' (°)
Untreated Peat	-	10.6	40.8	5.75	39.7
Pt + 25%OPC	7	21.6	44.1	42.8	39.8
	28	23.5	45.9	59.3	37.4
Pt + 50%OPC	7	24.5	45.4	59.0	40.6
	28	21.5	45.7	61.5	41.9

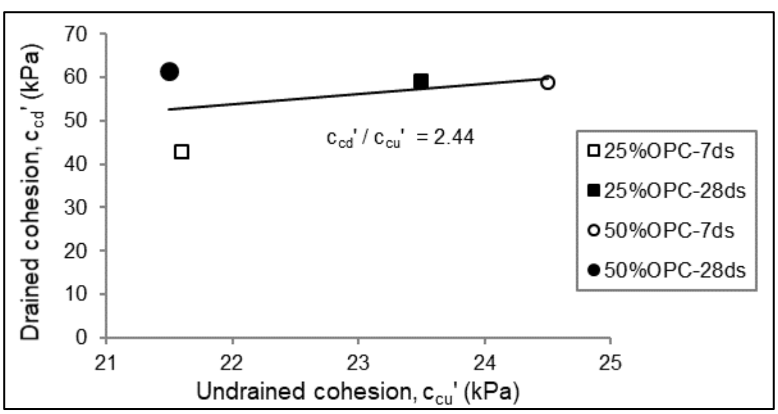


Figure 11. Relationship between CIU Cohesion and CID Cohesion

Secant Modulus of Elasticity and Shear Strength Relationship

Figure 12 shows the relationship between secant modulus of elasticity (E_{50}) and shear strength for untreated and cement stabilized peat. It was observed that the samples tested under CID test have a higher modulus if compared to CIU samples which means that the samples are stiffer. The ratio of E_{50} to q for the untreated and cement stabilized peat with curing time are in the range of 12 and 98.

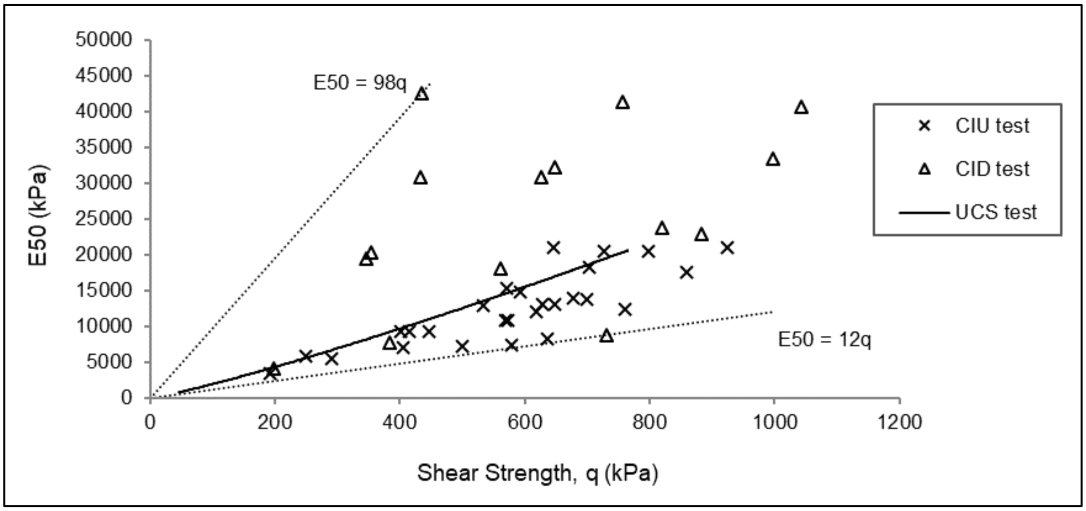


Figure 12. Relationship between E_{50} and Peak Shear Strength (CIU and CID tests)

CONCLUSION

In conclusion, the studied Matang peat is classified as fibrous peat with H_4 degree of humification, an average moisture content of 715.21%, organic content of 91.14%, liquid limit of 144.8%, linear shrinkage of 6.4%, specific gravity of 1.265, highly acidic with pH value of 3.91, fibre content of 76.86%, maximum dry density of 0.513 g/cm^3 and optimum moisture content of 101.5%. The value of specific gravity, pH, maximum dry density and moisture content are affected by adding cement in peat. Specific gravity is increasing with higher cement content but decreases in longer curing time. It can also be concluded that natural peat can be neutralized or changed to alkaline state by adding cement content of above 10%. As the cement content increases, the optimum moisture content is decreased, and maximum dry density increased. On the results of triaxial tests, CID tests on stabilized specimens indicate that cementation increases peak shear strength, and thus increases the cohesion. The strength of stabilized peat samples also increase as the curing process continues. For CIU tests, the effective cohesion decreases with higher cement content. The effective cohesion of stabilized peat samples increases with longer curing time except for samples with 50% OPC. This could be an anomaly in this test. The friction angle of treated peat for CIU tests is higher than untreated peat. However, the change in friction angle is not significant in higher cement content and longer curing time for both CID and CIU tests. For CID test, the drained friction angle of cement stabilized peat is relatively of little change with untreated peat. Out of these findings, a reduction factor of 0.81 to 0.97 can be introduced to obtain CID's friction angle from CIU results. In addition, the drained cohesion (CID test) of the untreated peat has a reduction factor of 0.5 from the undrained cohesion (CIU test). The ratio between CID and CIU tests results for cohesion of cement stabilized peat is in the opposite trend from the untreated peat with an average additional factor of 2.44. A useful relationship between E50 and Peak Shear Strength (CIU and CID tests) for tropical fibrous peat stabilized with cement can be improved in later works to increase other types of tropical peat.

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STRUCTURING OF COMPOSITE SYSTEMS BASED ON LIME HARDEN THROUGH CARBONATION AND SECONDARY LIMESTONE RAW MATERIALS

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Abstract
The article presents a study of the structuring of composite systems based on lime harden through carbonation and secondary limestone raw materials. It has been revealed that limestone aggregate enters into active chemical interaction with calcium carbonate produced in the carbonation process. It leads to the formation of strong cohesive coalescence contacts, characterizing high mechanical strength and durability of carbonized material. The resulting calcium carbonate 'duplicates' to a certain extent the properties of the limestone aggregate introduced into the raw mix. Due to this, strength and water resistance of the carbonized samples on a marbleized aggregate are higher than the same properties of the samples produced based on limestone aggregates of sedimentary origin.

Keywords: *lime; limestone; carbonizing hardening; structuring; calcium carbonate; strength*

INTRODUCTION

The problem of natural raw materials arisen in recent decade forces searching for new sources of raw materials and technological ways of producing construction materials and products. The most upcoming trend is the use of secondary raw materials of natural and technogenic origin (Zhuravlev 2010; Sutan et al. 2014). In the development of rocks in quarries and extraction of natural stone (cutting limestone blocks, marble, etc.), a substantial amount of fine limestone waste is accumulated in the tailings.

One of the new promising methods of producing construction materials and products is artificial carbonation of lime based composite systems based on lime and calcium carbonate aggregate and filler, whose particles can act as a substrate for the oriented crystallization of new growths on the surface of the carbonate particles to form contacts through the mechanisms of epitaxial growth (Palatnik and Papirov 1971; Chernyshev et al., 2015). The mechanism of epitaxial intergrowth is possible if the parameters of unit cells of the respective substances do not exceed 10 to 12%. Since the unit cells of portlandite and calcite have a crystallo chemical affinity, the conjugation of the respective planes may result in formation of epitaxial coalescence contact (Chernyshev et al., 2002). As a source of calcium carbonate aggregate and filler, various wastes from the mining and limestone processing can be used.

According to common theoretical beliefs, carbonation of the limestone mortars is a superficial process. Carbonation process results in formation of a calcium carbonate layer 5 mm thick. Then the carbonation process stop because of the limited access of carbon dioxide to the inner layers of the mortar due to the resultant dense layer of calcium carbonate (Volzhenskiy et al., 1979; Dvorkin and Dvorkin, 2011). However, studies of old brickwork mortars show the presence of large amounts of calcium carbonate there. It was found (Maravelaki-Kalaitzaki et al., 2003; Lobzova and Nosov 2009) that the binding component in the intergranular spaces of the aggregate is represented by fine-grained calcium carbonate, while the strength of the contact 'binder-aggregate' is close to the strength of the aggregate, and in some cases surpasses it.

It has been revealed in some researches on the artificial lime carbonation (Lubomirskiy et al., 2010) that the beginning of a chemical reaction is characterized by the formation of amorphous calcium carbonate, which further turns into the calcite crystals, scalenohedral or rhombohedral in shape. This ensures great cohesive force and significant mechanical strength to the crystals growing in various directions.

It has been found out (Lawrence et al., 2007; Ball et al., 2011) that carbonation of the putty starts in the upper layers and then drifts gradually and uniformly to the centre of the sample. The X-ray analysis of the tested carbonized samples has shown only the presence of calcite. Metastable crystal forms of calcium carbonate (aragonite and witherite) have not been found. Electronic microscopy of the samples has revealed that test samples are mostly represented by rhombohedral and scalenohedral calcite crystals. Noteworthy is the fact that the calcite crystals morphology changes along the entire cross section of the samples depending on carbon dioxide concentration and depth of the sample. Scalenohedral calcite crystals with cracked surface due to excess amounts of CO_2 were observed as well (Cizer et al., 2008).

The purpose of this article is to identify the regularities of structuring of composite systems based on lime harden through carbonation and secondary limestone raw materials, as well as to determine dependence of the end-use properties of artificially carbonized stone on the type of the limestone fillers.

MATERIALS AND TEST METHODS

To achieve the desired goal, theoretical and practical feasibility of secondary limestone raw materials in the systems based on lime harden through carbonation was assessed.

The most common fine limestone waste with the particle size of up to 5 mm was used, which is generated through cutting of yellow shell limestones and nummulitic limestones as well as crushing and fractionation of marbleized limestones.

Yellow shell limestone is a heterogeneous rock composed almost entirely of shells or fragments cemented with calcareous cement.

Nummulitic limestones consist of large shells of nummulites with detritus material between them. It is partially recrystallized dense and quite durable sedimentary rock.

Marbleized limestone is a product of limestone metamorphization and chemical differentiation. It is mainly represented by its dense and solid varieties. Depending on various impurities (iron oxides, manganese oxides, and clays), limestones have a colour ranged from light pink to reddish, yellowish and dark brown.

Chemical composition as well as mechanical and physical properties of limestone by-products are given in Tables 1 and 2.

Table 1. Chemical composition of limestones, wt%

Limestone type	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Ignition loss
Yellow shell limestone	7.88	1.2	1.83	49.17	0.15	0.14	39.5
Nummulitic limestone	9.87	0.65	0.92	48.35	0.47	—	38.9
Marbleized limestone	1.9	0.68	1.57	48.08	2.54	0.67	43.8

Table 2. Mechanical and physical properties of limestones

Limestone type	Density, kg/m^3	Average density, kg/m^3	Pinhole rating, %	Water absorption, % mass	Compression resistance, MPa	Coefficients		
						Softening point	Saturation	Heat conductivity, W/(m·K)
Yellow shell limestone	2700–2720	890–1900	30.2–66.9	7.4–33.3	0.4–2.6	0.56–0.96	0.51–0.98	0.21–0.37
Nummulitic limestone	2700–2730	1500–2100	23.0–44.3	6.9–19.3	4.1–34.6	0.46–0.97	0.55–0.99	0.35–0.70
Marbleized limestone	2700–2750	2600–2700	1.40–4.00	0.05–1.30	35.7–182.3	0.75–1.0	0.74–0.99	—

Each waste sample of a particular kind of limestone was grinded down to the specific surface area of 350 m^2/kg.

The cylinder-shaped test samples were moulded from a raw material mix consisting of slaked lime and limestone filler in the proportion of 1:1 by dry pressing at specific pressure of 10 MPa. The carbonation time was 18 000 seconds. The CO_2 concentration in the carbonation chamber was within the range from 30 to 35%.

Mineral and phase composition of the studied systems was determined in derivatographic and X-ray phase analyses. Derivatographic thermogravimetric analysis was carried out with the use of the derivatograph Q-1500D, the rate of temperature elevation was 10 degrees/min, the heating time was 6,000 s.

X-ray phase analysis was carried out with the use of the diffractometer DRON-2,0 under the following conditions: Fe emission, V = 30 kV, A = 20 mA, speed range 200 counts/sec, rate of turn 2 deg/min. The angular range was 1–100°. Samples for the X-ray phase analysis were prepared through pressing the sample powder into the form. The X-ray pictures were processed with a special computer program.

The structure of the studied systems was examined through electron micro scanning by the focused-beam microscope REM-106, SELMI.

The thickness of the carbonized layer (effective deficient layer) δ was defined by application of the phenolphthalein alcoholic solution on the sample chipping. Calcium carbonate resulted from the reaction of lime with carbon dioxide doesn't have any alkaline reaction and isn't tinted, while non-carbonized or partially carbonized areas are reactive with phenolphthalein and discolour to purple.

RESULTS AND DISCUSSION

Results of differential thermal analysis (DTA) of the carbonized material of the lime and limestone compositions (Figure 1) do not have significant differences depending on the kind of the limestone filler used. Endothermic effect within the temperature range 373–339 K corresponds to the removal of free moisture released in the chemical reaction of calcium carbonate formation. Endothermic effect within the temperature range 763–783 K shows the removal of chemically bound water and indicates the presence of unreacted particles of $Ca(OH)_2$. However, it should be noted that the corresponding endothermic effect at DTA of raw mixes of the studied calcareous and limestone compositions amounted to 803 K (Bakhtin, 2010). It indicates either the development of defects in the crystal lattice of $Ca(OH)_2$ or decomposition of other hydrated forms of calcium formed during lime carbonation.

Endothermic effect of $CaCO_3$ dissociation is 1173 K. It corresponds to the temperature of calcium carbonate decomposition in crystalline limestone (Ivanova et al., 1974), which indicates the formation of a solid crystalline aggregation concretion of the newly formed $CaCO_3$ crystals with calcite crystals of natural limestone.

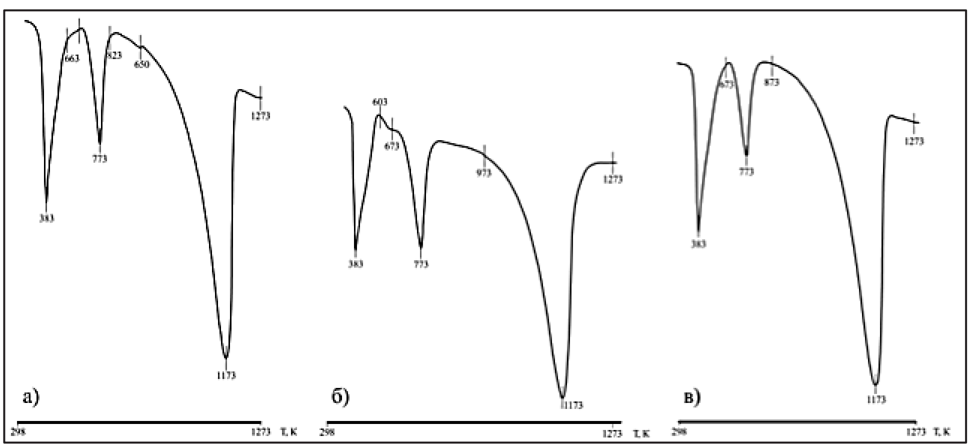

Figure 1. Thermograms of the test samples material depending on the type of the filler: a) marbleized limestone; b) shell limestone; c) nummulitic limestone

Roentgenogram of the studied samples of calcareous and limestone compositions made before and after carbonation allowed tracing the formation of $CaCO_3$ crystals. Figure 2 and Table 3 represent roentgenogram and phase composition of the material of samples of calcareous and limestone compositions based on marbleized limestone before and after their maturing in the elevated CO_2 environment. A slight increase in the interplanar spacing of

$Ca(OH)_2$ in the roentgenograms made after carbonation on average by 0.0002–0.0007 nm confirms the defectiveness of the crystal lattice of $Ca(OH)_2$ crystals.

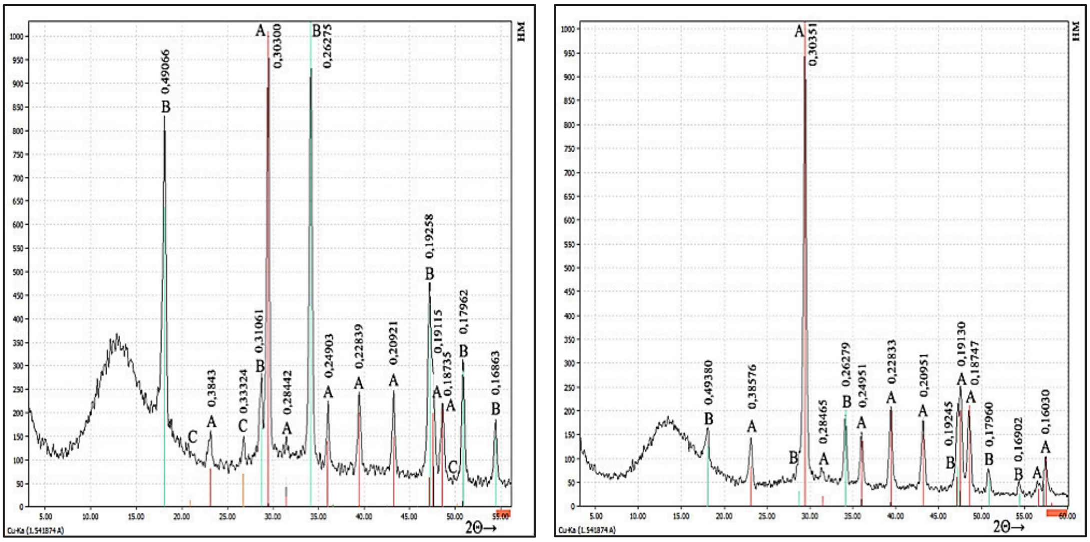

Figure 2. Roentgenogram and quantitative phase composition of the raw mix of calcareous and limestone compositions based on marbleized limestone before (a) and after (b) their maturing in carbon-dioxide-gas-air environment

Table 3. Phase composition of the material of calcareous and limestone compositions based on marbleized limestone for the raw mix composition equal to 1:1, wt%

	Calcite (A)	Portlandite (B)	Quartz (C)
Before carbonation	50.47	46.88	2.56
After carbonation	83.05	14.33	2.62

According to X-ray fluorescence analysis (XFA), in consequence of artificial carbonation of tested samples for 18 000 seconds, carbonation rate of the lime component was 69.4%. The change of limestone filler does not change the nature of the roentgenograms and quantitative phase composition of the material.

Nevertheless, about 30% of lime in the samples remains unchanged. As a result, the structure of a material matrix (binder portion) is formed as a heterogeneous system consisting of carbonate (carbonized) portion formed of secondary $CaCO_3$ crystals, and limestone portion similar to the one that is inherent to hydrate. Qualitative analysis of the reaction of phenolphthalein applied to the cleaved test sample (Figure 3) confirms the presence of cores containing calcium hydroxide, and an outer carbonized layer in the samples. The residual amount of $Ca(OH)_2$ concentrated in the deep layers of the material will be gradually carbonized due to the absorption of carbon dioxide from the atmosphere. This will result in formation of a uniform and durable carbonate structure of the material.

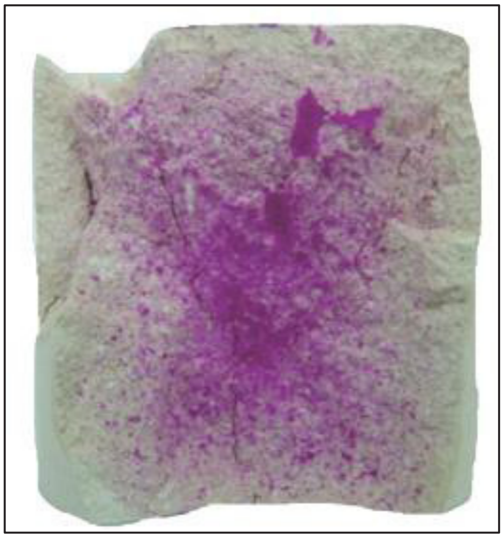

Figure 3. Formation of a carbonized layer of the calcareous and limestone sample based on marbleized limestone as a result of its artificial carbonation

Findings of the researches on the carbonized samples microstructure obtained using scanning electron microscopy are exemplified by calcareous and limestone composition based on marbleized limestone in proportion of 1:1 (Figure 4 and 5). The microstructure of test samples material before carbonation (see Figure 4) is mainly composed of rhombohedral crystals of limestone filler of 2–5 μm and lamellar crystals of $Ca(OH)_2$ of 0.5–1.5 μm oriented around them. In some places, there are needle-like calcite crystals of sub microscopic size, formed apparently by the reaction of lime with carbon dioxide of the atmosphere during storage. The material structure consists of uniformly distributed interconnected pores of 1 to 4 μm.

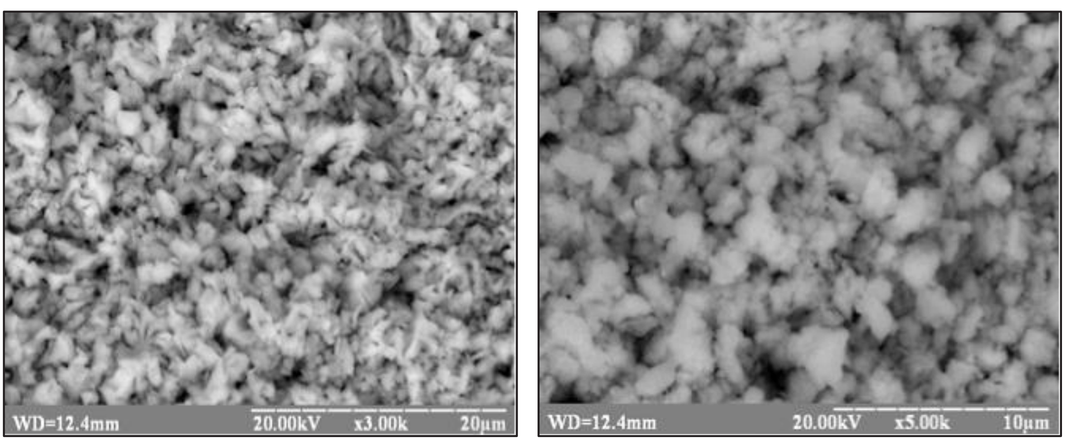

Figure 4. Microstructure of samples of calcareous and limestone composition based on marbleized limestone before carbonation: a) ×3000; b) ×5000

After carbonation, the microstructure of the material changes substantially (see Figure 5). In the outer layers of the cylinder-shaped test samples, the space between large rhombohedral crystals of limestone filler is filled with smaller newly formed calcite crystals of rhombohedral and scalenohedral shapes of less than 2 μm, tightly packed between each other and the grains of the filler (see Figure 5a and 5b). In some instances, intergrowth of newly formed calcite crystals with calcite crystals of limestone is observed, which forms a single crystal-jam (see Figure 5). Scalenohedrons most likely result from the $CaCO_3$ crystals deposition due to the decomposition of calcium bicarbonate salts in the samples drying. In some areas in the centre of the samples (see Figure 5d), the amorphous transition form of calcium carbonate not having a specific crystal lattice, though with distinct sub microscopic centres of calcite crystallization, is observed. After carbonation, due to increase in the volume of the solid phase of $CaCO_3$, total porosity of the test samples material decreased significantly; at that, closed pores of 0.1–0.3 μm appear in small quantities.

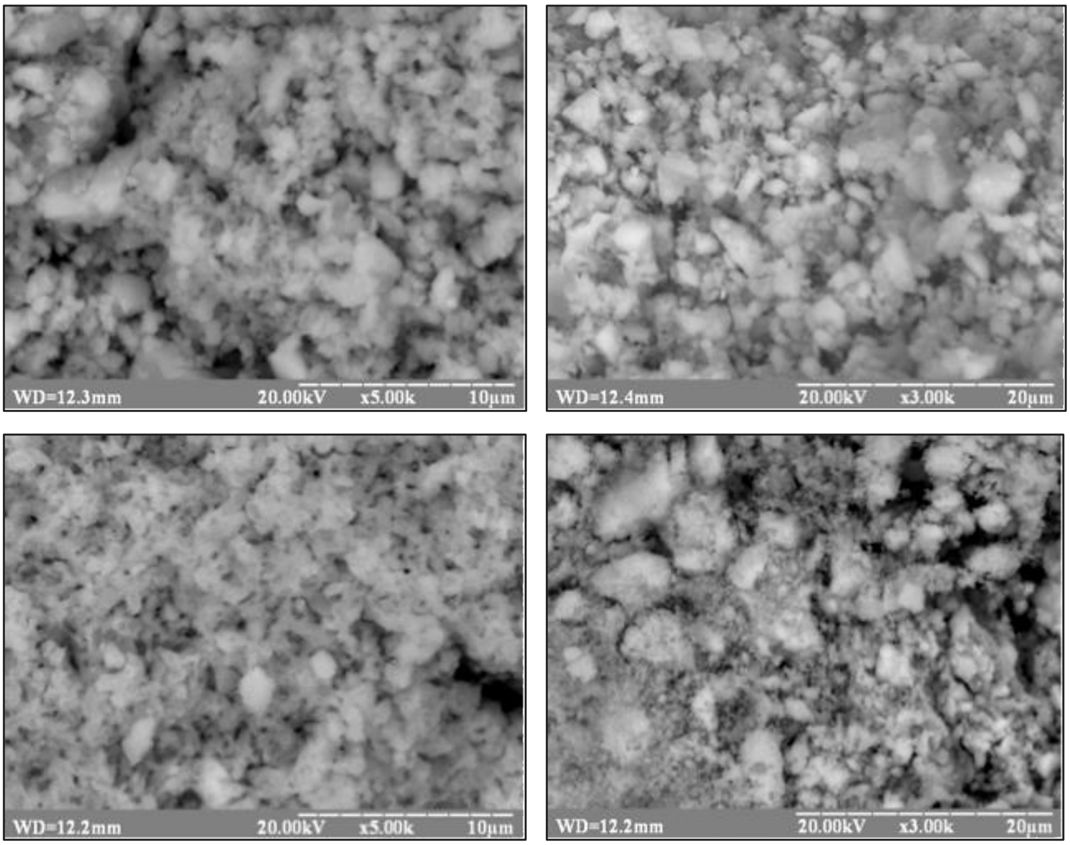

Figure 5. Microstructure of samples of calcareous and limestone composition based on marbleized limestone: outer layer of the sample, ×3000 to ×5000 (a, b, c); centre of the sample, ×3000 (d)

The nature of the changes in the structure of calcareous and limestone compositions based on nummulitic and shell limestones as a result of carbonation of the lime binder is the same. Similarity in the change of porosity, shape and size of formed calcium carbonate crystals is observed, as well as in the formation of a single crystal-jam characterizing the homogeneity of the material.

Despite the material impaction in the course of artificial carbonation, the samples made of the raw material mix based on lime and fine limestone filler (specific surface area is about 350 m^2/kg) applying dry pressing at specific pressure of 10 MPa have significant porosity of the structure after both moulding and maturing in a high CO_2 environment (number of pores exceeds 50%). Certainly, such a large porosity is an obstacle in obtaining durable and water-resistant materials. On the other hand, more dense structure of the material would hinder the diffusion of carbon dioxide into the sample. In this regard, calcareous and limestone samples were produced based on the coarse limestone aggregate with less content of lime, applying a large pressing force.

The cylinder-shaped test samples were moulded from a raw material mix consisting of slaked lime and marbleized limestone sifted through a sieve with cells of 2.5 mm. The lime content in the mixture was 20 wt%, the water content in the raw material mix was 5 wt%, specific moulding pressure was 30 MPa, the carbonation time was 18,000 secs, the CO_2 concentration in the carbonation chamber was within the range of 30–35%.

Macrostructure of the samples (Figure 6) is represented by the marbleized filler grains located in the lime carbonized matrix. In the samples compression test, brittle fracture peculiar to extra-strong calcites with an average or perfect cleavage was observed, as well as smooth shiny planes at the fractures.

Figure 6. Macrostructure of carbonized test samples of calcareous and limestone compositions based on marbleized limestone, ×100

Microstructure of the test carbonized samples based on marbleized limestone (Figure 7) reflects the general dependence of the distribution of coarse grains of limestone filler in carbonized lime matrix and is presented by uniformly distributed rhombohedral and scalenohedral calcite crystals 1–4 μm in size. There are groups of calcite crystals tightly fused to each other, with the size in the cross section of 5–7 μm.

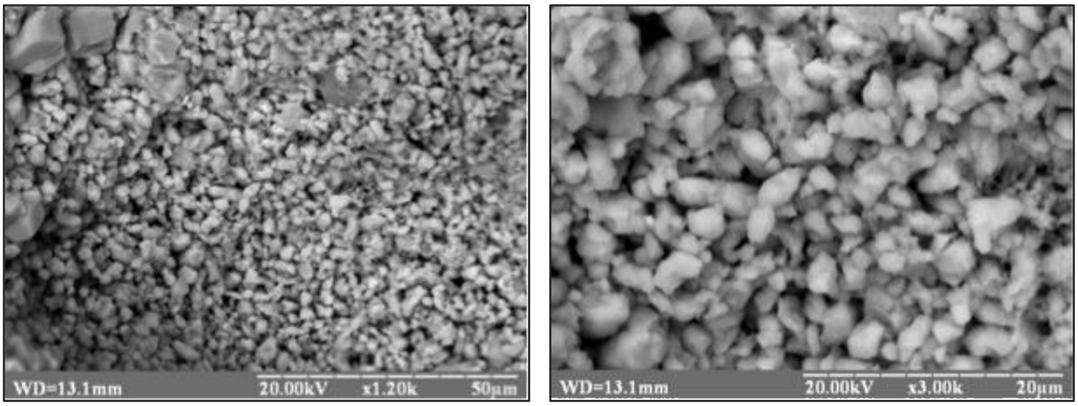

Figure 7. Microstructure of carbonized test samples of calcareous limestone compositions based on marbleized limestone, ×1200, ×3000

The research conducted in the contact zone of coarse grains of limestone filler and the newly formed carbonized matrix at the location of the fracture occurring in the samples test (Figure 8) indicates a high homogeneity of the obtained material and strength of adhesive-cohesive contacts of the grains of the filler and carbonized matrix. As is obvious from the photomicrograph (Figure 8a), the crack has passed through the faux carbonate stone that fills the intergranular space, as well as over grains of limestone aggregate. The revealed phenomenon may indicate that the strength of the matrix of the newly grown calcium carbonate crystals is not inferior to the strength of marbleized limestone. Strong adhesion is also caused by the rough shape of the filler grains contributing to their entrapment in carbonized stone (see Figure 8b). The fracture pattern of the material shows that there is an active physicochemical interaction between grains of limestone aggregate and carbonate stone obtained through artificial carbonation. This interaction results in the formation of durable coalescence contacts, which are manifested in a high mechanical strength of the carbonized material.

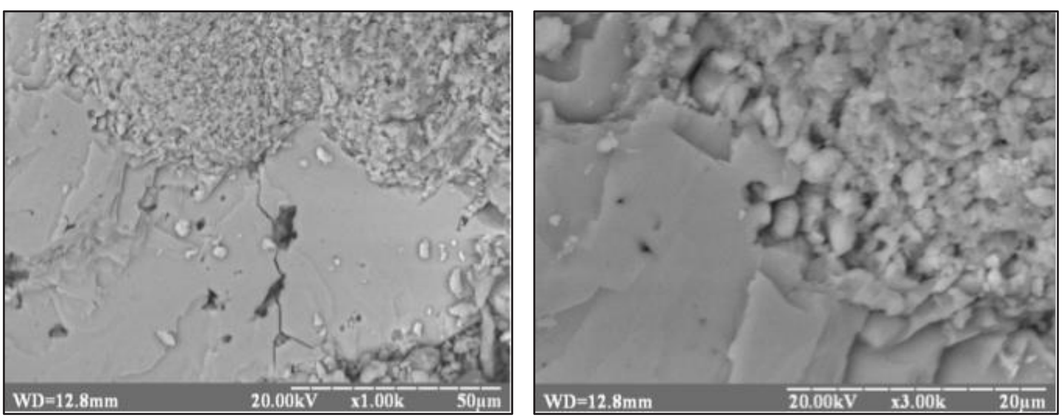

Figure 8. Microstructure of the material in the contact zone of the grains of limestone filler and carbonized matrix in the test samples of calcareous and limestone composites based on marbleized limestone: a) ×1000; b) ×3000

Mechanical and physical properties of carbonized test samples depending on the type of limestone aggregate are presented in Table 4.

Table 4. Mechanical and physical properties of carbonized cylinder-shaped test samples of calcareous and limestone compositions depending on the type of limestone aggregate

Test samples obtaining conditions			Properties of carbonized samples dried to constant weight				
Lime content, wt%	Water content of raw mix, wt%	Specific pressure of pressing, MPa	Compres-sive strength, MPa	Average density, kg/m^3	Water absorption by weight, %	Water absorption by volume, %	Softening coefficient
			Marbleized limestone				
20	5.0	30.0	37.8	2105	10.5	21.8	0.87
			Nummulitic limestone				
			32.7	2011	12.5	24.7	0.83
			Shell limestone				
			31.1	2001	13.1	25.0	0.82

It can be seen from the experimental data of Table 3 that mechanical and physical properties depend on the type of the limestone aggregate used. This is due to both physical and mechanical properties of the limestone and structural features of crystallization contacts appearing in the course of generation of secondary calcium carbonate due to carbonation of $Ca(OH)_2$ on the substrate of limestone aggregate. The one and the other depend on the genesis of limestones. Since marbleized limestones have a crystal structure similar to the morphology of the calcite crystals newly formed as a result of lime carbonation, one can assume that calcium carbonate generated in the system 'duplicates' to a certain extent the properties of the limestone aggregate introduced into the raw mix. Due to this, strength and water resistance of the carbonized samples on a marbleized aggregate are higher than the same properties of the samples produced from sedimentary limestones (yellow shell limestone and nummulitic limestone).

CONCLUSION

The conducted studies of the material microstructure of the carbonized test samples indicate the strong influence of limestone filler on structure formation processes of calcareous and limestone compositions hardened in the environment of increased carbon dioxide concentration. It has been established that nascent $CaCO_3$ crystals accrete on the facets of limestone crystals through the epitaxy mechanism, forming strong cohesive coalescence contacts, which provide overall high mechanical strength and durability of the carbonized material.

It has been revealed that mechanical and physical features depend on the type of the limestone filler used: the strongest samples with the highest density are carbonized samples on the marbleized limestone. It may owe to the fact that marbleized limestones have a crystal structure similar to the morphology of the calcite crystals so that the structure of the carbonized calcareous and limestone composition is stronger and denser.

The results of DTA of the carbonized lime and limestone compositions do not have significant differences depending on the kind of the limestone filler used. Endothermic effect of the $CaCO_3$ dissociation, corresponding to the decomposing temperature of the calcium carbonate in the crystalline limestone, indicates formation of a solid crystalline aggregation of the newly formed $CaCO_3$ crystals with calcite crystals of natural limestone. According to XFA, in consequence of artificial carbonation of the tested samples, carbonation rate of the lime component was 69.4%. The change of limestone filler does not change the nature of the roentgenograms and quantitative phase composition of the material.

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DIMENSIONALITY ANALYSIS OF TECHNICAL COMPETENCY FOR MALAYSIAN CONSTRUCTION MANAGERS

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Abstract
Gap has been found regarding the provision slated for construction managers in Malaysia's construction industry. Non-existence of term of reference for construction manager's competency profile are dictated as a major hindrance. Therefore, a comprehensive research was dedicated to unfold the rudimentary by focusing on their technical competency as a central phenomenon. In this instalment, further deliberation will emphasise on the subsequent works which leads to establishment of technical competency of construction manager (TCCM). Here the question of 'How?' lingered to the authors, especially when 'dimension' is being considered. Therefore, the authors only reported on the issue of dimensionality in this paper through analysis by using Rasch model since it is the utmost concerned for prior central phenomenon in hand. In short, interestingly, Rasch analysis outlaid quite different perspective especially on items PR9 (Knowledge of Lean Construction), PR8 (Knowledge of Constructability), and PR7 (Knowledge of Value Engineering). Those items represent the current knowledge on construction concepts which considered important to be equipped by the construction manager. Finally, the authors posited that all items were to be retained until further analysis of significance are conducted through classical test theory, in order to confirm the removal of construction managers' technical competency item(s).

Keywords: *dimensionality analysis, Rasch model, technical competency, construction manager*

INTRODUCTION

Undeniably, construction industry is one of the important industry for a nation. Thus, periodic check and balance especially towards their processes, people, and related engineering standpoints is very much needed since the particular industry is susceptible to fast changing environment (e.g. technology, climate change, etc.). Consequently, related to the people, Construction Manager (CM) has become the highlight. Given that they are one of the key person in construction phase, their incompetency is the last thing we hoped for. Unfortunately, it's happened and relatively became a conundrum for unsuccessfulness of construction project (Abdul-Rahman et al., 2006; Sambasivan & Soon, 2007; National Audit Department Malaysia, 2013; Unit Penyelarasan Pelaksanaan, 2013; National Audit Department Malaysia, 2014). Non-existence of established technical competency dispensed a huge gap which eventually translated into the latter issue. Therefore, a research is dedicated to establish their technical competency as a term of reference for the benefits of education, training, development, recruitment, and so on. The focus towards technical competency is deemed important due to the fact that it was a vital consideration to match individual to their job scopes (Mansfield, 1996). Additionally, since the dynamic nature of construction industry is concerned, technical competency is relatively visible, teachable, and requires much shorter time to acquire, and as a result it will compensate any efforts towards betterment in a much positive manner (Stoof et al., 2002; Deist & Winterton, 2005; Rudarakanchana et al., & Cheshire, 2015).

Noting the severe impact regarding the matter, a pragmatic exploratory study are conducted. Deliberately, several phases were outlined starting with qualitative inquiries that answers; what are the generic technical competency of Malaysia's construction manager? By using multi layered thematic process, and a series of structured interviews as tools for central phenomenon measures, the findings can be perused in Mohammad et al. (2016), and Yaman et al. (2015). Hence, moving on to quantitative inquiry as these question arose; "how importance does the generic technical competency of construction manager towards category and grade of Malaysia's contractors?" Given the fact that construction manager is generally representing contractor within diverse clusters, i.e. category as for civil engineering construction, building construction, and mechanical and electrical, and grade as for G1 to G7 (the highest number signifies large size contractor), the need to validate by analysing the importance of the technical competency and summing up generalised perceptions throughout entire country is paramount, whilst also the preferred methodology for past similar researchers (Young, 1993; Riggs, 1998; Egbu, 1999; Love & Haynes, 2001; Souder & Gier, 2006; Waluyo, 2007; Fester & Haupt, 2008; Ahn et al., 2010; Mullin & N. Williams, 2010; Wandahl & W. Ussing, 2010; Farooqui & Saqib, 2010; Gunderson & Gloeckner, 2011 - to name a few). Therefore, the subsequent topics were brought forward which encompassing the overall standpoints and paradigm towards the aforementioned methodology, and precisely presented in a step-by-step undertakings.

OVERALL QUANTITATIVE PARADIGM

Quantitative method usually has underlying theory to be bridged together (Creswell, 2008), therefore a thorough literature revision which have relatively similar topic in nature had been done in order to conceptualise the interconnected components and the norm towards related analysis processes. Prior to questionnaire design, a number of hypothesis were constructed which pillars on "the significant of importance for construction manager's technical competency towards contractors' grades". The said technical competency has been selected as independent variables, their importance as dependent variable, and contractors' category and grade as control variable (see Figure 1). Given the fact that the previous phase of research exploration has identified 271 independent variables, the authors were further clustered them into three (3) major clusters, namely; Macro level (16 variables), Meso level (34 variables), and Micro level (271 variables) to ease subsequent processes. Those clusters were formed according to past literatures' recommendations which centred on construction project's resources, objectives, general tasks, and overall essential competency. Though, for the purpose of quantitative enquiry, the technical competency questions will be limited to up to Meso level with 34 variables. The move was taken up since Micro level of technical competency with 271 variables had already been scrutinised at the previous phase of research methodology (Yaman et al., 2015), and it was also the preferred approach by past researchers for establishment of generic set of competency clusters (McDaniel, 2005; Waluyo, 2007; Isa, 2007; Benhart & Shaurette, 2011 - to name a few).

Additionally, the research were not attempted to distribute the detail breakdown of technical competency for validation and generalisation in this phase since time completion and response rate are the major hindrances. However, as a guidance for the respective respondents on answering Meso level questions, the Micro level of technical competency were partly included by using bracket '( )' for their convenience. Apart, in order to ease the respondents in answering the stated questions, dual languages were chosen; i.e. English and Malay. Then, two (2) sections were developed, namely; for demographics, and main body of questions. The questions were designed according to neutral intonations (i.e. without leaning towards negative or positive intonations), and five (5) points Likert scale were utilised throughout (i.e. 1 for extremely not important, and 5 for extremely important). Finally, before the questionnaire were being piloted, it was aptly embedded into previous structured interview (i.e. in preceding phase), which also doubled as validation process for preliminary questionnaire script. Interviewees were asked on the initially prepared questionnaire survey sheet in term of their overall construct and design in order to shed light on improvisation before pilot test were conducted. It was a pertinent move since the approach can saved valuable time and effort during revision especially post-pilot surveys' period.

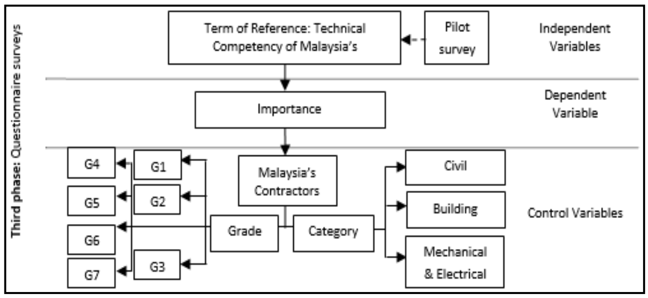

Figure 1: Variables outlined for questionnaire survey

Finally, the questionnaire itself were primarily undergone a small scale pilot test. It was distributed to ten (10) construction practitioners as a pilot survey in order to seek for reliability of the questions before mass distribution of survey were conducted. The result for the reliability analysis by using the Cronbach Alpha (α) is 0.977 for all questions. It shows that the questions were measured what it is intended to measure, and having satisfactory consistency between each respondents' perceptions. Therefore, it permits for subsequent mass questionnaire distribution to be undertaken.

GATHERING RESPONDENT

Questionnaire distribution covers the entire Peninsular Malaysia, and a small attempt to reach Sabah and Sarawak were also made but through minimal efforts. To ease the handling and distributing processes, zoning system was imposed; Zone 1 – Southern Region, Zone 2 – Middle Region, and Zone 3 – Northern Region. Apart, respondents were not limited to the existing construction managers itself, but also to the entire management and operational classes of contractor's organisation. The move was apt given the fact that the construction managers might use different title for certain organisations, yet hard to locate, and the precious opinions by surrounding construction practitioners within contractors' organisation that worked together with them (Egbu, 1999). Besides, the combination of self-administered, and online survey is deemed to be a better option in order to reach the targeted respondent. For nearly 70,000 contractors' organisation, response number in the range of 300 to 400 is preferred (Krejcie & Morgan, 1970). Thus, purposeful stratified random sampling were used, with snowballing were embedded into distribution process in order to maximise the response rate.

Additionally, email was used as a medium of distribution (for online survey) towards the respondents. Email addresses are collected through "Daftar Projek CIDB 2007-2014" which published by the CIDB Malaysia since only the active contractors are being considered, regardless of their grades. The layout of the online survey itself was constructed based on the suggestion by Toepoel et al. (2009). "Survey Monkey" as an online survey provider is selected based on the features they offered in a reasonable subscription price. It also became the main database frame to gather all responses (including self-administered) since the online software grant the simplicity of results generation. However, the online survey did not follow the previous zoning system since it was easier to distribute the emails in bulk (within 10 to 20 addresses per email) according to contractors' yearly active construction projects. Two waves of email distribution were taken place since the first wave did not successfully reached the targeted number of respondents. The authors applauded the assistance of many parties including the CIDB Malaysia and individual persons to disseminate the questionnaires, which appeared to be fruitful.

Eventually, a total of 680 questionnaires had been distributed (through self-administered) to respondent regardless of their organisation, grade, specialisation, and their position in the organisation around Peninsular Malaysia. Response rate of 47.35 % has been achieved through 322 accepted questionnaires. On the other hand, 1500 questionnaires were distributed through online email and received 51 accepted responses with 3.4 % of response rate. Therefore, the total accepted number of response suitable for analysis is 373 after sieving process is conducted, where incomplete, blank, and unsuitable responses were preliminarily rejected in order to treat missing data and errors, and ease subsequent analysis processes (see Table 1 for their breakdown). The generation of results for both "Microsoft Excel" format and "SPSS" format were made.

Following the respondents' specific demographics, several information were deemed important to the research, namely; their category, their grade registration, their position, and years of construction experience. Classification of category and grade of contractors were appropriately follows the recommendation from the CIDB Malaysia (Construction Industry Development Board Malaysia (CIDB), 2012). From Table 1, it can be observed that the contractors' organisation may have more than a single category since the total number of responses was more than the collected questionnaires. Majority of them were from building construction's category, and grade G7 dominates the lot with 123 responses. It was a fairly expected result given that higher grade contractors were believed to be the market leader, actively seek new opportunities (especially to upgrade themselves in term of knowledge and skills), and their willingness to share experiences – which finally made them visible to the research. On the other hand, majority of the respondents were coming from the top level of management (e.g. directors and project managers), and more than half of them had more than 10 years of construction's experience.

Table 1: Summary of collected data

Details	Test/Data		Results	Total
Pilot survey	Reliability (α)		0.977	-
Actual survey	Reliability (α)		0.969	-
	100% accepted responses (minus incomplete, blank, and unsuitable responses)		373 no.	-
	Percentage of response (self-administered)		47.35%	-
	Percentage of response (online)		3.4%	-
	Category of contractors	Civil engineering	178 no.	482
		Building construction	219 no.	
		Mechanical and electrical	85 no.	
	Grade of contractors	G1	47 no.	373
		G2	25 no.	
		G3	61 no.	

Details	Test/Data		Results	Total
		G4	37 no.	
		G5	52 no.	
		G6	28 no.	
		G7	123 no.	
	Position of respondents	Director	131 no.	373
		Project Manager	68 no.	
		Contract Manager	21 no.	
		Construction Manager	30 no.	
		Site Manager	14 no.	
		Site Supervisor	56 no.	
		Architect / Engineer / Quantity Surveyor	53 no.	
	Years of experience	4 years and below	73 no.	373
		5 years – 9 years	101 no.	
		10 years and above	199 no.	

RASCH MODEL ANALYSIS

Before any other statistical analysis were made, Rasch model analysis are conducted through Winsteps v.3.9 due to precarious concern on the dimensionality of the items in question. The particular software is compatible with SPSS file, where uploading, converting, and operating of data is not an issue. Though, in order to assist the analysis in term of nomenclature, full abbreviations as in Table 2 will be used throughout. To begin with, as a brief introduction, backbone of the Rasch model is IRT (Item Response Theory), where it is a psychometric approach on the fact that individual person will response to a set of item based on the quality of the individual and the quality of the item itself (Furr & Bacharach, 2007). While it is superior to Classical Test Theory (CTT), through the Rasch model, collection of items in any instruments needs to be unidimensional (i.e. measuring a single construct). If there are evidence of multidimensional, it represents that there are items which not measuring the same traits (maybe other construct is being considered). Furthermore, it is not appropriate to consider all items (multidimensional items) as having similar traits and summing up their total scores as one. Therefore, by adapting latent traits (from response to individual items), Rasch model transforms ordinal scores into interval scores by using logit scale, whereby successfully ranks the items difficulty in order to seek unidimensionality (Nilsson & Tennant, 2011; Lu, et al., 2013).

Thus, through the guidance of the works of several researchers on Rasch model analysis (Linarce, 2003; Royal, 2009; Aziz, 2010; Linacre, 2011; Conrad, Conrad, Riley, Funk, & Dennis, 2012; Apple, 2013), a vigorous steps of analysis were proposed accordingly, namely: Person fit analysis (consistency of person), Item fit analysis (coherence of items), Item-Person Map (visual representation of endorsement level), and Principle Component Analysis (PCA) of Item Residual (unidimensional construct). In Person fit analysis, several iterations were necessary in order to achieve consistency based on infit criteria, Rasch reliability of person, and Rasch person separation. The infit criteria are as follows; Misfit = < 0.5 MNSQ or -3.0 ZSTD, and Misfit = > 1.50 MNSQ or 3.0 ZSTD. The main driving agenda is to make an inference towards the values of Rasch reliability of person (consistency of person's response) and Rasch person separation (ability of the instruments to separate respondents into different level of the construct) before eliminating any response that considered misfit. From the results (see Table 3), both iterations showed very minimal differences on Rasch reliability of person and Rasch person separation. Given that Rasch reliability of person is quite high (~0.89), it was an indication that the respondents were suitable and consistent in answering the questions. Further, as the Rasch person separation is closer to each other for each iterations (< 3.00), retaining all persons for subsequent analysis are suggested because the outcomes still shows that there are at least three separated groups across the construct. Therefore, all person responses are retained without harming the succeeding analysis.

Table 2: Full abbreviations used throughout the Rasch analysis

Items	Detail		Meso Items
1	STAFF	Knowledge and skills of staff management (including their development, welfare, laws, etc.).	ST
2	MATERIALS 1	Knowledge of construction materials (concrete, steel, wood, soil, etc.).	MT1
3	MATERIALS 2	Knowledge and skills of material management (including their procurement, logistics, supplier, etc.).	MT2
4	LABOUR	Knowledge and skills of labour management (including their productivity, welfare, laws, etc.).	LB
5	PLANT 1	Knowledge of construction plant/equipment and their utilization.	PL1
6	PLANT 2	Knowledge and skills of plant management (including their requisition, maintenance, supplier, etc.).	PL2
7	SUBCONTRACTOR 1	Knowledge and skills of sub-contractor management (including their claims and payments, variations, insurances, etc.).	SU1
8	SUBCONTRACTOR 2	Knowledge and skills of sub-contractor tendering and bidding (procedures, pretender, bid analysis, quantity take-off, etc.).	SU2
9	HEALTH & SAFETY 1	Knowledge of health and safety equipment and manual.	HE1
10	HEALTH & SAFETY 2	Knowledge and skills of health and safety management (including their practices, compliance, regulation, training, etc.).	HE2
11	HEALTH & SAFETY 3	Knowledge and skills of risk management (including their assessment and analysis, etc.).	HE3
12	MONEY	Knowledge and skills of financial and cost management (including their claims and payments, pricing and purchasing practice, etc.).	MO
13	QUALITY 1	Knowledge of construction specifications, TQM, building codes and standards, etc.	QU1
14	QUALITY 2	Knowledge and skills of quality management (including their administration, assurance, quality control, etc.).	QU2
15	TIME	Knowledge and skills of time management (including understanding of project scheduling, updating, etc.).	TI
16	ENVIRONMENT 1	Knowledge and skills of environment management (including their assessment, Environment Management System (EMS), etc.).	EN1
17	ENVIRONMENT 2	Knowledge of green and sustainable construction (including Green Building Index (GBI), green construction techniques, etc.).	EN2
18	ADMINISTRATION	Knowledge and skills of construction administration (including documentation and record, submissions, plans/drawings, meeting, etc.).	AD
19	PRECONSTRUCTION 1	Knowledge and skills of construction site surveying, site layout, temporary structures/work, etc..	PR1
20	PRECONSTRUCTION 2	Knowledge and skills of construction site management (including overall resources management, master programme, construction sequences, Work Breakdown Structure, project start, meetings, etc.).	PR2
21	PRECONSTRUCTION 3	Knowledge of civil/structural design.	PR3
22	PRECONSTRUCTION 4	Knowledge of construction systems (including Industrialized Building System (IBS), etc.).	PR4
23	PRECONSTRUCTION 5	Knowledge of mechanical and electrical systems.	PR5
24	PRECONSTRUCTION 6	Knowledge of quantity surveying.	PR6

Items	Detail		Meso Items
25	PRECONSTRUCTION 7	Knowledge of Value Engineering (eliminating unnecessary cost which does not contribute to the value of construction).	PR7
26	PRECONSTRUCTION 8	Knowledge of Constructability (analysis of construction coordination issues associated with various trades).	PR8
27	PRECONSTRUCTION 9	Knowledge of Lean Construction (application of production management to construction).	PR9
28	CLOSEOUT & HANDOVER	Knowledge and skills of construction closeout and handover procedures (including their management, commissioning, acceptance, transfer, etc.).	CL
29	RESPONSIBILITIES 1	Knowledge and skills of construction law and legislation (including authorities processing, etc.).	RS1
30	RESPONSIBILITIES 2	Knowledge and skills of construction businesses (sales, commercial, trades, economic analysis, etc.).	RS2
31	RESPONSIBILITIES 3	Knowledge and skills of administering and assisting/facilitating client, senior manager and junior manager (including their coordination, liaison of works, orders, etc.).	RS3
32	COMPUTER & I.T. 1	Knowledge and skills of general computer application (MS Excel, MS Office, Adobe, internet based, etc.).	CO1
33	COMPUTER & I.T. 2	Knowledge and skills of construction information technology / software application (MS Project, Primavera, CAD, scheduling, estimating, accounting, etc.).	CO2
34	CONTRACT ADMINISTRATION	Knowledge and skills of construction contracts (including their administration, document, variations, Extension of Time, claims and payments, subcontracts, conflict, etc.).	CT

Table 3: Person fit analysis result

Person Fit	Response no.	Remove no.	Rasch reliability of person	Rasch person separation	Misfit no.
First iteration	373	None	0.9	2.98	60
Second iteration	313	60	0.89	2.87	None

For Item fit analysis, the fit of the items was analysed where the coherence of items is concerned. Similarly, several analysis iterations were made in order to achieve coherence; through infit criteria, Rasch reliability of item, and Rasch item separation. The infit criteria are as follows; Misfit = < 0.5 MNSQ or -3.0 ZSTD, and Misfit = > 1.50 MNSQ or 3.0 ZSTD. For the particular analysis, all items (34 items) were being considered since the previous preliminary screening tests indicated data appropriateness and suitability. The main driving agenda is to make an inference towards the values of Rasch reliability of item (coherence of items) and Rasch item separation (ability of the respondents to distinguish between items measuring different level of construct) before eliminating any item that considered misfit. From the results (see Table 4), both iterations showed similar Rasch reliability of item and very minimal differences on Rasch item separation. While the Rasch reliability of items shows high coherence, both the Rasch item separation indicates at least six different level of the construct as measured by the items. Further, in order to justify both results and to examine changes in construct validity, correlation analysis of disattenuated person measures (person measures of 34 items vs. person measures of 31 items) was conducted. In short, disattenuated person measures are able to signify the error of measurement when transforming raw and ordinal scales into true interval measures. The analysis was helped by SPSS on Pearson correlation with 99% confidence interval and two-tailed analysis in order to seek correlation value for both events (see Table 5). The result for disattenuated correlation is r=1.0 (round up from 1.11), where it outlays strongly correlated items (signifying the misfitting items could be removed without affecting the overall measurement). *"Disattenuated values greater than 1.00 indicate that measurement error is not randomly distributed, thus report the* *disattenuated correlation as 1.0"* (Schumacker & Muchinsky, 1996). Therefore, all items are retained without harming the subsequent analysis. Nonetheless, later confirmation through PCA of residual analysis will be done.

Table 4: Item fit analysis result

Item Fit	Item no.	Remove no.	Rasch reliability of item	Rasch item separation	Misfit no.
First iteration	34	None	0.97	5.67	3
Second iteration	31	3	0.97	5.73	None

Table 5: Pearson correlation for disattenuated person measures

Measures				34 items
31 items	Pearson Correlation			.994**
	Sig. (2-tailed)			.000
	N			373
	Bootstrap[b]	Bias		.000
		Std. Error		.001
		99% Confidence Interval	Lower	.990
			Upper	.997
			Upper	1

Moving on to Item-Person map, visual representation of endorsement level was analysed (see Figure 2). Person endorsement values are located at the left side of the map section, meanwhile item endorsement values at the other side. On the person endorsement section (left side), most top indicates easier endorsement level and most bottom indicates difficult endorsement level. Meanwhile, on the item endorsement section (right side), most top indicates difficult endorsement level and most bottom indicates easier endorsement level. The most difficult item to endorse is Item PR9 ("Preconstruction – Knowledge of Lean Construction") with Rasch item difficulty measure = 1.07. Meanwhile, the easiest item to endorse is Item MO ("Money = Knowledge and skills of financial and cost management") with Rasch item difficulty measure = -1.24. From the Item-Person Map, clearly the person mean falls around 3 logits and the item mean falls around 0 logits. On the other hand, person on top of the map found it easier to endorse items than person situated below them. The situation was a bit different for items, where item on top of map signify difficulty of endorsement rather than item below them.

```
             PERSON - MAP - ITEM
                  <more>|<rare>
  8     .##########  +
                     |
                     |
                 .#  |
  7                  +
                     |
                 .#  |
                    T||
  6              .#  +
                .##  |
                 .#  |
                 .#  |
  5              .#  +
               .### S|
               .###  |
                ###  |
  4           .####  +
               .###  |
              .####  |
             .#####  |
  3            #### M+
              .####  |
            .######  |
           .#######  |
  2            .###  +
             .#####  |
                .## S|
                 .#  |T
  1              .#  +  PR9
                 .#  |  CO2     PL2     PR4     PR5     PR7     PR8     RS2
                  .  |S CO1     EN1     EN2     RS3
                  #  |  PL1     PR3     PR6     RS1
  0               . T+M CL
                 .#  |  AD      CT      HE3
                  .  |S HE1     HE2     LB      MT2     PR1     PR2     QU1     QU2
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EACH "#" IS 4. EACH "." IS 1 TO 3
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Figure 2: Item-Person Map

In providing some context to the Item-Person Map, items on the extreme ends of the particular map will be discussed, i.e. PR9 for knowledge of lean construction and MO for knowledge and skills of financial and cost management. Thus, based on the map, item PR9 fell at the top which indicates the most difficult item to endorse. Mirror to the item PR9 are the proportion of person that endorsing the item, where below imaginary horizontal line of PR9 are persons who found that the item was difficult to endorse. However, the vast majority of persons were found that the item was easily to endorse (proportion of above 1 logits). On the other hand, by following the similar procedure as before, there was no person below the imaginary horizontal line of item MO. It suggests that the item was rather easy for the respondents to endorse, where all persons data is at above item MO (proportion of above -1 logits). As a quality measure for the Item-Person Map; it makes sense that the management of money (MO) is the critical and a must have knowledge and skills for construction managers, despite their seniority. Meanwhile, the concept of Lean Construction (PR9) as uttered by previous researchers was still in the stage of gaining acceptance in Malaysia, where most probably some of the respondents were not familiar or found that it was not very concerning. Additional to the previous Item-Person Map, the following reconfigured Item-Person Map (see Figure 3) were produced in order to give clearer understanding of level of construct for each study respondents. The figure shows items on the left side and individual respondents (represents their grade registration under CIDB's) on the right side. Mathematically, the person's means are far higher than two-standard deviation "T" on the items' side (left). Thus, it is suggested that all items were placed on a rather similar level by most respondents, which conforms to unidimensional level of construct. Further, a PCA analysis will be conducted in order to pinpoint the extent of unidimensionality.

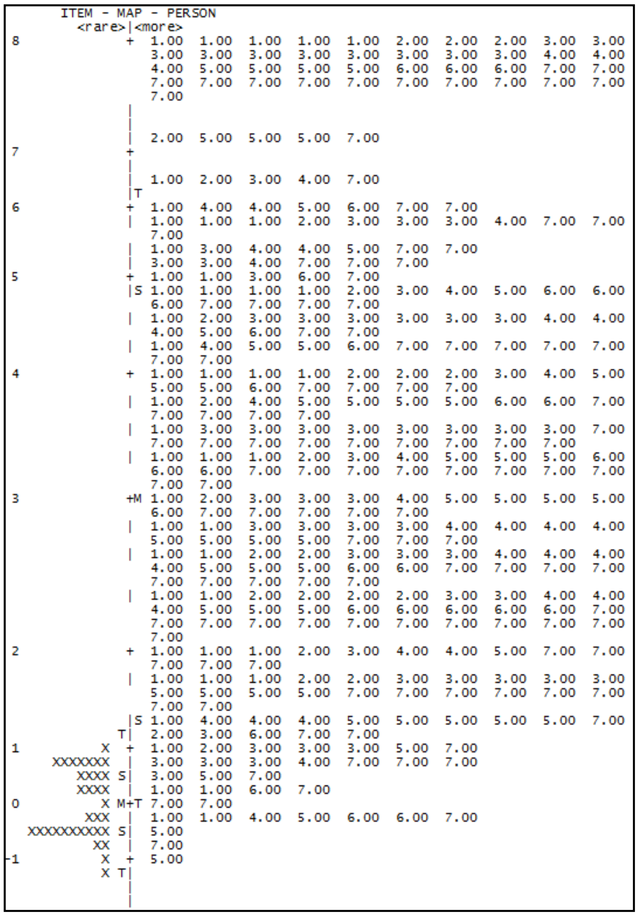

Figure 3: Reconfigured Item-Person Map

The last instalment of Rasch analysis is Principle Component Analysis (PCA) of Item Residual. A Rasch PCA of item residuals was conducted for all items (34 items) and persons (373 persons). As far as the analysis is concerned, unidimensional construct is important for the research since it is well aware that the questionnaire construct are seeking for single dimension, i.e. technical competency of construction manager. In this analysis, the most important agenda is to look for unexplained variance particularly in the first contrast where similar pattern of unexplained are observed. This pattern (consist of collection of items) might share similar attribute which resembling secondary dimension (Linarce, 2003). The supplied contrast plot is able to differentiate between primary (e.g. A, B, C) and secondary dimension (e.g. a, b, c). Manual observation is needed to interpret the contrast plot between both dimensions in order to rationalise their differences by inspecting their underlying content of each items. Since the result is just an indicative identification, proper judgement is needed (i.e. acceptance of either the items are having secondary dimension or only one dimension) (Linarce, 2003). Therefore, the Eigenvalue of above 2.0 in the unexplained variance in first contrast signify possibility of secondary dimension, which considered being above the noise level (Linarce, 2003; Apple, 2013). Additionally, at least 50% of "raw variance explained by measures" and less than 10% of "unexplained variance in first contrast" is needed for the measurement to be considered strong (Linarce, 2003). However, a slightly different view by Conrad et al. (2012) on benchmark to measure the strength of measurement dimensions as follows (particularly for raw variance explained by measures); ≥ 40% is considered a strong measurement dimension, ≥ 30% is considered a moderate measurement dimension, ≥ 20% is considered a minimal dimension. Thus, the research is taken both views of accounted percentage of total variance in order to seek for the strength of measurement dimensions.

Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)

		-- Empirical --			Modeled
Total raw variance in observations	=	64.2	100.0%		100.0%
Raw variance explained by measures	=	30.2	47.1%		47.3%
Raw variance explained by persons	=	17.9	27.9%		28.1%
Raw Variance explained by items	=	12.3	19.1%		19.3%
Raw unexplained variance (total)	=	34.0	52.9%	100.0%	52.7%
Unexplned variance in 1st contrast	=	3.5	5.4%	10.2%	
Unexplned variance in 2nd contrast	=	2.8	4.4%	8.3%	
Unexplned variance in 3rd contrast	=	2.3	3.6%	6.8%	
Unexplned variance in 4th contrast	=	2.1	3.3%	6.3%	
Unexplned variance in 5th contrast	=	1.9	3.0%	5.6%	

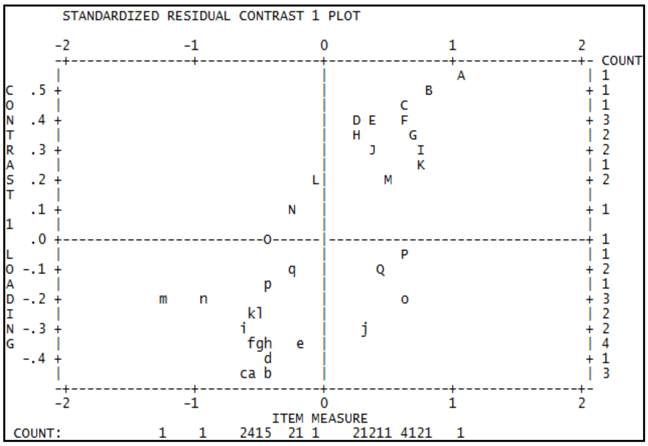

Figure 4: Result for Rasch's PCA analysis

In Rasch PCA with all items and persons intact (see Figure 4), the Rasch dimension explains 47.1% of variance in the data and 10.2% of variance in unexplained first contrast. Although it was not surpassing the threshold as suggested by Linarce to be considered as a strong measurement dimension, however the reported percentage were deemed acceptable to outlay good construct validity since the values is very close to the suggested threshold (whilst surpassing Conrad et al. (2012) suggestion). Meanwhile, variance in first contrast shows 5.4% and raw variance explained by items accounts for 19.1%. The 19.1% is roughly three times the variance in first contrast which indicates a noticeable secondary dimension in the items. Additionally, the eigenvalue of the first contrast is 3.5, which indicates that it has the strength of about 4 items, somewhat bigger than the strength of two items (eigenvalue of 2 to signify the smallest amount of a single dimension), which subsequently suggest multidimensionality. Since we do not expect a value of more than 2 items by chance, and at least 2 items to assume the situation as a dimension which not idiosyncratic items, therefore the secondary dimension might need to be checked manually for their substance.

Table 6: Proposed dimensions by PCA analysis

CON-TRAST	LOADING	MEASURE	INFIT MNSQ	OUTFIT MNSQ	ENTRY	NUMBER ITE
1 1	.54	1.07	1.06	1.03	A	27 PR9
1 1	.50	.83	.95	.93	B	26 PR8
1 1	.44	.64	.91	.93	C	25 PR7
1 1	.41	.27	.78	.74	D	29 RS1
1 1	.39	.38	.76	.75	E	31 RS3
1 1	.39	.65	1.11	1.10	F	22 PR4
1 1	.36	.68	1.00	.99	G	30 RS2
1 1	.33	.24	.93	.97	H	24 PR6
1 1	.29	.73	1.10	1.11	I	23 PR5
1 1	.29	.35	1.17	1.12	J	21 PR3
1 1	.26	.75	1.39	1.47	K	33 CO2
1 1	.22	-.06	.89	.85	L	28 CL
1 1	.19	.51	1.42	1.55	M	32 CO1
1 2	.09	-.27	1.04	1.05	N	34 CT
1 3	-.44	-.58	.99	.91	a	9 HE1
1 3	-.43	-.41	.96	.95	b	10 HE2
1 3	-.43	-.65	1.05	1.26	c	2 MT1
1 3	-.38	-.46	1.00	1.04	d	3 MT2
1 3	-.36	-.21	1.01	.95	e	11 HE3
1 3	-.35	-.55	.95	1.10	f	7 SU1
1 3	-.34	-.48	.94	1.01	g	4 LB
1 3	-.34	-.42	.85	.82	h	14 QU2
1 3	-.31	-.64	1.04	1.13	i	1 ST
1 3	-.30	.32	1.13	1.18	j	5 PL1
1 3	-.26	-.59	.93	.89	k	8 SU2
1 3	-.25	-.55	.86	.83	l	13 QU1
1 3	-.22	-1.24	1.13	1.09	m	12 MO
1 3	-.21	-.91	.89	.77	n	15 TI
1 3	-.21	.65	1.09	1.19	o	6 PL2
1 2	-.15	-.43	.91	.83	p	19 PR1
1 2	-.11	-.22	1.01	1.00	q	18 AD
1 2	-.11	.46	.89	.85	Q	16 EN1
1 2	-.04	.60	1.01	.98	P	17 EN2
1 2	-.02	-.45	.84	.75	O	20 PR2

By referring to the Standardized Residual Contrast 1 Plot (see Figure 4), we can see that obviously items ABCDEFGHIJKLMN are separated vertically from the other items (above horizontal line of 0), where they have a series of positive loadings. On the other hand, below the horizontal line of 0 are a series of negative loading items (namely; abcdefghijklmnopqQPO). Subsequently, guided by the works of Linacre (2011), and Apple (2013), cross checks for the contrast influence of the secondary dimension are done by inspecting Table 6. Items that have values of loading ≥0.40 (for positive), and ≥-0.40 (for negative) were scrutinised, a threshold that is considered as extreme and substantive (Linacre, 2011). Positively loaded items (i.e. secondary dimension) was perceived to have a quite different perspective, especially on Items PR9, PR8, and PR7. Those items represent the current knowledge on construction concepts which considered important to be equipped by the construction manager (i.e. lean construction, constructability, and value engineering; respectively). Though, the concepts were perceived to be less concerned by the respondents. As contrasted to Items HE1, HE2, and MT1, these items were considered as essential knowledge towards construction manager. Additionally, by referring back to previous item fit analysis, only RS1 (responsibility towards construction law and legislation) appeared to violate both analysis. Subsequently, in order to prove either it is worth to eliminate the respective items, a quick run of Winsteps analysis (see Table 7) in order to make an inference towards the values of Rasch reliability of item (coherence of items) and Rasch item separation (ability of the respondents to distinguish between items measuring different level of construct) is conducted towards both occasions (i.e. with all items intact, and with removing Items PR9, PR8, PR7, and RS1). Therefore, based on the results for both occasions, it can be concluded that removing the particular four items are not disrupting items reliability. Further, a minor difference on Rasch item separation (of 0.4) is deemed to be insignificant enough to warrant removal exercise. Moreover, based on the previous research findings and as far as the research is concerned, splitting the secondary dimension into separate instrument will degrade the central phenomena that being investigated, i.e. technical competency of construction manager. Hence, to confirm on the dimensions, disattenuated correlation on item measures was conducted. Eventually, the result for disattenuated correlation outlays strongly correlated correlation, r=1.0 (round up from 1.04). Therefore, based on the above, the items are judge to be a unidimensional measure, where single perspective of technical competency of construction manager is concerned. However, further significant analysis through classical test theory (CTT) by using SPSS will be conducted in order to conform items' significant through hypothesis testing.

Table 7: Item fit analysis result (for quick inference)

Person Fit	Item no.	Remove items	Rasch reliability of item	Rasch item separation
First occasion	34	None	0.97	5.67
Second occasion	30	PR9, PR8, PR7, RS1	0.97	5.27

CONCLUSION AND WAY FORWARD

The question of 'How?' in social research are frequently associated with the usage of quantitative nature of methodological approach. Therefore, the authors selected quantitative analysis with several perspectives in order to answer the particular research question; hence this manuscript tackled the dimensionality viewpoint.

Looking back at the respondents, in summary, all respondents fits the bill. The combination of their organisation's nature, positions, and experience were believed to strongly outlays fruitful results - both integrity and significant. Then, apart from sieving all incomplete returned questionnaire surveys, and before full fledge of CTT analysis were conducted, dimensionality investigation through Rasch Model analysis were directed towards the data in a form of person fit analysis, item fit analysis, item-person map analysis, and PCA of item residual, respectively. The first two analysis is to confirm the consistency of persons/respondents and items in questions. While the item-person map analysis was made to inspect the visual representation of endorsement level. The last analysis is crucially for determining the dimensionality of the construct. In a nutshell, by inspecting Table 6, there are negatively loaded items (i.e. secondary dimension) which perceived to have a quite different perspective, especially on Items PR9, PR8, and PR7. Those items represent the current knowledge on construction concepts which are considered important to be equipped by the construction manager (i.e. lean construction, constructability, and value engineering; respectively). However, any removal exercise towards items are yet to be materialised in this stage, since critical conformation from the succeeding analysis (i.e. CTT) is aptly needed.

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CRITICAL FACTORS IN SECURING FINANCE FOR PFI PROJECTS IN MALAYSIA

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Abstract
The Private Finance Initiative (PFI) is seen as an alternative procurement method for developing public infrastructure projects. The PFI scheme requires the private sector investment in public infrastructure projects. The private sector faces challenges in securing capital, and fulfilling financial requirements with attractive terms and conditions, which are cost-effective. This paper aims to explore the sources of financing available for PFI projects and to understand critical factors affecting financing requirements for PFI projects in Malaysia. Structured questionnaires were distributed to licensed financial institutions in Malaysia. The results show that the two financing options available in Malaysia are conventional and Islamic financing, and most financing facilities offered are term loan and *Istisna* respectively. The analysis indicates that project risks, project viability, and the company's financial strength are among the most critical factors that the financiers consider before granting any financing for the PFI projects. The findings may be valuable to the PFI key players, particularly in enhancing ways to securing finances.

Keywords: *Critical factors, Finance, Private Finance Initiative (PFI), Securing*

INTRODUCTION

Private Finance Initiative (PFI) was believed to be an alternative procurement strategy packages for funding the development of public projects. PFI employs a comprehensive concession agreement for long-term period, mostly from 20 to 30 years (Pantelias et al., 2015). Apart from being a designer and constructor, the private sector plays an important role as a financier and operator of the PFI projects. PFI has been proved to be effective in reducing government expenditure in the development of public infrastructure and services (Abdullah et al., 2014). PFI encourages better delivery of public services with excellent Value for Money (Pitt et al., 2006). Value for money is defined as 'the optimum combination of whole- life cost and quality or fitness to meet the user's requirement (Grimsey and Lewis, 2005).

There are three key players in the structure of a PFI: the public authority, the concessionaire also known as special purpose vehicle (SPV), and the lenders. The public authority acts as the awarding agency, and there is a concession agreement between the public authority and the SPV. The SPV is a legal entity, which is set up as the main player to deal with the financiers, construction companies, suppliers, investors, insurance providers, and public agencies. The third player is the lenders who are involved as equity and debt providers to fund projects under PFI. During the project operations, SPV receives revenues in the form of unitary charges appropriate to the rates specified in the contract agreement (Demirag et al., 2011). These regular payments are used to cover SPV's initial investments for both CAPEX (capital expenditure) and OPEX (operation and maintenance expenditure). Payments are paid by the users via toll or tariff or indirectly by the taxpayers (Pantelias et al., 2015).

The critical component of PFI is the highly leveraged capital structure. At the initial stage, particularly during project formulation and construction, the private sector has to secure large project funding. These early financial investments require long-term financial commitment before receiving payments (Engel et al., 2010; Sharma, 2013). Failure in securing finance or insufficient funding will affect the progress of projects (Demirag et al., 2015). The Malaysian banking institutions' lack of involvement in funding PFI projects is a constraint to the project growth (Saidan Khaderi and Abdul Aziz, 2009). They are still relatively inexperienced in PFI projects. Another constraint is that the lenders are reluctant to commit in funding the PFI projects due to high risks in terms of how capital intensive and complex projects are, and the long-term concession periods (Takim et al., 2008; Ismail, 2012). Mega funding imposes a high cost of borrowings which later escalate construction costs (UN ESCAP, 2011). During the loan proposal assessment, the lender needs to be assured that the capability of loan repayment due to additional risks of a high level of debt that exists in project finance transactions is observed (Yescombe, 2007). Therefore, it is a necessity to warrant the viability of the project and its completion on time that may help in returns earned from the project, which will provide enough cash to cover debt service adequately.

Based on the above, it is clear that financing is a significant element in PFI projects. Hence, this research looks into two analysis questions. Firstly, what are the financing facilities available from the financial industry in Malaysia? Secondly, what are the factors needed to be considered and how critical are the identified factors in securing finance for PFI projects?

LITERATURE REVIEW

Overview Private Finance Initiative in Malaysia

Since Malaysia aims to become an industrialised and developed nation, as expressed in its Vision 2020, several policies, such as the Malaysia Incorporated Policy and Privatisation Policy, have been established to encourage the involvement of private companies in funding and improving the delivery system of infrastructure facilities and public services ("Economic Planning Unit -Vision 2020, 1991-2020," n.d.). Public Private Partnership Unit (UKAS) was formed by the government, acts as the secretariat for the implementation of the policies. In March 2006, under the Privatisation Policy, the Malaysian government expanded the private sector's contribution through the Private Finance Initiative (PFI) to inspire smart partnerships with the private sector in national building efforts (Public Private Partnership Unit, 2009). PFI is part of the new strategies of procurement under the Public-Private Partnership (PPP). The PPP concept is defined as: *"…a form of cooperation between the public and private sectors where a standalone business was created, funded and managed by the private sector as a package that includes construction management, maintenance, repair and replacement of public sector assets include buildings, infrastructure, equipment, and facilities"* (Public Private Partnership Unit, 2009) .There are other implementation methods through PPP such as Build-Operate-Transfer (BOT), Build-Lease-Transfer (BLT), Build-Operate-Own (BOO), Build-Lease-Maintain-Transfer (BLMT) and land swap.

The Malaysian PFI model is similar to that of the UK model (Abdullah et al., 2014). It is structured in a way that the SPV will firstly be formed as key players of PFI implementers. They will enter into a concession that lasts for 20 to 23 years. The concession period normally consists of 3 years of construction and the rest is operation and maintenance of the assets. Lastly, the assets will be transferred to the public agency at the end of the concession period at zero costs. For the period of 2006 to 2015, there were 28 projects that were implemented under the PFI scheme as listed in Table 1. Most of the Ministry of Higher Education's projects have completed the construction stage and now are operated by the SPV (UKAS, n.d.).

Table 1. PFI project in Malaysia

Government Agency	No. of Project	Type of Project
Ministry of Health	1	Hospital
Ministry of Higher Education	19	University
Ministry of Public Works	4	Infrastructure
Ministry of Agriculture	1	Building
Ministry of Federal Territory	2	Housing
Ministry of Transport	1	Port
Total	28	

(Source: UKAS, n.d.)

PFI projects financing

PFI projects financing are project finances that are principally associated with the future revenues of the project (Akintoye et al., 2001; Yescombe, 2007). Project finance is defined as financing a stand-alone project in which a lender is satisfied at the cash flows and incomes of that project as the source of money from which a loan will be repaid and the assets of the economic unit as collateral for the loan is viable (Nevitt, 1983; Scannella, 2013). From the literature, the major features that form project finance are as follows: a) A stand-alone project company is created that will assume the ownership of the project; b) Non-recourse or limited recourse funding is secured, where project assets and revenues are assured as collateral for the lenders; c) Off balance sheet financing, which refers to the financing apart from the sponsor's balance sheet is secured; d) The expected project cash flow generated that will service the debt; and e) The risk-sharing principle, which refers to the spread of risks between all parties involved (Yescombe, 2002; Gatti, 2008; Scannella, 2013). Project finance is different compared to corporate finance because corporate finance includes obtaining funding for the project based on the balance sheet of the company rather than the project alone (Merna and Njiru, 2002; Gatti, 2013; Milbank, 2013). Financiers will study the company's financial strength or company's balance sheet before granting credit approval for a project. Due to the company's stable financial structure, the lenders feel secure that the company will not default on payment, although the project may fail.

Since the introduction of the PFI concept in the 1990s, the combination of equity and debt financing has been used to fund PFI projects. The SPVs invest a small amount of equity, approximately 10% to 15% of total project cost, and the remaining are funded by several financial sources (Akintoye et al., 2001). There are two key sources of financing. Firstly, the traditional sources of financing, which consist of commercial banks, development banks, and export credit agencies. Secondly, other sources of financing such as Islamic finance, capital markets, and equity (Milbank, 2013). In Malaysia, PFI projects are financed at least 80% via long-term loans for 15 years, and the balance is added internally by SPV (Abdullah et al., 2014). Other financing options available are bonds, mezzanine finance, and grants (UN ESCAP, 2011; Duffield and Clifton, 2009). Nowadays, Islamic project finance offers better terms and conditions for PFI project financing particularly Muslim countries in the Middle East and Asia like Malaysia and Indonesia. Islamic finance of profit and loss sharing that fulfils the Sharia law provides an alternative to SPV for investment through PFI projects. Some researchers state that *Sukuk* (Islamic bond) is an efficient Islamic instrument in PFI project financing (Ismail, 2013; Abdullah et al. 2014; Zawawi et al., 2014). In England and Wales, although Islamic financing instruments such as an *Istisna*, *Ijarah*, *Wakala* and *Murabahah* have been used for acquisition finance and corporate finance, they have not yet been used in project finance (Ransome and Hussain, 2016).

Sponsors who invest in the equity and the debt issuers may have different perspectives towards PFI project risks as to which party should bear the risk especially during the financing process because a project's risk profile will directly influence debt and equity provisions (Dewar and Irwin, 2015). The assessments on PFI risks will be easier for the lenders to provide or make financial decision-making. The risk is defined as the probability that a particular adverse event occurs during a stated period or results from a particular challenge (Royal Society, 1983). It also refers to the uncertainty that an asset will earn an expected of returns, or that a loss may occur (Fitch Thomas P., 2012). The risks that arise in the context of PFI, are different, in order to quantify factors such as market opposition, public perceptions, clients attitude, environmental threats and misconduct or misappropriation (Asenova and Beck, 2003). The risk assessment process, in which lenders measure qualitative and quantitative risks before the project financing is approved entails four steps (Hampl et al., 2011). Step 1: Through interview and available information, qualitative screening of the risk-return assessment based on the legal and regulatory environment, the reputation of the project, and lenders experience. The lender then makes a decision whether to pursue further or not. Step 2: Lenders evaluate the bankability of the project. They perform a quantitative risk assessment via detailed assessment of applicant's company and project potential including licenses and permits, cash flow model, project life cycle and agreement. Step 3: Lenders compute qualitative risk factors from step 1 and quantitative risks factors from step 2. The default risks are quantified and rated. The lenders assess whether the project, as well as the borrower, complies with the particular lenders' policy. Step 4: Computing of default risk from step 3 is executed. If all the lenders' requirements are fulfilled, the loan is approved, and the financial structure and financing credit conditions are outlined.

In the assessment of creditworthiness and bankability, many factors will be measured including financial and non-financial factors before a decision is made to invest in PFI project (Demirag et al., 2011). Financial factors like cash flow, liquidity, leverage, internal rate of return and return on equity are among the most significant factors to be considered (Demirag et al., 2011; Chiang and Cheng, 2011; Ngugi, 2014; Engel et al., 2014). Borrowers with a weak financial position face more difficulties in securing financing due to the perception that they cannot support the cost incurred in case of unexpected events (Ngugi, 2014). Non-financial factors include reputation, familiarity with the industry and client relationships, the profitability of the project, experience in PFI project, and knowledge of company project members (Demirag et al., 2011; Asenova and Beck, 2010).

When financing is approved, a legally binding agreement specify the loan terms that refer to the financing structure and conditions such as loan margin, repayment schedule, interest rate, and other enforceable conditions agreed by the borrower and the lender (Friedman, 2012). The lender will concern on whether the terms and conditions will affect profits (Osano and Languitone, 2016). They focus on the downside risks if the project is not viable, which may affect project capacity to generate significant cash flow for loan service obligations (Demirag et al., 2011). Moreover, lenders need assurance that the project can meet the stakeholders' interest to ascertain that the project is not being abandoned before completion

(Asenova and Beck, 2003). Table 2 summarises previous researches on factors affecting PFI projects financing.

Table 2. Key factors affecting PFI projects financing

Dimensions/ Factors	Sub-factors	References
Project Attributes		
Project Formulation	Location of PFI project; permits and site clearances; transparency in project selection; schedule of construction/project; favourable of term and conditions of agreement/termination/insurance; project agreement incorporate with operation/maintenance	(Zhang, 2005), (Singh & Kalidindi, 2009), (Asenova & Beck, 2010), (Meng & McKevitt, 2011), (Hampl et al., 2011), (Gupta et al., 2013), (Demirag et al., 2011), (Engel et al., 2014)
Project Viability	Life cycle costing; revenue generated; percentage of profit; cost of project; project's net present value	(Zhang, 2005), (Singh & Kalidindi, 2009), (Chiang & Cheng, 2009), (Asenova & Beck, 2010), (Demirag et al., 2011), (Marco et al., 2012)
Project Complexity	Scope of project; size of project; design and planning; technology; innovation of the project; construction period; concession period; completion on time	(Zhang, 2005), (Singh & Kalidindi, 2009), (Chiang & Cheng, 2009), (Asenova & Beck, 2010), (Hampl et al., 2011), (Marco et al., 2012) (Gupta et al., 2013), (Engel et al., 2014)
Project Risks	Construction cost overruns; construction time delay; construction incompletion; shortage of resources; bankruptcy of SPV; lack of commitment from either partner; poor quality workmanship; public opposition	(Zhang, 2005), (Singh & Kalidindi, 2009), (Asenova & Beck, 2010), (Meng & McKevitt, 2011), (Gupta et al., 2013), (Demirag et al., 2011), (Engel et al., 2014)
Company Attributes		
Company Profile	Year of company's establishment; organisational structure/legal structure; size of company; type of company/business activity; resources (equipment/man); technical expertise	(Singh & Kalidindi, 2009), (Chiang & Cheng, 2009), (Hampl et al., 2011), (Marco et al., 2012), (Gupta et al., 2013), (Engel et al., 2014)
Financial Strength	Company's profit; return on asset; return on equity; cash flow; company's liquidity; outstanding loans; debt level/leverage of the company; high equity-debt ratio; payback period/debt repayment; source of loan payment/payment mechanism; adequate collateral; sufficient reserve to cover construction/cost overruns; debt service reserve	(Zhang, 2005), (Singh & Kalidindi, 2009), (Chiang & Cheng, 2009), (Asenova & Beck, 2010), (Meng & McKevitt, 2011), (Gupta et al., 2013), (Engel et al., 2014)
Management	Management structure/team; management capabilities; governance; financial management knowledge; business network	(Chiang & Cheng, 2009), (Hampl et al., 2011), (Marco et al., 2012)
Performance	Reputation/market position of the company; good project track record; quality of work; project completion on time; experience in PFI project; familiarity with industry; quality of subcontractor; client relationship	(Zhang, 2005), (Singh & Kalidindi, 2009), (Asenova & Beck, 2010), (Hampl et al., 2011), (Meng & McKevitt, 2011), (Demirag et al., 2011), (Marco et al., 2012), (Engel et al., 2014)
Government Attributes		
Legal and regulatory provisions	Well-developed legal system; comprehensive and transparent concession law; government issuance of guidelines; enforcement of legislation	(Singh & Kalidindi, 2009), (Gupta et al., 2013), (Wibowo & Alfen, 2015)
Policy Framework	Clarity of government policy; clarity of government objectives; strong political support	(Gupta et al., 2013), (Wibowo & Alfen, 2015)
Government Guarantee	Government's guarantee on debt; government's equity participation; government grants; government's guarantee on tariff/charges	(Zhang, 2005), (Chiang & Cheng, 2009), (Meng & McKevitt, 2011), (Gupta et al., 2013)

Dimensions/ Factors	Sub-factors	References
Government Capacity	Competency of public agencies in PFI's management; government support regarding approvals and permits; efficiency of government in decision-making process	(Zhang, 2005), (Singh & Kalidindi, 2009), (Gupta et al., 2013)
Financing Attributes		
Rate	Inflation rate; interest rate/profit rate; debt-service coverage ratio(DSCR); internal rate of return (IRR)	Zhang (2005), (Meng & McKevitt, 2011), (Demirag et al., 2011), (Marco et al., 2012)
Market	Credit facilities offered by financial institutions	(Demirag et al., 2011), (Gupta et al., 2013)
External Factors		
Political	Political stability; political consensus on the need for the project	(Singh & Kalidindi, 2009), (Chiang & Cheng, 2009), (Marco et al., 2012), (Gupta et al., 2013)
Economic	Economic stability; effective market	(Zhang, 2005), (Marco et al., 2012), (Gupta et al., 2013), (Engel et al., 2014)
Social	Social acceptability	(Singh & Kalidindi, 2009), (Chiang & Cheng, 2009)

METHODOLOGY

A quantitative research methodology has been adopted for this study. A literature review was conducted and it was followed by questionnaire surveys to collect the required data. The comprehensive literature review facilitated the identification of five dimensions of critical factors in securing finance for PFI projects: project attributes; company attributes; government attributes, financing attributes; and external factors as listed in Table 2. Then, a survey questionnaire instrument was developed based on the critical factors identified from the literature review to obtain quantitative data from the selected participants in PFI projects. The questionnaire comprised of three sections. Section one required respondents to provide general information about themselves and section two dealt with financing options. In this section, the respondents were required to rate the frequency of financing options offered for PFI using Likert scale from 1 (never) to 7 (always). In section three, a seven-point Likert scale was used to rate the critical factors associated with securing PFI financing. The respondents were asked to rank each question (1-7), in which the scale is interpreted as 1 (not important at all) to 7 (extremely important). Before the actual distribution of the questionnaire, a pilot study was conducted on six respondents: three lecturers with construction and finance background, two colleagues, and one finance manager. This was to avoid any ambiguities and misunderstandings regarding the questionnaire.

Relative Importance Index (RII)

In this study, the Relative Importance Index was used to determine the significance of each variable rated by the respondents. This method was used by previous researchers when conducting an evaluation on questionnaire data, for example (Doloi, 2009; Abdul Azeez et al., 2015). RII was evaluated using the following formula (Doloi, 2009).

$$\text{Relative Importance Index, RII} = \frac{\sum W}{A \times N}$$

Where 'W' is the weight given to each factor by the respondents within the range from 1 to 7 using the same Likert scale as earlier; 'A' is the highest weight, and 'N' is the total number of respondents. Ranking of the items under consideration was based on their RII values. The item with the highest RII value was ranked first (1), the next highest (2) and so on. Then, the RII values were grouped into four categories to enhance the interpretation of the ranking. The categories were: a) very high ranked with RII ≥ 0.900; b) high ranked with 0.900 > RII ≥ 0.800; c) middle order ranked with 0.700 > RII > 0.800; and d) low ranked with RII < 0.700.

DATA ANALYSIS AND RESULTS

To achieve the objectives of this paper, detailed statistical analysis is presented in this section. The descriptive statistical analysis technique was used to describe the demographic and the Relative Importance Index.

Respondents' profile

A total of 66 questionnaires were distributed to licensed financial institutions in Malaysia, which consisted of 27 commercial banks, 19 Islamic banks, 13 investment bank, five statutory banks and two cooperative banks. The questionnaires were distributed in January 2016 and after two months, 18 responses were received. However, only 15 questionnaires were completed with a response rate of 22.7% and used for analysis. Eight (53.3%) respondents were from commercial banks followed by four (26.7%) from Islamic banks and three (20%) from statutory banks. As seen in Table 3 and 4, the survey indicates that twelve (80%) respondents had more than ten years of experience in the banking industry. However, only two (13.3%) respondents had more than ten years of experience in financing PFI projects. Most of the respondents were new in financing PFI projects because as reported by Abdullah et al. (2014), only two main banks provide funding to PFI projects in Malaysia. Other commercial banks are yet to get involved as they are not used to it and can only provide long-term loan for a maximum of ten years. Moreover, in earlier PFI implementation in 2006, Employees Provident Fund (EPF) raised RM20 billion in the form of loan to fund PFI projects (Takim et al. 2008). The response rate (22.7%) was low, and the data may be considered to be highly reliable for the analysis due to respondents' experience in the banking industry and their knowledge and understanding of PFI concepts.

Table 3. Respondents' experience in banking industry

Banking Institutions	Experience/Years				
	<5	6-10	11-15	>15	Total
Commercial	0	1	2	5	8
Islamic	0	2	1	1	4
Statutory	0	0	1	2	3
Percentage (%)	0	20	26.7	53.3	100

Table 4. Respondents' experience in financing PFI Project

Banking Institutions	Experience/Years				
	No	1-5	6-10	> 10	Total
Commercial	0	6	1	1	8
Islamic	1	1	1	1	4
Statutory	0	3	0	0	3
Percentage (%)	6.7	66.7	13.3	13.3	100

Sources of PFI projects finance

The analysis of the questionnaire response data helped produce rankings for financing facilities offered by conventional and Islamic project finance. Based on all the survey responses, for conventional project finance options, seven financing facilities were used to fund PFI projects. Based on Table 5, term loan and bank guarantee are the most frequent facilities awarded and are ranked high with RII greater than 0.800. The analysis also shows that bonds, revolving credit, overdraft, and factoring are ranked low as the RII was less than 0.700. The mean is 4, 3.9, 3.6 and 1.9 respectively, in which the frequency of the facilities approved is never to sometimes.

In Islamic project finance, all the RII scores of financing facilities were less than 0.700, which can be interpreted as low ranked as shown in Table 6. Even though *Istisna* is ranked first, all the Islamic financing facilities are seldom utilised for PFI project. Besides, Islamic finance is new in funding a large project, particularly PFI project (Zawawi et al., 2014). As seen in the same table, the mean score is less than 4, which shows that the frequency of the facilities offered is never to occasionally.

Table 5. Conventional project finance

Financing Facilities	Mean	SD	RII	Rank
Term Loan	5.800	1.751	0.829	1
Bank Guarantee	5.800	0.789	0.829	2
Letter of Credit	5.100	0.738	0.729	3
Bonds	4.000	2.667	0.571	4
Revolving Credit	3.900	2.025	0.557	5
Overdraft	3.600	1.647	0.514	6
Factoring	1.900	1.287	0.271	7

Table 6. Islamic project finance

Financing Facilities	Mean	STD	RII	Rank
Istisna	3.818	2.316	0.545	1
Ijarah	3.455	2.162	0.494	2
Murabahah	3.364	2.292	0.481	3
Sukuk	3.000	2.646	0.429	4
Musharakah	2.364	1.912	0.338	5
Tawaruq	2.091	2.023	0.299	6
Mudarabah	1.909	1.640	0.273	7
Bai Bithaman Ajil	1.727	1.618	0.247	8
Bai Salam	1.636	1.433	0.234	9

Critical factors in financing PFI projects

Based on all the responses received from the questionnaire surveys, as shown in Table 7, two factors are in the highest ranking category with RII ≥ 0.900, 13 factors are considered as high ranked, two factors are the middle order ranked factors, and no factor was ranked the lowest factor. 'Project risks' scored the highest rank with RII of 0.924 followed by 'project viability' with RII of 0.918. Both of these critical factors are in Project Attributes dimension. These findings, as indicated in the literature, shows that lenders give the highest priority to project risks and profitable project when considering investments in PFI project (Asenova and Beck, 2010; Demirag et al., 2011).

The five most important factors with RII greater than or equal to 0.800 are company's financial strength (RII=0.895), management of the company (RII=0.890), the performance of the company (RII=0.882), project formulation (RII=0.881) and government policy (RII=0.879). These three factors, i.e., company's financial strength, management and performance of the company are ranked high, indicating that project company attributes play a significant role in securing finance. For example, in Germany, the researchers found that characteristics such as good company profile, commercial track record, and company experience in the industry indicate excellent reputation of the company in the market, are important in securing finance for projects (Hampl et al., 2011). These characteristics will support the capabilities of the company to implement and complete the project successfully. Earlier research by Chiang and Cheng (2009) indicates that company features such as size, type, and governance of company did not influence the lenders to finance PFI projects in Hong Kong.

Table 7 shows that the factors in government attributes such as policy framework, government capacity and legal and regulatory provisions are ranked 7, 8 and 12 respectively. Government guarantee is ranked the lowest at number 17. Policy framework comprises of clarity of government policy and government objectives. When the government objectives are spelled out clearly, it provides a clear direction in ensuring the success of the project. Furthermore, all parties involved could strive to achieve these objectives.

Table 7. Financiers' perception of the critical factors to secure financing of PFI projects

Critical Factor	Mean	SD	RII	Rank	Dimension
Project risks	6.467	0.572	0.924	1	Project attributes
Project viability	6.427	0.618	0.918	2	
Company's financial strength	6.262	0.554	0.895	3	Company attributes
Management of the company	6.227	0.534	0.890	4	
Performance of the company	6.183	0.463	0.882	5	
Project formulation	6.167	0.721	0.881	6	Project attributes
Policy framework	6.111	0.686	0.879	7	Government attributes
Government capacity	6.111	0.720	0.873	8	
Political	6.067	0.704	0.871	9	External factors
Project complexity	6.050	0.607	0.864	10	Project attributes
Company profile	5.933	0.731	0.848	11	Company attributes
Legal and regulatory provisions	5.933	0.723	0.848	12	Government attributes
Financing rate	5.817	0.853	0.831	13	Financing attributes
Economic	5.700	0.941	0.814	14	External factors
Social	5.600	0.986	0.805	15	
Financing market	5.533	1.060	0.790	16	Financing attributes
Government guarantee	5.467	0.963	0.781	17	Government attributes

The analyses indicate that the financing rate (ranking number 13) in financing attributes ranked higher than financing market (ranking number 16). Any fluctuations in the interest rate will impact debt and loan payback (Meng and McKevitt, 2011). The purchase of interest rate swaps, for a full term and a full amount of debt, are recommended to avoid interest rate risk, which could be mitigated especially during unexpected rises in the interest rate that could impact the borrower's ability to repay its debt.

This study shows that the external factors are high ranked with RII more than 0.800. The lender is willing to approve the loan application when there is stability in the political and economic, which it gives directly impact on project success (Sundaraj and Eaton, 2011). The analysis reveals that among the 17 critical factors in this study, financing market and government guarantees are ranked as low, with RII of 0.790 and 0.781 respectively.

CONCLUSION

This study explores the sources of financing and identifies the critical factors in securing finance for PFI projects in Malaysia. Exploring the sources of PFI project financing provides an insight of the financing options and financing facilities available for PFI projects funding. By identifying the critical factors, lenders can enhance their decision-making processes and PFI project companies can adjust their preparations in securing project funding.

The data was collected by sending a questionnaire to 66 identified financial institutions in Malaysia, whereby 15 responded. The results have shown that the two project finance options available in Malaysia are conventional and Islamic financing and most financing facilities offered were term loan and *Istisna* respectively. The analysis indicates that project risks, project viability, and company's financial strength are among the most critical factors that financiers consider in granting finance for PFI projects. The findings may be valuable to PFI key players, particularly companies to enhance their abilities to secure required finances to undertake PFI projects.

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PRELIMINARIES AND THEIR PRICES FOR RESIDENTIAL BUILDINGS: A CRITICAL ANALYSIS

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Abstract
Preliminaries form the first section of the bills of quantities or schedule of rates in almost all tender and contract documents for construction works. They provide important information necessary for the proper execution of the works. Consequently, tenderers are expected to consider all preliminaries items in their pricing. In spite of their importance there is a dearth of published literature on the subject. The study reported herein and carried out via desk research focuses on preliminaries and their pricing for construction works of residential buildings. Key findings from the study include that there is no specific format for the presentation of preliminaries items in the bills of quantities and no specific pattern of pricing the items by the tenderers, preliminaries form between 4.40% and 8.73% of the contract sum and for residential buildings' projects the study has identified the top ten preliminaries items. The findings is significant to clients, quantity surveyors and contractors as they may be incorporated into their estimating and tendering strategies respectively.

Keywords: *Building, bills of quantities, contract, construction, preliminaries, quantity surveying, tender*

INTRODUCTION

Preliminaries form the first section of the bills of quantities (Cunningham, 2015) or schedule of rates in almost all tender and contract documents for construction works. The preliminaries provide, among others, information on the work and its scope, the requirements of the client, temporary works and other items necessary for the proper execution and completion of the works. However, preliminaries do not form part of the completed or permanent works (Ahamad and Khairuddin, 2004; Packer, 2017). In other words "Items that are of a general nature and do not necessarily relate to the quantity of permanent work are set out in the preliminaries section…" (Willis and Trench, 1998).

Preliminaries normally appear in the bills of quantities or schedule of rates as items complete with descriptions. During tendering, tenderers are expected to consider all preliminaries items in their pricing for the works (The Entrusty Group, 2009). Each item should be priced as a lump sum (Ahamad and Khairuddin, 2004). According to Cunningham (2015) the cost of preliminaries in a building project could exceed 10% of the contract sum. Therefore, preliminaries are considered very important to the Contractors and other key players of the construction industry. As such a quantity surveyor, being the professional tasked to prepare the preliminaries section, must ensure all items considered necessary for the proper execution and completion of the works are included and that all tenderers endeavor to ensure all preliminaries items are studied, their requirements for the works thoroughly considered and appropriately priced.

However, in spite of the importance of preliminaries in construction works there is a dearth of published literature on the subject. In fact it would not be an exaggeration to contend that the same is also true on the presence of published literature on other subjects related to the core businesses and practices of quantity surveying in Malaysia. Based on the authors' casual observations lately there appear to be a trend among quantity surveyors to indulge in subjects related to the laws such as construction laws and contracts, disputes and disputes resolution and management but little emphasis have been given on the study or research on subjects like bills of quantities and documentations, estimating, pre and post-contract administration, preliminaries as well as efforts to modernize the practice of quantity surveying in Malaysia. The authors do not disagree for quantity surveyors to acquire knowledge and skills in the broader areas of the laws, management and the likes as they are very much related to quantity surveying but equal effort and emphasis, if not greater, should also be placed on the core knowledge areas and skills in quantity surveying so as to enable the practice to be enhanced and sustained well into the future.

In the context of the present study the interest to carry out a study on preliminaries arises when the authors were often asked by students and practitioners alike on how to better understand preliminaries including the items contained therein and their prices. Explaining preliminaries were often hampered by the almost total absence of locally published literature on the subject. The authors acknowledge the subject on preliminaries for construction works is wide and deep therefore the scope of the present study was designed to focus only on preliminaries and their pricing for construction works of residential buildings. The authors hope that the study and its findings, to be reported herein, would contribute towards the body of knowledge on the subject of preliminaries in construction works.

This paper is presented in 5 parts. The first part provides an introduction to the subject of preliminaries for construction works and introduces the paper. Parts 2 and 3 provide a review of the key literature on preliminaries and describes the methodology and the carrying out of the study respectively. Part 4 presents the results from the study and the ensuing discussions. Finally, Part 5 provides concluding remarks to the study and suggestions on how best to move the study forward.

LITERATURE REVIEW ON PRELIMINARIES

In almost all tender and contract documents for construction works, the first section of the bills of quantities or schedule of rates is a section labeled as 'Preliminaries' (Cunningham, 2015). Willis and Trench (1998), Ahamad and Khairuddin (2004) and Packer (2017) have given their respective definition of the term preliminaries and these definitions have been discussed earlier in this paper.

According to the Aqua Group (1992) the preliminaries is among the three basic information to be found in bills of quantities, the other two are the preambles and measured works. They proposed that contents of the preliminaries should include, among others, a complete description of the works and the conditions under which those works are to be carried out, scope of the works, details of the proposed standard form of contract to be used and a list of amendments thereof if applicable, description of the administrative mechanisms required in the implementation of the contract, a list of drawings used in preparing the tender and contract documents and any special requirements as to the method of pricing and presentation of the tender.

The Malaysian Standard Method of Measurement of Building Works, 2nd Edition (SMM2, 2000) dedicated one section, namely Section B, on preliminaries for building works. The section on preliminaries provides guidance for the quantity surveyors, clients and other key players of the building industry on the identification and descriptions of items considered necessary for the proper execution and completion of the works and yet these items would not be forming any part of the completed works.

Referring to SMM2, Table 1 presents a summary of items recommended to be listed in the preliminaries section of a tender and contract documents of a typical building works. In all SMM2 listed a total of 13 main categories of preliminaries (B.1-B.13) and 29 sub-categories. Generally, the preliminaries items include particulars of the contract and of the works, particulars of the clients and other key players, goods and materials to be provided by others, general facilities and obligations of the clients and the contractors respectively and contingencies.

From the 13 main categories listed by SMM2 all the categories, except one i.e. B.12 - Pricing, provide guidance on the kind of information that must be included in the preliminaries to facilitate tenderers' understanding of the project in all the key areas and aspects. However, B.12 – Pricing as the term suggests, requires information on 24 items related to general facilities and obligations to be provided so that tenderers' attention would be directed on them and they may consider pricing these items in their tenders (see Table 2).

Table 1. Main categories of Preliminaries items in SMM2

SMM2 Item Ref.	Brief Description
B.1	Project, parties and consultants Information about the project such as name, nature and location of the project, works to be done and addresses of the employer and consultants.
B.2	Description of site Information about the site that includes its boundaries, access, availability of services and any adjacent or abutting buildings.
B.3	Drawings and other documents Information to be included herein is list of drawings used to prepare BQ and the address where the drawings and other documents may be inspected.
B.4	Form, type and conditions of contract Information on the conditions of contract to be used and on whether the condition of contract is a standard version or otherwise.
B.5	Contractor's liability This item describes the contractor's liability for risk or injury to persons and property and of damage to the works and the requirement for the contractor to effect insurance.
B.6	Employer's liability This item concerns the cost of insuring any liability of the employer.
B.7	Obligations and restrictions imposed by the Employer Information on any obligations or restrictions to be imposed by the employer such as access to and possession or use of the site, limitations of working space and of working hours, the provision of hoardings, maintenance of existing services, temporary accommodation for use of the employer and installation of telephones for the use of the employer.
B.8	Works by the nominated sub-contractors Information on works which are to be carried out by a nominated sub-contractor in which a prime cost sum should be included in this section of the preliminaries. Further information includes the provision of attendances and builder's works in connection with works by the nominated sub-contractor.

SMM2 Item Ref.	Brief Description
B.9	Goods and materials from nominated suppliers Information on goods and materials which are to be supplied by a nominated supplier in which a prime cost sum should be included in this section of the preliminaries.
B.10	Works by government or statutory authorities Information on works which are to be carried out by a government or statutory authority shall be included in this section of preliminaries as either a provisional or prime cost sum.
B.11	Works or goods and materials by the Employer Should the employer decide to directly engage others to supply goods and materials for the works then details of such goods and materials and fixing thereof shall be given in this section of the preliminaries.
B.12	Pricing This provision of the preliminaries requires a list to be provided for items that the contractor might want to price. Such items include plant, tools and vehicles, scaffolding and other temporary works, site administration, security and transport for work people, health and safety, control of noise and pollution, progress reports and clearing up upon completion of the works.
B.13	Contingencies Contingencies, if deemed necessary, are to be given as provisional sum and stated in this section of the preliminaries.

(Source SMM2, 2000)

Table 2. Preliminaries items under B.12 of SMM2 to be considered for pricing by the Tenderers

SMM2 Item Ref.	Brief Description
B.12	Pricing 1. Plant, tools and vehicles 2. Scaffolding 3. Site administration and security 4. Transport for workpeople 5. Protection of works in all sections 6. Water for the works 7. Lighting and power for the works 8. Temporary roads and hard-standings, etc. 9. Temporary accommodation for the contractor 10. Temporary telephones for the contractor 11. Traffic regulations 12. Safety, health and welfare for the workpeople 13. Disbursements arising from the employment of workpeople 14. Maintenance of public and private roads 15. Clearing on completion 16. Drying the works 17. Temporary fencing, hoardings and the likes 18. Control of noise, pollution and other statutory obligations 19. Surety or performance bond 20. Drawings 21. Schedules, charts and the likes 22. Progress photographs 23. Adjacent, surrounding, concurrent works, adjoining owners 24. Others

(Source SMM2, 2000)

The SMM2 style of presenting preliminaries items appears to be broadly similar to the styles adopted in Australia and the UK. In Australia, as explained by Marsden (1999, p166-167), the Australian SMM broadly divides preliminaries items into two categories of what he calls as “global information” and “items for the various contractual conditions and the site conditions.” The former category contains information to enable the tenderers to educate themselves about the project while the latter contains items for the tenderers to consider pricing. However, Marsden (1999) pointed out one aspect of the Australian practice considered unique and is different from the practice in Malaysia i.e. in Australia the Government departments discourage tenderers from pricing the preliminaries items but any costs required to comply with the conditions specified in the Preliminaries are to be allowed for in the various unit rates in the subsequent trade sections of the Bills of Quantities. According to Marsden such a practice would assist contract administration but he did not provide further explanation on the matter.

In the UK Brook (2002) explained that preliminaries give opportunity for the tenderers to price project overheads i.e. "the site cost of administering a project and providing general plant, site staff, facilities and site-based services and other items not included in all in rates". He estimated the cost for overheads that could be applied to a new project, for small repetitive works, to be about 15% of the contractor's total annual operation costs. Brook (2002) also proposed a typical sequence of events for pricing preliminaries, i.e. a tenderer should;

1. Make notes of general requirements, such as temporary works and sub-contract attendances,
2. Prepare a site layout drawing showing the position of facilities and services and access routes and he should inspect the site for features and feasibility of his proposals,
3. Refer to the tender work programme when preparing for staff, plant and temporary works,
4. Study the client's requirements and all the tender documents, and
5. Price the project overhead sheet.

In addition, the practice in the UK is as such that preliminaries are divided into two categories namely time-related and fixed charges (Willis and Trench, 1998; Ashworth, 1999: Brook, 2002; Cartlidge, 2011). According to Willis and Trench (1998) the former refers to "one that is considered to be proportional not to the quantity of the items but to the length of time taken to execute the work" while the latter refers to "one that is considered to be proportional neither to the quantity of the works nor to the time taken."

One of the common criticisms on preliminaries is that while the quantity surveyor preparing the tender documents took great care to prepare the preliminaries but it is not uncommon that most of the items thereof were left un-priced by the tenderers. The practice, according to Cartlidge (2011), is due to that some of the preliminaries items are difficult to quantify and therefore to price leading to the tenderers pricing major items only such as accommodation, staffing and mechanical plant. Ashworth (1999) claimed that "the remainder of the un-priced items is there for information only, or their appropriate costs have been allowed for elsewhere.

In addition, Ashworth (1999) offered brief explanations on how preliminaries items are priced by the tenderers i.e. (i) the relevant preliminaries items have been priced independently including, in some cases, detailed breakdown of fixed and time-related charges, (ii) the costs of preliminaries items have been calculated and shown in the documents as a lump sum, and (iii) preliminaries items were left un-priced. In this instant, the costs would have been added to the rates of measured quantities of works.

Furthermore, Ashworth (1999) identified the factors that could affect the costs of preliminaries items. The factors include location of the project such as in congested urban areas or in the country side, availability of space on the site required for storage of materials, plant and temporary accommodation, security and the needs for temporary fencing, hoarding and the likes, contract period and construction method. In all, Ashworth claimed that the value of preliminaries for a typical project is somewhere between 8% and 15% of the contract sum.

Ashworth (1999) discusses the importance of preliminaries for construction works from the perspective of cost studies. He pointed out that the cost considerations of the various elements in a building in relation to the costs associated with preliminaries items may be shown, in the cost studies, either as an individual element of the works or they may be apportioned and distributed among the other elements. Ashworth reminds that the key reason for the analysis of the costs of the preliminaries items is to for the information to be gathered in a systematic way for ease of re-use in estimating for future projects.

The literature review thus far focuses only on preliminaries for building works. In the case of civil engineering works, the style of measurement of quantities is as provided by the Malaysian Standard Method of Measurement for Civil Engineering Works (CESMM, 2003). In the context of preliminaries for civil engineering works, the CESMM appears to have adopted a slightly different approach whereby items of preliminaries in nature and style, such as those listed in SMM2, are not labeled as preliminaries but they are classified and listed under Class A - General Items of the CESMM.

Admittedly, there are other aspects of preliminaries that have not been discussed in this part of the paper. They were excluded for convenience and also due to space limitation.

METHODOLOGY

The study reported in this paper focuses on preliminaries and their pricing for construction works of residential buildings. Specifically, the study endeavors to seek answers to the following questions;

1. Are the provisions on preliminaries, as provided in Section B of SMM2, being presented for tenderers of residential building projects to price?
2. Are the preliminaries items presented in the tender documents priced by the tenderers?
3. Is there a pattern, in terms of the value of preliminaries items in the overall contract sum of the projects?
4. What are the top 10 preliminaries items priced by the tenderers?

In carrying out the study the desk study approach was selected and adopted for use. The desk study approach was executed in two phases, phase one involved reviewing related literature on preliminaries for construction works, and phase two involved detailed examination of historical data on items and costs of preliminaries for construction works of residential buildings. The outcome of the first phase of the study has been reported in the aforementioned part of this paper.

In effort to gather historical data on preliminaries for construction works of residential buildings, requests to borrow copies of past tender and contract documents were made to practicing quantity surveyors known to the authors. Unfortunately, only 3 past contract documents that contained complete information on the preliminaries section of the bills of quantities were obtained. Table 3 and 4 provide brief information on the 3 residential projects that form basis for the present study. In the interest of confidentiality, only brief descriptions of the projects were given.

Table 3. Basic Information on Projects

Project Brief	Form of Contract	Contract Sum	GFA (m^2)	Duration (Month)	Tender Close
Project A - 22 Units of houses (North of Malaysia)	PAM (with Quantities)	8,800,000.00	5,374	16	2012
Project B - 123 units of houses (Klang Valley)	PAM 2006 (with Quantities)	50,400,000.00	27,443	18	2012
Project C - 81 units of houses (Klang Valley)	PAM 1998 (with Quantities)	23,028,616.15	22,728	Not available	2009

Table 4. Basic Information on Preliminaries for the Projects

Project Brief	Preliminaries		
	Amount (RM)	(%) Contract Sum	Cost/m^2
Project A - 22 Units of houses	768,076.56	8.73	142.92
Project B - 123 units of houses	2,218,853.69	4.40	80.85
Project C - 81 units of houses	1,450,000.00	6.30	63.80

In the absence of further data and in acknowledging that data containing costs of projects is considered sensitive to many quantity surveyors and other key players of construction projects, it was decided that the three past contract documents is deemed sufficient to be used for the present study. In addition, due to the absence of generously available data for the study, it was decided that the present study served as a preliminary study, further and in-depth study would have to be carried out in the future when more data for the study becomes available.

In examining the documents, key information on the projects and their respective preliminaries items were identified and examined. The identification and examination serve to address the questions that have been designed for the study. The following part describes the examinations that were carried out, their results and the ensuing discussions.

RESULTS AND DISCUSSIONS

The first research question designed for the study seeks to find answers whether the provisions on preliminaries, as provided in Section B of SMM2, were presented for tenderers of residential building projects to price. In carrying out the examination, a list of preliminaries items as provided for in SMM2 were prepared, in accordance to the 13 main categories i.e. B.1-B.13, and the list was compared with the preliminaries items present in each of the 3 contract documents of the residential projects. The results of the examination are presented in Table 5.

Table 5. Preliminaries presented and priced in the examined projects

SMM2 Item Ref.	Brief Description	Provision in the Contract Document			Item priced by Contractor		
		A	B	C	A	B	C
B.1	Project, parties and consultants	√	√	√	x	x	x
B.2	Description of site	√	√	√	x	x	x
B.3	Drawings and other documents	√	√	√	√	√	x
B.4	Form, type and conditions of contract	√	√	√	√	√	√
B.5	Contractor's liability	√	√	√	√	√	√
B.6	Employer's liability	√	√	√	√	√	√
B.7	Obligations and restrictions imposed by the Employer	√	√	√	√	√	√
B.8	Works by the nominated sub-contractors	x	√	√	x	x	x
B.9	Goods and materials from nominated suppliers	x	√	√	x	x	x
B.10	Works by government of statutory authorities	√	√	√	√	√	√
B.11	Works or goods and materials by the Employer	x	√	√	x	x	√
B.12	Pricing	√	√	√	√	√	√
B.13	Contingencies	x	x	x	x	x	x
	Provision in contrast to SMM2 and Priced by tenderers	69%	92%	92%	54%	54%	54%
Others	*Qlassic*		√	√		x	
	GBI (Green Building Index)		√			x	

The results suggest that almost all of the 13 categories of preliminaries, as recommended by SMM2, were present in two of the projects i.e. Project B and C, their presence stood at 92%. Project A scored 69% because items related to nominated sub-contractor (B.8), nominated supplier (B.9), and works by others (B.11) were not present in the project. However, all three projects did not have contingencies (B.13) in their preliminaries. The results herein suggest that the provisions on preliminaries, in terms of the main categories as contained in SMM2, have been followed by all the projects, with projects B and C showing almost total adherence to SMM2.

The second research question seeks answer whether the preliminaries items presented in the tender documents were priced by the tenderers. Referring to Table 5 it appears that only slightly more than half of the preliminaries items in each of the 3 projects were priced by the respective tenderers. While there is no uniformity in the items being priced or un-priced but there appear to be a pattern that all the tenderers regard items on B.4 (contract matters), B.5 (Contractor's liability), B.6 (Employer's liability), B.7 (Obligations imposed by the Employer), B.10 (Works by government bodies) and B.12 (Pricing of key sub-preliminaries items) to be significant that compelled them to price. In addition, there appear to be a pattern that items on B.1 (Project, parties and consultants), B.2 (description of the site), B.8 and B.9 (Nominated sub-contractors and suppliers), and B.13 (Contingencies) are regarded to be less significant and therefore they were not being individually priced. However, this does not mean that these un-priced items were not entirely considered by the tenderers, perhaps their pricing have been included elsewhere in the tender documents.

Within each project, the number of preliminaries items left un-priced is very high. Table 6 shows that the number of priced preliminaries items in each of the project stood at 28%, 18% and 17% for projects A, B and C respectively (see Table 6).

Table 6. No. of Preliminary Items Presented and Priced

Project	Items Presented in BQ (No)	Items Priced by Contractor (No)	(%) of Items Priced by Contractor
A	134	38	28.36
B	146	27	18.49
C	117	20	17.09

The third research question seeks answer whether there is a pattern, in terms of the value of preliminaries items in the overall contract sum of the projects. In order to answer the question the top 10 priced preliminaries items in each project were identified and examined. The results on the examination, in terms of the item itself, its amount and percentage of the amount to the project's total amount for preliminaries and contract sum and the preliminaries item costs, expressed in terms of the building cost per square meter are as shown in Tables 7 to 9 for projects A, B and C respectively.

Table 7. Top 10 Priced Preliminary Items in Project A

	Items	Amount (RM)	Percentage (%)		Cost/m^2
			Preliminaries	Contract Sum	
1.	Plant & Equipment	150,000.00	19.53	1.70	27.91
2.	Site Agent	70,000.00	9.11	0.80	13.03
3.	Temporary Buildings	55,000.00	7.16	0.63	10.23
4.	Safety	35,000.00	4.56	0.40	6.51
5.	CIDB Levy	35,000.00	4.56	0.40	6.51
6.	Watching and Lighting	30,000.00	3.91	0.34	5.58
7.	Hoarding	30,000.00	3.91	0.34	5.58
8.	Laws, Regulations & Requirements	28,000.00	3.65	0.32	5.21
9.	Lighting & Power	25,000.00	3.25	0.28	4.65
10.	Water for the Works	24,000.00	3.12	0.27	4.47
	Sub-total	482,000.00	62.75	5.48	89.69
11.	Others	286,076.56	37.25	3.25	53.23
	Total	768,076.56	100.00	8.73	142.92

Table 8. Top 10 Priced Preliminary Items in Project B

	Items	Amount (RM)	Percentage (%)		Cost/m²
			Preliminaries	Contract Sum	
1.	Plant & Equipment	1,194,703.67	53.84	2.37	4,353.40
2.	Site Staff	269,500.00	12.15	0.53	982.04
3.	Contract Stamping	255,390.00	11.51	0.51	930.62
4.	Scaffolding	106,800.00	4.81	0.21	389.17
5.	Hoarding	65,030.00	2.93	0.13	236.96
6.	Temporary Buildings	54,100.00	2.44	0.11	197.14
7.	Setting Out	30,650.00	1.38	0.06	111.69
8.	On Completion	24,000.00	1.08	0.05	87.45
9.	Lighting & Power	24,000.00	1.08	0.05	87.45
10.	Water for the Works	24,000.00	1.08	0.05	87.45
	Sub-total	2,048,173.67	92.31	4.06	7,463.37
11.	Others	170,680.02	7.69	0.34	621.94
	Total	2,218,853.69	100.00	4.40	8,085.32

Table 9. Top 10 Priced Preliminary Items in Project C

	Items	Amount (RM)	Percentage (%)		Cost/ m²
			Preliminaries	Contract Sum	
1.	Plant & Equipment	340,000.00	23.45	1.48	1,495.95
2.	Site Staff	340,000.00	23.45	1.48	1,495.95
3.	Performance Bond	176,000.00	12.14	0.76	774.38
4.	Lighting & Power	120,000.00	8.28	0.52	527.98
5.	Water for the Works	120,000.00	8.28	0.52	527.98
6.	Scaffolding	70,000.00	4.83	0.30	307.99
7.	Health & Safety	45,000.00	3.10	0.20	197.99
8.	Insurance	42,500.00	2.93	0.18	186.99
9.	CIDB Levy	32,500.00	2.24	0.14	143.00
10.	Setting Out	30,000.00	2.07	0.13	132.00
	Sub-total	1,316,000.00	90.76	5.71	5,790.21
11.	Other	134,000.00	9.24	0.58	589.58
	Total	1,450,000.00	100.00	6.30	6,379.80

The results show that the top 10 preliminaries items constitute 62.75%, 92.31% and 90.76% of the total amount of preliminaries in projects A, B and C respectively. The total amount of preliminaries constitutes 8.73%, 4.40% and 6.30% of the contract sum in projects A, B and C respectively. Consequently, there appears to be no identifiable pattern in terms of the value of preliminaries items in the overall contract sum of the 3 projects being examined. Perhaps, factors such as the location of the projects, their complexity (within the context of residential buildings) and the year when their tenders were closed influenced the outcome of the examination.

In relation to the fourth question of the research that concerns identification of the top 10 preliminaries items priced by the tenderers detailed examination of the top 10 priced preliminaries items in each project were performed. The results suggest there is a broad pattern, in terms of the top 10 items deemed to be significant by the tenderers. However, there is no identified pattern in terms of the prices of each of the top 10 items. The results of the examination, as shown in Table 10 and illustrated in Figure 1, show that the top 10 priced preliminaries items, in order of importance, are;

1. Plant and equipment,
2. Site staff,
3. Scaffolding,
4. Health and safety,
5. Hoarding,
6. Temporary building,
7. CIDB levy,
8. Setting out,
9. Lighting and power, and
10. Water for the works.

Table 10. Top 10 Preliminaries Items for Projects A, B, and C

Items Description	Priced Range Expressed as			Frequency (3 projects)
	% of Total Preliminary	% of Contract Sum	In cost/m^2 GFA	
Plant & Equipment	19.53 - 53.84	1.48 – 2.37	27.91 – 4353.40	3/3
Site Staff	9.11 – 23.45	0.53 – 1.48	13.03 – 1495.95	3/3
Scaffolding	4.81 – 4.83	0.21 – 0.30	307.99 – 389.17	2/3
Health & Safety	3.10 – 4.56	0.20 – 0.40	6.51 – 197.99	2/3
Hoarding	2.93 – 3.91	0.13 – 0.34	5.58 – 236.96	2/3
Temporary Building	2.44 – 7.16	0.11 – 0.63	10.23 – 197.14	2/3
CIDB Levy	2.24 – 4.56	0.14 – 0.40	6.51 – 143.00	2/3
Setting Out	1.38 - 2.07	0.06 - 0.13	111.69 – 132.00	2/3
Lighting & Power	1.08 – 3.25	0.05 – 0.52	4.65 – 527.98	3/3
Water for the Works	1.08 – 8.28	0.05 – 0.52	4.47 – 527.98	3/3

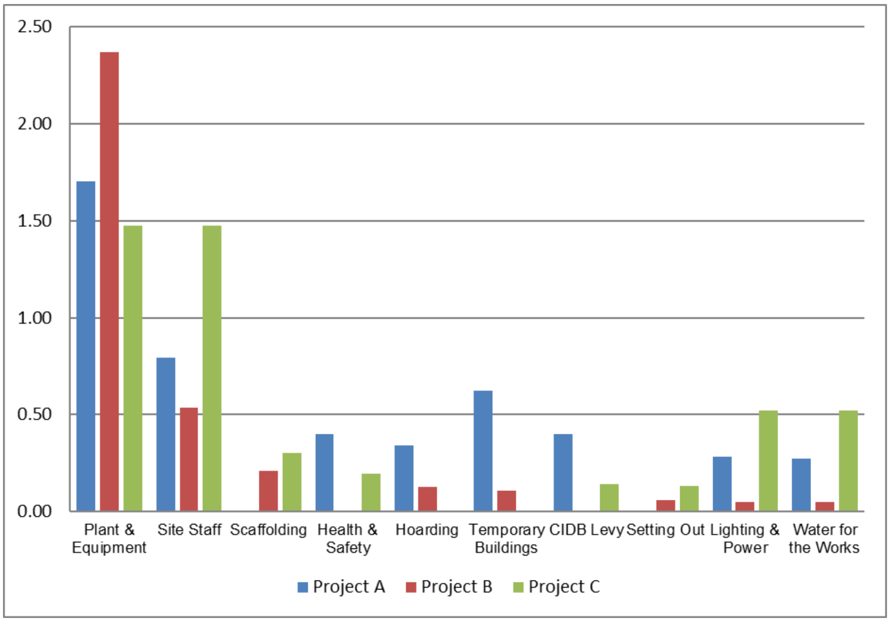

Figure 1. Top 10 Preliminary Item Expressed as % of Contract Sum

CONCLUSION

This paper reported a study on preliminaries and their prices for residential buildings. It is therefore concluded that:

1. Preliminaries are important to a project. Its importance may be assessed in terms of (i) the information provided that is necessary for the contractor to properly execute and complete the works and (ii) the amount, in terms of their costs in a contract, which could be in the range of between 4.40% and 8.73% of the contract sum;
2. The style of presenting preliminaries varies between the practices in Malaysia, Australia and the UK. In Australia the preliminaries are grouped into two namely 'global' that does not require pricing and 'items for various contractual conditions' that would require the tenderers to price. In addition, Government departments discourages tenderers from pricing the preliminaries. In the UK preliminaries are categorized into two categories namely time-related and fixed charges. Neither of these practices applies to Malaysia for in the case of Malaysia the preliminaries are there for the tenderers to price or otherwise, as they wish;
3. It is common for tenderers to leave preliminaries items un-priced. In the present study, the proportion of preliminaries items left un-priced ranged from 72% to 83%. But this does not mean that these un-priced items were not entirely considered by the tenderers, perhaps their pricing have been included elsewhere in the tender documents;
4. In the present study, there appear to be undefined pattern in terms of the style of pricing the preliminaries items. Broadly, in a project it could be presumed that the top 10 items of the preliminaries constitute about 90% of the total amount of preliminaries or about 6% of the contract sum;

5. The top 10 priced preliminaries items have been identified, they are, in order of importance: (i) plant and equipment, (ii) site staff, (iii) scaffolding, (iv) health and safety, (v) hoarding, (vi) temporary building, (vii) CIDB levy, (viii) setting out, (ix) lighting and power, and (x) water for the works.

The constraints and limitations to the present study have been identified. Consequently, further and in-depth study is required in order to draw a more meaningful conclusion. In addition, further and in-depth studies on the subject of preliminaries in construction works are recommended including on pricing strategies used by tenderers, the impact of taxation such as the recently introduced GST on the costs of preliminaries and contractors' claims for loss and expense on additional preliminaries arising from extension of time (EOT).

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CONSTRUCTION PROCUREMENT SYSTEMS IN USE IN MALAYSIA

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Abstract
This paper reports on a study on the systems of construction procurement in use in Malaysia. Specifically, the study's objectives were to identify the systems of construction procurement in use, to assess whether the systems used matched the criteria as proposed by the theory on procurement systems and to identify Clients' top priority in procurement and whether their objectives were met or otherwise. Data for the study was obtained from records and interviews with project team members from twenty on-going and completed construction projects and analyzed using descriptive statistics. Findings from the study suggest that: the traditional design-bid-build (DBB) system of procurement remained Malaysia's most dominant system of procurement, Clients' top priority in procurement is speed of completion and in terms of meeting the Clients' overall objectives on time, cost and quality, these objectives, combined together and in most projects they were not met. In addition, problems that caused delays and constraining the processes of procurement were identified, the top two being contractors' related (lack of expertise and time overrun) and local authorities' related (delay in obtaining approvals). The paper concludes with ideas as way forward in effort to increase the chances of Clients achieving their objectives when they procure construction projects. They include capacity building and the need for a systematic selection matrix to assist Clients in choosing the most appropriate system of procurement that suit their procurement needs, priority and risk appetite.

Keywords: *Building, client, contractor, consultant, construction, project, procurement, statutory approvals*

INTRODUCTION

Procurement, in the context of construction, refers to the processes of acquiring built facilities (Khairuddin, 1998; 2002). The processes, starting with the process of initiation of the project and all the way to completion and handing over of the completed facility may be arranged in various styles: sequential, some to run earlier than the others, or some of the processes may be arranged to run in parallel or overlapped. Each style is distinct and has its own merits and demerits (see e.g. Khairuddin 1998; 2002; 2003; 2004; 2006).

Generally, Clients' objectives in procurement are time or speed of completion, cost or budget, and quality of the works. Among these, one will become the top priority. It is therefore highly likely that the Client's objectives and top priority in procurement would be met if the most appropriate system of procurement is designed, adopted and used. For instance, if the system is arranged for the processes to run in sequence then time and cost may suffer while overlapping the processes may save time and perhaps costs but quality may suffer.

In the 1990s and through the early 2000s reports on studies related to systems and processes of construction procurement were frequently published in journals and presented in seminars and conferences. However, in recent years and in particular during the last five years or so such frequent publication has receded implying that the subjects are losing their significance. Consequently, in an effort to re-ignite interest on the systems and processes of construction procurement and to highlight their significance, given that the selection and application of the most appropriate procurement would greatly enhance the chances of meeting Clients' objectives (Khairuddin, 2002), a report on a study on the systems of construction procurement in Malaysia is herein presented.

The study has 4 main objectives: (i) identification of the system of construction procurement in use, (ii) assessing whether the system used matches those criteria as proposed by the theory on procurement system, (iii) identification of Clients' top priority in procurement, and (iv) assessing whether their objectives were met or otherwise.

This paper is structured into 5 sections. The first section introduces the paper. The second section provides a review on the systems of construction procurement in use in Malaysia. This is followed by the third section that describes the methodology used in carrying out the current study namely desk study and interviews with key players of on-going and completed projects. Section four presents the results of the study including the dominant systems of procurement used, Client's top most priority in procurement and on whether the Client's objectives in procurement were met or otherwise and the ensuing discussions. Finally, section five concludes the paper and proposed ideas considered useful as way forward.

LITERATURE REVIEW ON SYSTEMS OF PROCUREMENT

According to Khairuddin (1998; 2002) the term procurement refers to the processes of acquiring built facilities. He developed a conceptual model on the processes of construction procurement that comprises of the processes of initiation, funding, design, statutory approval, tendering, construction and allocation of risks (Khairuddin, 1998; 2002,). However, his model is only relevant to works adopting the traditional way of procurement that separates the processes of design and construction and the processes stop once a project reaches physical completion.

In the more modern styles of construction procurement the processes of design and construction are increasingly being integrated; the source or sources of funds, especially for public projects, are no longer within the ambit of the Clients and/or their funders but expand to include private investors and even the end-users under the concepts of Public Private Partnership (PPP), Private Finance Initiative (PFI) and Privatization. These newer approaches focus on the total costs of the built facility that spends over its entire life otherwise known as Life Cycle Costing (LCC) and contract for a built facility may be as long as 20-60 years that takes into accounts funding, reimbursement and income generation, design and construction, commissioning and completion, maintenance and management of the completed facilities, delivery of services, refurbishment, handing over and perhaps even demolition and rebuilding (Khairuddin, 2009; 2012; 2013). In addition, authors have reported on the move by Clients to embrace co-operation and relationship and alliancing styles of procurement systems that they contended would enhance achieving the best performance (Liu and Fellows, 2009; Mahesh and Kumaraswamy, 2009; Rowlingson and Cheung, 2009; Chew, 2009).

The environment of a construction project is like an enterprise. Perhaps more than that for it may be akin to a melting pot. In a typical construction project there would be the presence of a myriad of activities, utilization of economic resources, involvement of people of various skills, expertise and backgrounds, the Client's objectives, contractual relationships between the various parties, site requirements, conditions and constraints, risks, politics, commercial and other external and internal factors, etc. Above all the works must be performed and completed to a specified time frame, quality and budget. It requires that the entire processes of procurement to be managed in the most efficient and effective manner. Khairuddin (2002) argued the management of the entire processes of procurement is the function of the system of procurement.

In Malaysia the three most dominant systems of procurement, dominant refers to the most frequently used, in order of importance are: Traditional or Design-Bid-Build (DBB), Design and

Build (D&B) or Turnkey, and Management Contracting (MC). Full review of the systems is not within the scope of this paper and readers may refer to the works of Khairuddin (1998; 2002; 2003; 2004), Turner (1997), Masterman (2002), Chang, Chin and Khairuddin (2005), Khairuddin (2006), etc.

Traditional system of procurement

The Traditional or DBB system of procurement works on the basis that the seven processes of procurement are performed in a sequential manner, the process of design is separated from the process of construction and that the various parties: Client, Contractor and Consultants, carries their respective risks. The Traditional system allows the contract price to be fixed in advance of construction and that the designers have full control of the design while the contractor takes care of all construction related risks. This system often required longer development period and that the style of the distribution of risks encourages adversary between the parties. The traditional system of procurement is most frequently used by the public sector for it satisfies the requirement for the procurement processes to be transparent and for the various parties to be accountable for the works.

Design and Build and Turnkey system of procurement

The Design and Build (D&B) system of procurement is an integrated and single source procurement system. The system allows the design and construction processes to be integrated and overlapped and the Contractor acts as the main player responsible for the entire processes of design and construction until the works is completed. The single point responsibility allows better coordination of the various processes of procurement hence reduce the potential of disputes among the parties while the overlapping of the processes of design and construction would lead to shorter overall development period (as opposed to the sequential style of the traditional system). Among the key criticisms of the D&B system include the system often lacks aesthetic values (probably due to the incorporation of the concept of *buildability* by the Contractor). When the responsibilities of the Contractor include the supply, installation and commissioning of furniture and equipment for the entire built facility then the system is often referred to as Turnkey system of procurement. Like the Traditional system of procurement, the D&B and Turnkey systems of procurement allow the contract price to be fixed in advance of construction. The D&B and Turnkey systems are used when time is the top most priority, i.e. speed of completion.

Management contracting system of procurement

Under the Management Contracting (MC) system of procurement, the system is broadly similar to the Traditional system in the sense that a Main Contractor is employed for the works. But his main responsibility is not to construct but to manage the works. This includes planning of the works that would permit overlapping of not only the processes of design and construction but of the various sections of the works itself. Works are split into packages, each package to be tendered out to different works' contractors. The act of splitting the works and tendering them out would lead to increased competition, hence the probability of achieving a much lower overall costs for the project, while the overlapping of the processes of design and construction and of the various works' sections would increase the probability of a much shorter development period (as opposed to the two earlier systems of procurement). However, MC system of procurement would not permit the contract price to be fixed in advance of construction as the price would only be known once the final package is let out to the works' contractor.

Selection of the most appropriate system of procurement

According to Khairuddin (2002) in Malaysia most Clients are not quite aware of the choices available to them in terms of the presence of the various systems of procurement and they do not have the skills and expertise to conduct a thorough assessment of the systems.

In most cases the Traditional system is adopted simply because most consultants are familiar with it while in the public sector the system satisfies the requirements of transparency and accountability. In addition, design consultants may influence Clients to adopt the Traditional system it allows them to take command of the design and construction processes on behalf of the Clients as opposed to the Design and Built, Turnkey or Management Contracting wherein these systems the design consultants would have to work under the command of Contractors.

Elsewhere methods have been developed that could assist Clients in choosing the most appropriate system of procurement. One such method is the UK's National Economic Development Office's (NEDO) Procurement Assessment Criteria (PAC) (NEDO, 1985). A full review of NEDO's PAC or other methods is not within the scope of this paper but readers may refer to the works by NEDO itself (NEDO, 1985), Turner (1997) or by Ng, Luu and Chen (2002).

METHODOLOGY FOR THE STUDY

The methodology involved review of literature on systems of construction procurement, collection and examination of projects' documents and interviews with their key personnel. The study's objectives were set as follows: (i) identification of the system of construction procurement in use, (ii) assessing whether the system used matches those criteria as proposed by the theory on procurement system, (iii) identification of Clients' top priority in procurement, and (iv) assessing whether their objectives were met or otherwise.

The collection of the data was conducted, initially as a class exercise for the course AQS3140 Systems of Construction Procurement, cohort for the academic session 2013/14 of the Bachelor of Quantity Surveying (Honours) at the International Islamic University Malaysia. A total of 96 students were involved. They were divided into 14 groups, each comprising of between 5-7 persons. The first author acted as the class tutor and coursework supervisor. Steps taken in carrying out the study is as shown Figure 1 below.

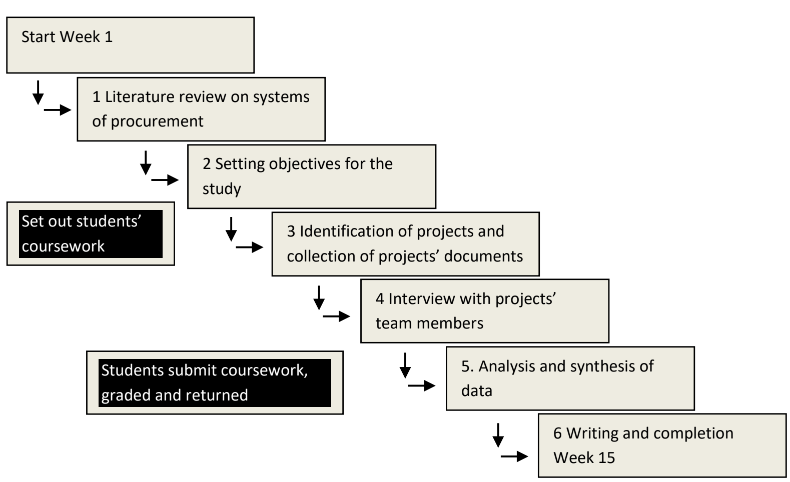

Figure 1. Steps taken in carrying out the study

Documents and personnel from 28 (twenty-eight) ongoing and completed construction projects were gathered by the students. All data was obtained from firms that were willing to share data for the study. Sampling was not done, the key reason being to facilitate harvesting as much data as possible. However, in this study data from 8 (eight) projects was found to be incomplete and therefore was excluded from the study.

Tables 1 and Figures 2 to 6 provide basic information of the 20 projects. In summary, the majority of the projects are public projects (85%); new works (70%); are of the research and education category of buildings (40%) followed by training and residential (15% respectively); the majority of the projects' contract sum is within the category of not exceeding RM10 million (9 projects); the majority of the projects' contract duration falls within the category of exceeding 12 months but not exceeding 24 months (57%); and the majority of the projects were managed by in-house experts assisted by Consultants (60%).

Table 1. Information on projects studied

	Project brief / Client's Main Representative	Contract sum (RM, million)	Contract period (months)
Project 1	Upgrading of a Training Centre / Consultant.	5.3	12
Project 2	Construction and completion of a New Training Centre (Fishing Industry) / Consultant.	14.0	10
Project 3	Construction and completion of a Sports Training Centre. Project Management Consultant (PMC).	8.8	10
Project 4	Construction and completion of a Multi-purpose Centre and Kindergarten /Government Agency (assisted by Consultants).	6.0	18
Project 5	Upgrading of Office Space of an institutional building. Government Agency (assisted by Consultants).	4.5	3
Project 6	Construction and completion of a Green House. Government Agency (assisted by Consultants).	3.2	10
Project 7	Construction and completion of Low cost apartments. Consultant (Private project).	49.2	19 ¼
Project 8	Upgrading of a Training Centre /Consultant.	22.4	19 ½
Project 9	Construction and completion of Students' Self-catering Apartments / Government Agency (assisted by Consultants).	4.6 (Final Account pending)	9
Project 10	Construction and completion of Terrace Houses. Consultant. (Private project).	27.8	18
Project 11	Completion of Abandon Research Facility Building. Government Agency (assisted by Consultants).	6.7	6
Project 12	Construction and completion of a School. Project Management Consultant (PMC).	7.5	18
Project 13	Construction and completion of a Police Station. Project Management Consultant (PMC) (This project is under the Government's PPP scheme, i.e. Built-Lease-Transfer, BLT).	42.9	24 ¾
Project 14	Construction and completion of a Mixed Housing Development /In-house (assisted by Consultants).	46.9	15
Project 15	Construction and completion of a school / Consultant.	16.8	18
Project 16	Completion of Abandoned Students' Hostel. Government Agency (assisted by Consultants).	23.4	18
Project 17	Athlete Training Centre. Government Agency (assisted by Consultants).	13.3	12

	Project brief / Client's Main Representative	Contract sum (RM, million)	Contract period (months)
Project 18	Construction and completion of a School. Government Agency (assisted by Consultants).	27.0	18
Project 19	Construction and completion of a Hotel. Project Management Consultancy (PMC).	147.0	30
Project 20	Upgrading Works to a *Surau*. In-house (assisted by Consultants). (Private project).	2.0	5

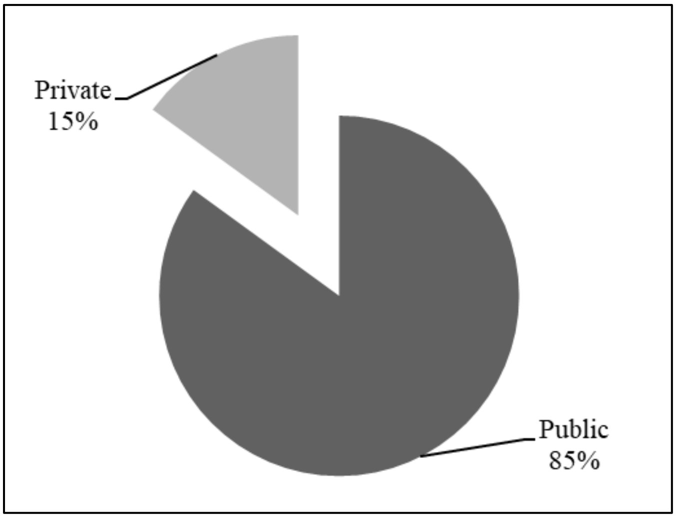

Figure 2. Types of Client

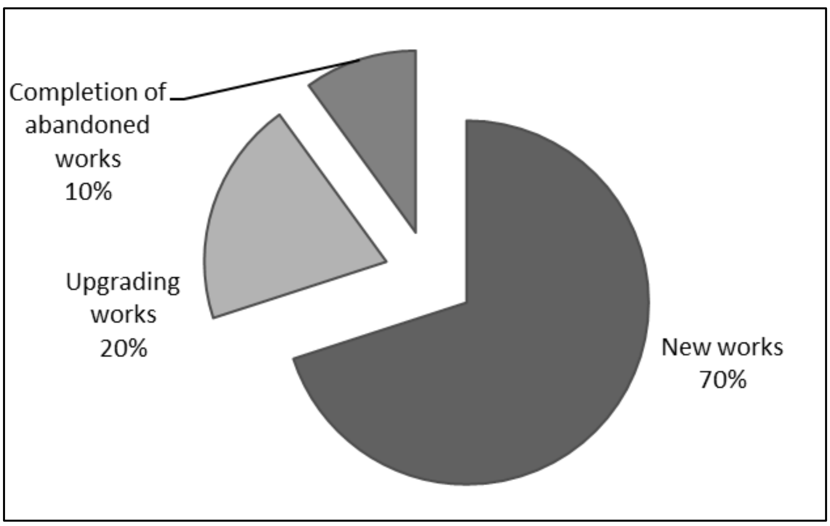

Figure 3. Nature of project

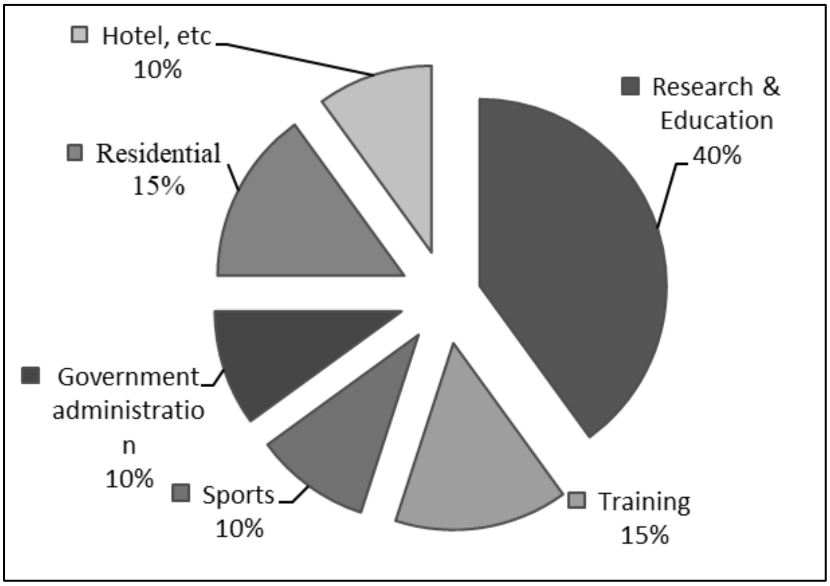

Figure 4. Types of project

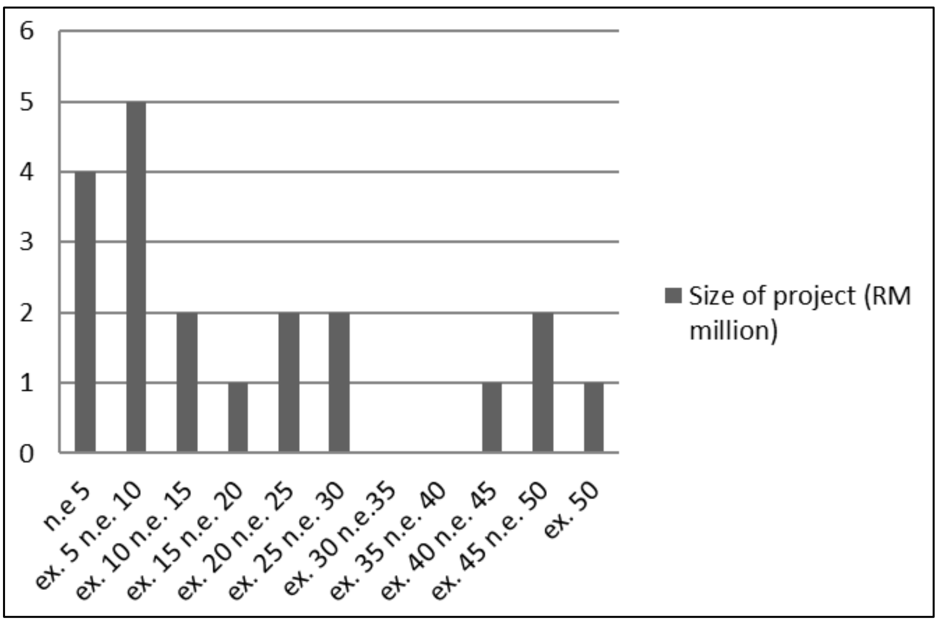

Figure 5. Size of project (RM million)

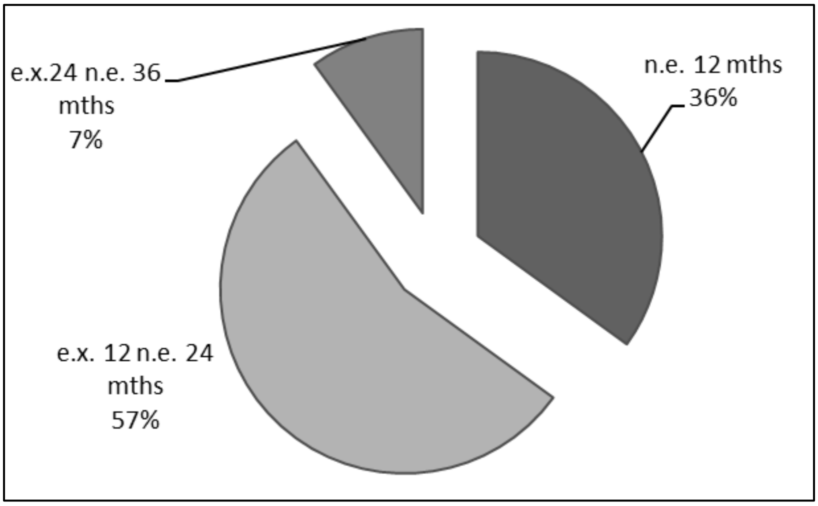

Figure 6. Contract duration

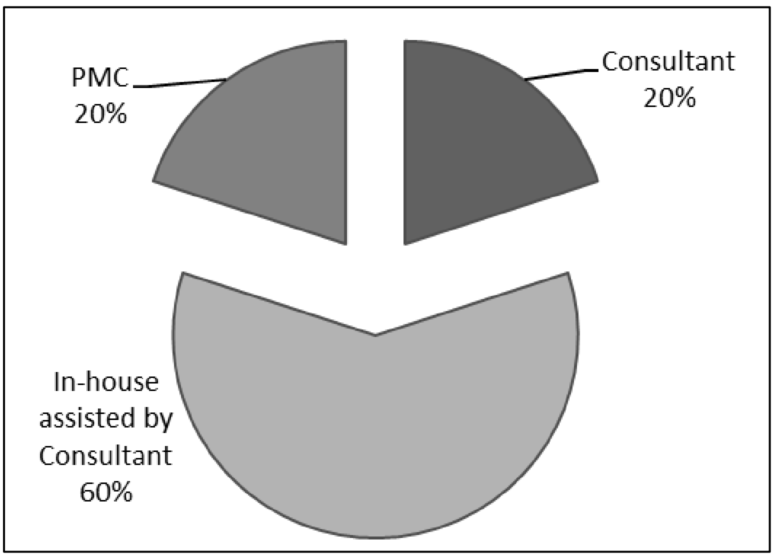

Figure 7. Client's representatives

RESULTS AND DISCUSSIONS

Table 2 presents the overall results of the study in terms of the five (5) variables that were collated and synthesized from the data gathered namely: procurement system used, system that should have been used as suggested by the Procurement Assessment Criteria (PAC; NEDO, 1985), Client's top most priority (time/cost/quality), whether price is known in advance or otherwise, and is the Client's overall objectives met or otherwise.

Table 2. Procurement systems used, Procurement Assessment Criteria (PAC) and achievement of objectives

	Procurement system used	PAC	System used = PAC	Top-most priority (time/cost/quality)	Price to be known in advance	Overall Objective achieved	Remarks
Project 1	Traditional	Traditional or Management Contracting	Yes	Cost	Yes	No	Cost overrun by 3%. Time overrun by >2 years. Issues: Design and Contractor's problems.
Project 2	Traditional	Traditional or Management Contracting	Yes	Time	Yes	No	Time overrun by 11 months. Issues: Design problem. Contract sum reduced by 14% through variation.
Project 3	D&B (Novated)	D&B	Yes	Time	Yes	No	Time overrun by 11 months. Issues: Contractors lacking in D&B skills, poor management of funds and delay in obtaining statutory approval.
Project 4	Traditional	Traditional or Management Contracting	Yes	Quality	Yes	No	No serious complaint on quality. Time overrun by 3 months. Issues: Delay in obtaining statutory approval.
Project 5	Traditional	Traditional or Management Contracting	Yes	Time	Yes	No	No time overrun. Cost overrun making the total cost almost RM6 million. Issue: Contractor's problem.
Project 6	D&B	D&B	Yes	Quality	Yes	No	No serious complaint on quality. Time overrun by 1 ½ months. Issues: poor Needs Statement, un-timely supply and delivery of specialized equipment (from overseas).
Project 7	Turnkey	D&B / Turnkey	Yes	Time	Yes	Yes	No time and cost overruns reported. Issue: Contractor experienced losses (due to poor pricing strategy).
Project 8	D&B	D&B	Yes	Time	Yes	No	Time overrun: Delay in completion by the D&B Contractor by 4 months; and Delay in site possession by some 3 months. The latter was due to the presence of squatters on the site Issue: poor Needs Statement, squatter problems on the site, eviction took longer than expected.
Project 9	D&B	D&B	Yes	Time	Yes	No	Time overrun: Major design change led to delay in the commencement of the works; and Delay in obtaining statutory approval.
Project 10	Traditional	Traditional	Yes	Cost	Yes	No	No cost overrun. Time overrun by 3 months due to delay in the supply of materials and delay in obtaining statutory approval.

	Procurement system used	PAC	System used = PAC	Top-most priority (time/cost/quality)	Price to be known in advance	Overall Objective achieved	Remarks
Project 11	Traditional	Traditional	Yes	Quality	Yes	No	No serious complaint on quality. Time overrun by 3 months due to rectification works taking longer than expected and delay in the supply of materials. Issue: The project was initially led out on D&B but due to changes to the design the D&B Contractor was not able to accommodate and his employment was terminated. The new contract was based on traditional system whereby the Contractor was requested to follow the D&B Contractor's design and complete the works.
Project 12	Traditional	Traditional	Yes	Quality	Yes	No	Inability to obtain the Certificate of Completion and Compliance. Time overrun, remained incomplete (as of June 2013). Delays included due to delay in obtaining statutory approval.
Project 13	Traditional	Traditional	Yes	Cost	Yes	No	No serious complaint on quality. Issue: the project during the initial stages had gone through a series of re-designing in order to adjust the scope of the works with the approved budget. The M&E Consultant terminated their own employment due to dissatisfaction with the time given for them to complete their portion of the design works. The termination and subsequent reappointment of a new M&E Consultant caused further delay to the works.
Project 14	Traditional	Traditional	Yes	Quality	Yes	No	No serious complaint on quality. Time overrun by 1 year due to inclement weather condition and a series of design change.
Project 15	Traditional	Traditional	Yes	Time	Yes	Yes	Completed 2 months ahead of the scheduled completion. The Client is satisfied with the quality of the completed works. (The project is using IBS. There is a constraint in the timely supply of building components due to the limited no of suppliers of IBS recognized by the Government).

	Procurement system used	PAC	System used = PAC	Top-most priority (time/cost/quality)	Price to be known in advance	Overall Objective achieved	Remarks
Project 16	Traditional	Traditional	Yes	Quality	Yes	Yes	No serious complaint on quality, time and cost overruns (for the current contract). Issue: The contract is to complete an abandoned project when the first Contractor was declared a bankrupt. As far as the project is concerned, the re-tendering led to overall increase in time and costs.
Project 17	Traditional	Traditional	Yes	Cost	Yes	Yes	No record on time and cost overruns (for the current contract). There was a delay in commencement of 2 months due to the initially appointed Contractor's failure to start work. It was then re-tendered.
Project 18	Traditional	Traditional	Yes	Cost	Yes	Yes	No record on time and cost overruns. (This project is using IBS).
Project 19	D&B	D&B	Yes	Time	Yes	No	Time overrun (duration not disclosed). Issue: Constraints in obtaining statutory approvals.
Project 20	Traditional	Traditional	Yes	Time	Yes	Yes	No time and cost overruns reported.

Identification of the system of construction procurement in use

The results from the study (Figure 8) show that the traditional or the Design Bid Build (DBB) system of procurement is the most frequently used or the most dominant procurement system in use (70%). Other systems of procurement in use are the Design and Build (D&B) (20%), Turnkey and the D&B Novated (5% respectively).

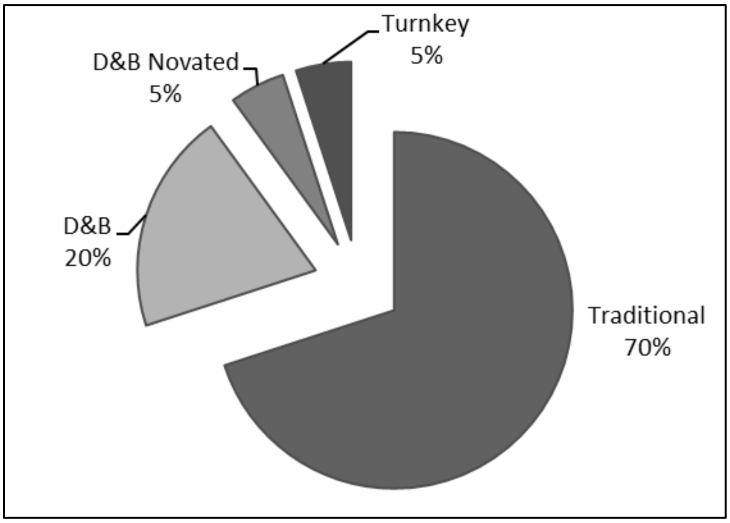

Figure 8. System of procurement used

The D&B Novated system refers to an arrangement whereby the Client would initially appoint design consultants to prepare preliminary designs. He thereafter appoints a D&B contractor. The D&B contractor would then take over the responsibilities and risks in completing the design and construction works and the responsibility in the employment of the design consultants. In some cases, the design consultants were not novated to the D&B contractor, only their designs.

Detailed examination of the results (Table 2) suggests that there is no particular preference detected in terms of the procurement system used. It seems that the traditional system (DBB) is simply the most frequently used system, notwithstanding the types of client, the nature, type and size of the projects, contract duration and who represents the clients. In addition, the fact that all the Clients or their Principal Advisors stating that they want the price of the contracts to be known in advance of construction suggests that Management Contracting would not become a preferred system of procurement. Such a requirement would only benefit either the traditional/DBB or D&B/Turnkey systems of procurement.

The findings of the present study, in terms of the dominant procurement system is the traditional/DBB followed by D&B, is consistent with the findings of past studies (see for example Khairuddin 1998; 2002; 2003; 2004; 2006). It suggests Malaysian Clients and their Principal Advisers are deep rooted in their belief and practice that the processes of design and construction are to remain separate and construction projects are better managed by Consultants rather than Contractors; the traditional/DBB is familiar to almost all design consultants, Clients and Contractors; and perhaps matters related to transparency and accountability and knowing the price in advance of construction are best achieved via the traditional/DBB system of procurement.

Assessing whether the system used matches those criteria as proposed by the theory on procurement system

The NEDO's PAC (1985) proposed a matrix comprising of key criteria and priority in procurement and matching these with the various types of procurement system. Through applying the NEDO's PAC a Client or his Principal Adviser would be able to identify an appropriate system of procurement for the Client's particular project, taking into consideration the Client's aims, objectives, priority and risk appetite in the procurement endeavour.

In the present study, it appears that the systems used for each of the 20 projects are consistent with the systems as proposed by the theory on procurement system i.e. each of the 20 projects' systems of procurement matches the PAC's recommended systems of procurement (Table 2). This conclusion is drawn after each project's personnel were administered the NEDO's PAC matrix and the outcomes recorded and compared with the actual system of procurement used for each of the projects. However, given that the Clients and their representatives were not aware of the existence of the NEDO's PAC matrix or similar methods of selecting procurement system, it has to be pointed out that the consistency recorded herein is merely a coincidence.

Identification of Clients' top priority in procurement

The majority of Malaysians seems to be a living in a hurry. It is therefore hardly surprising to note that the results from the study show that majority of the Clients place time, i.e. speed of completion, as their top most priority (45%) followed by cost (30%) and quality (25%).

Detailed examination of the results (Table 2, Figure 9) suggests that there is no particular preference detected in terms of the procurement system used and time being the top most priority. In theory, whenever speed is required, the preferred procurement system should either be the D&B or MC.

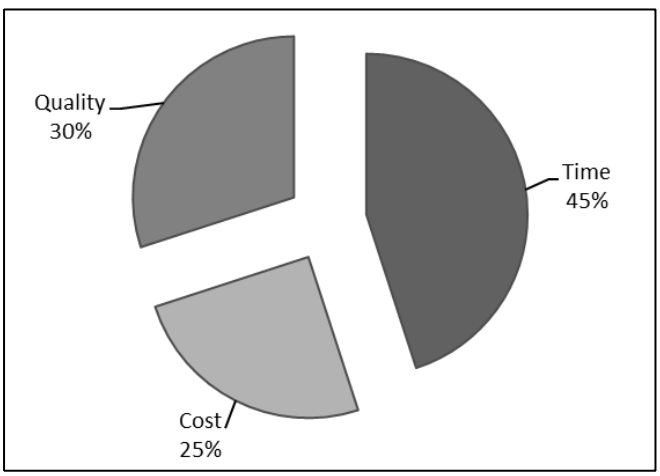

Figure 9. Top most priority in procurement

Are Clients' objectives met?

The results show that in 55% of the projects the Clients' top most objectives, either time, cost or quality, were met (Table 2 and Figure 10).

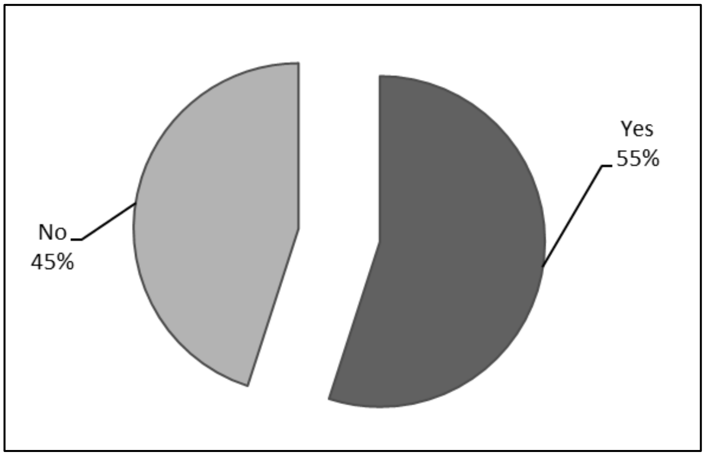

Figure 10. Achievement of top most priority

However, when the Clients' objectives are taken together, i.e. speed in completion, cost within the budget allocated and the Clients' satisfaction with the quality of the works done, the results show that only 30% of the projects met the said collective objectives (Figure 11). The majority of the projects (70%) failed to meet the Clients' overall collective objectives of time, cost and quality.

Table 3 shows the breakdown of the two categories of procurement systems in use namely Traditional (DBB) and D&B including Turnkey and Novated D&B. From the table it suggests that when the traditional system of procurement is used there is a 36% chance that a project might be able to meet the Client's overall objectives in terms of time, cost and quality while if the D&B system of procurement is used, similar chance is rated at only 16%. The results therefore suggest that the chances of Clients being able to meet their overall objectives in procurement is low notwithstanding whether the system is traditional or D&B but the chances of failure in meeting the overall procurement objectives is much higher when the D&B system of procurement is used. Overall and notwithstanding the system of procurement being used the chances of Clients meeting all of their objectives in procurement stood at only 30%.

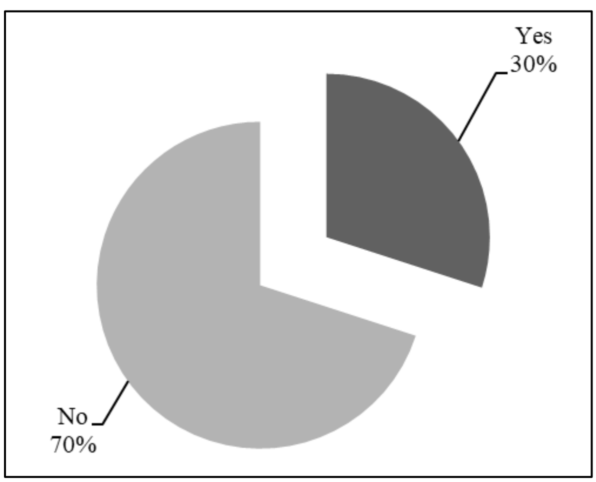

Figure 11. Overall achievement of procurement objectives

Table 3. Meeting overall objectives in procurement

System	Projects meeting overall objectives of time, cost and quality		
	Yes	No	Total
Traditional	5 (36%)	9 (64%)	14 (100%)
D&B (including Turnkey & Novated D&B)	1 (16%)	5 (84%)	6 (100%)
Total	6 (30%)	14 (70%)	20 (100%)

The reasons why the Clients' objectives were not met were probably due to the presence of constraints in procurement. Constraints identified and listed here in order of importance are; constraints related with the contractors (such as lack of expertise), delay and other problems related to obtaining statutory approvals, Clients related problems (such as design change), Consultants' related problems (such as poorly prepared needs statements) and delay arising from the unavailability and or untimely supply of construction materials (Figure 12). Khairuddin (1998; 2002) identified a set of constraints that inhibited the flow of the processes of construction procurement. From his list of identified constraints, most of them appear to remain as constraints as identified in the present study.

In projects utilizing the Industrialized Building System (IBS) approach the results show there was no time and cost overruns. Based on 2 projects in the sample size, one of the projects was completed ahead of time.

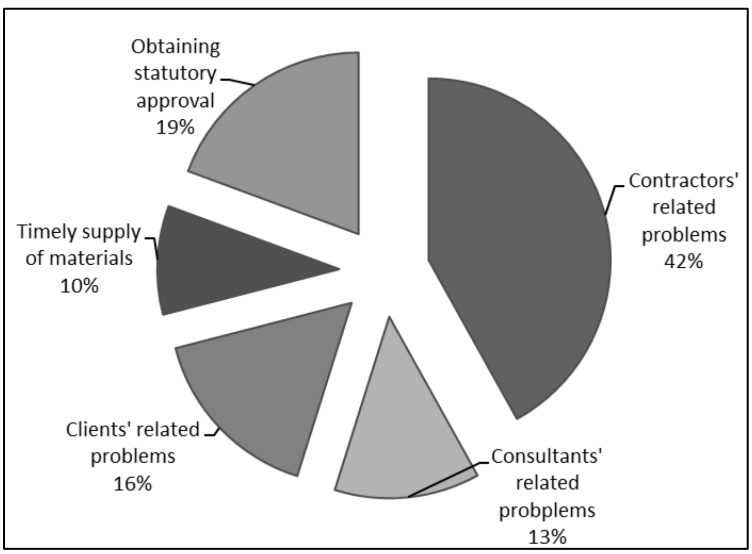

Figure 12. Key constraints/problems identified

CONCLUSION

This paper reported on a study on the dominant systems of construction procurement in use in Malaysia. Data for the study was obtained from records and interviews with project team members from twenty on-going and completed construction projects and analyzed using descriptive statistics. Consequently, the findings should be interpreted within the context of the study. However, broad inferences on the state and practice of construction procurement in Malaysia may be drawn from the findings.

Findings from the study suggest that:

- The traditional or design-bid-build (DBB) system of procurement remained Malaysia's most dominant system of procurement notwithstanding types of project, types of Client or their key priority in procurement;
- Clients' top priority in procurement is time or speed of completion;
- In terms of meeting the Clients' overall objectives on time, cost and quality in procurement, these objectives, combined together were not met. This suggest that chances of Clients meeting their overall objectives in procurement is low notwithstanding the system of construction procurement used; and
- Problems that caused delays and constraining the processes of procurement were identified i.e. problems arising from and/or related to the Clients, Contractors, and Consultants and constraints in the availability and timely supply of materials and in obtaining statutory approvals.

Drawn from the findings from the study, the following are proposed as way forward in effort towards a more efficient and effective implementation of construction projects;

- Capacity building comprising of a well-structured and sustainable style of knowledge sharing and transfer in construction procurement among Clients and key players of the construction procurement processes are urgently required;
- Strategies are required in effort to address constraints in the processes of construction procurement; and
- A systematic selection matrix or method is required in effort to assist Clients and their Principal Advisors in choosing the most appropriate system of procurement that suit their procurement needs, priority and risk appetite.

ACKNOWLEDGEMENT

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DELAYS IN CONSTRUCTION PROJECTS: A REVIEW OF CAUSES, NEED AND SCOPE FOR FURTHER RESEARCH

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Abstract
Infrastructure plays a key role & governs the economic development of any nation. It is needless to mention that infrastructure development & economic growth go hand in hand. However, construction projects which service the infrastructure requirements are plagued by a phenomenon of global occurrence: "Delays & Cost Overruns". The primary purpose this paper is to identify the critical causes of delays and mitigation strategies globally, identify the gaps in literature and present the scope for future research work, aimed at an improvement in construction project delivery. Fifty three research articles on causes of delays in different countries were reviewed in this study. Based on the country of research work, literature is segregated among developing and developed countries so as to distinctly compare and analyze the causes in these economies. The findings from the review of literature clearly indicated that the causes of delay vary from country to country; especially the critical causes in a developing country are quite different than in a developed country. Top ten causes of construction project delay in developing economies and developed economies are identified. The paper has presented the gaps in past studies and discussed the scope, direction for future research studies with the objective to address the root cause of construction project delays.

Keywords: *Infrastructure; Construction Projects; Delays; Causes; Mitigation*

INTRODUCTION

Construction sector is a catalyst for economic growth as it stimulates development in other sectors (Ismail, 2007). Construction projects provide the basic infrastructure requirements of housing, connectivity, water supply and power. It is essential that this infrastructure is continually developed and upgraded to meet with the ever growing population and demand. However, construction projects are plagued by a phenomenon of global occurrence: "Delays & Cost Overruns".

Delays in construction projects are a global phenomenon (Sambasivan and Soon, 2007). Time delays and cost overruns are among the most common phenomena in the construction industry (Koushki et al., 2005). The effects of delays in construction projects are not confined to the construction industry but influence the overall economy of a country (Arditi et al., 1985). Completing projects on time is an indicator of efficiency, but the construction process is subject to many variables and unpredictable factors, which result from many sources (Assaf and Al-Hejji, 2006). Even with today's advanced technology, and management understanding of project management techniques, construction projects continue to suffer delays and project completion dates still get pushed back (Stumpf, 2000).

Delays in construction projects have associated negative impacts and effects. The consequence of delays can be late completion, disputes, loss of reputation of the construction organization, loss of opportunity of future projects, loss or reduction of profit margins, insolvency of the organization, termination of the contract etc. Delays in construction projects can lengthen schedule, increase in project costs and jeopardize quality and safety (González et al., 2013). Delays result in huge cost overruns and hinder the economic growth. Although, the causes of delay in construction projects have been explored by many researchers and have been documented in the literature, construction projects across the world continue to suffer delays to varying magnitude. The causes of delays need to be investigated with fresh perspective with steps to mitigate the factors to ensure that projects are delivered on time within budget.

The objective of this paper is to bring out the critical causes of construction project delays in developing and developed economies, bring out the gaps in earlier research and also discuss the scope and directions of future research work aimed at limiting the root causes of delay and improve the construction project delivery timelines.

RESEARCH METHODOLGY

Literature search & selection

For the purpose of this study, qualitative research approach has been adopted wherein extensive review of research articles has been carried out. Keywords such as construction delay, causes of delay, and delay in construction projects were used for search of the research articles. The literature search process in itself spanned two months. The research articles reviewed in this paper have been gathered from reputed journals – International Journal of Project Management, Journal of Construction Engineering and Management, Construction Management and Economics, International Journal of Construction Management, Construction Economics and Building, Engineering Construction and Architectural Management and others. This provided an initial set of articles to start with the review. Review of these articles helped identify further literatures which were cited within these. While more than seventy articles are referred to in this study, fifty-three peer-reviewed research articles on causes of delays in different countries are selected for review and analysis. One of the articles (Shebob et al., 2012) covered the causes of delays in two countries Libya & UK. Table 1 provides the details of literature reviewed by source and time period of publication.

Table 1. Literature reviewed by source and time period

Description	Literature referred to in this study				Literature reviewed and analysed			
Research period	**1970-1990**	**1991-2000**	**2001-2010**	**2011-2016**	**1970-1990**	**1991-2000**	**2001-2010**	**2011-2016**
Journal articles	5	12	29	22	4	11	19	16
Conference Proceedings		2	3				3	
Corporate research/Web publications				3				
Total	**5**	**14**	**32**	**25**	**4**	**11**	**22**	**16**
	76				**53**			

Literature classification

In the next step, the identified research articles were segregated by country/ region in which the study was carried out, with a clear aim of identifying the causes of delay in different countries. These studies were further grouped under developing countries and developed countries, so as to analyze the causes in these two types of economies. Further, the studies are also classified based on the type of projects investigated by the authors in their study. Figure 1 & 2 present the details of the literature reviewed in this study by country and project type.

A comprehensive review of selected articles was done. During the review, the salient parameters of the research such as the type of projects investigated, the type / profession of respondents from whom the response was sought, methodology & statistical analysis adopted by the authors for identifying the causes of delay were noted. Figure 5 and Figure 6 summarize the details of studies in developing countries and developed countries respectively.

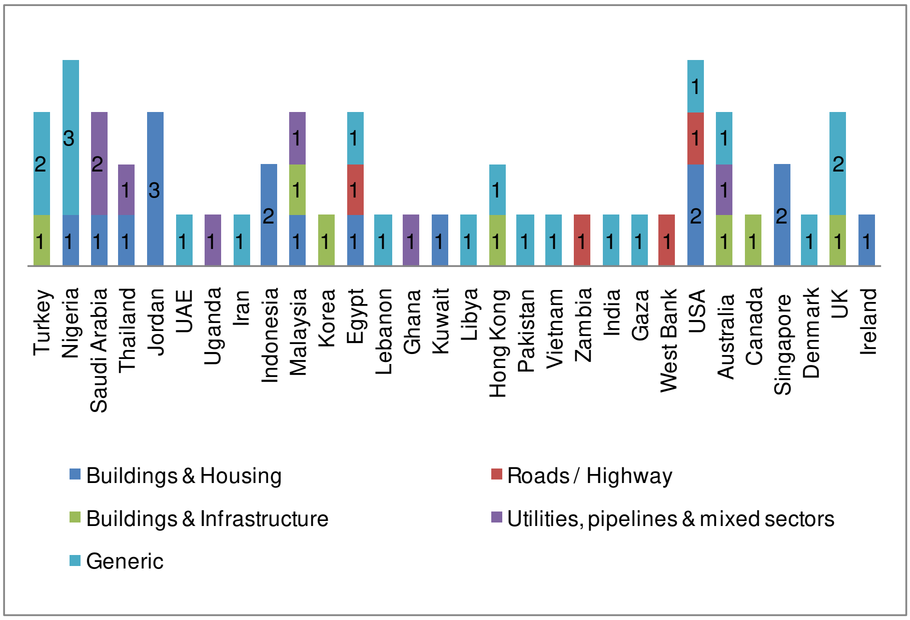

Figure 1. Literature reviewed in this study – by country and project type

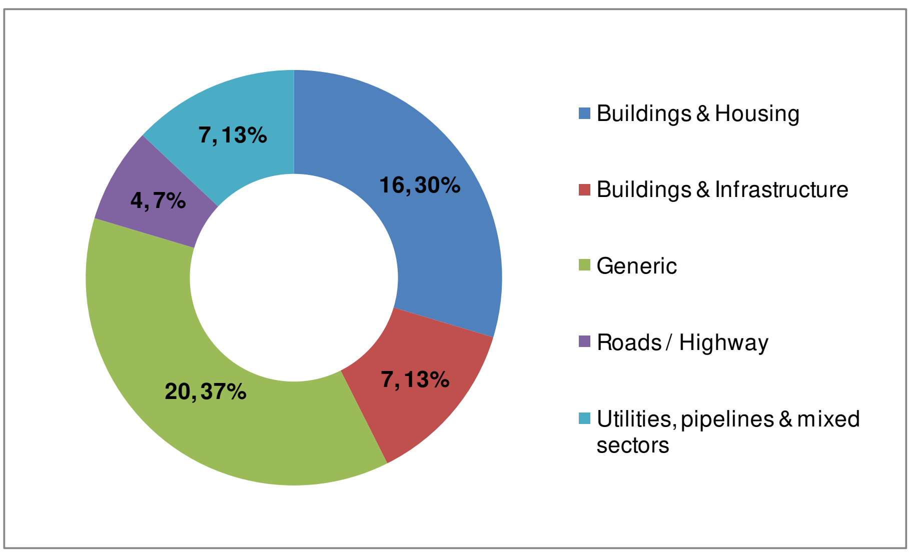

Figure 2. Break up of literature reviewed in this study by type of projects

Identification of critical causes

The top five causes of delay from the each of the reviewed article are taken up for further analysis in this study. Some of the studies have identified causes from the perspectives of owners, contractors and consultants separately. Wherever, the combined ranking and opinion of owners, contractors and consultants was not available, the top five causes from the perspective of contractors are used for analysis in this study.

The top five causes are grouped under three broad categories – Owner/ Consultant/ Architect related causes, Contractor related causes and External related causes. The critical causes of delay in developing and developed country are identified based on the frequency (%) of occurrence of the causes, defined as

$$\text{Frequency (\%)} = \frac{\text{Frequency of occurrence of causes}}{\text{Number of studies reviewed}}$$

The top five causes from each of the study reviewed are summarized in Figure 6 & 7, and the frequency (%) of the each of the causes calculated as above is indicated in the last column.

LITERATURE REVIEW

Arditi et al. (1985) surveyed investor public agencies & contractors in Turkey to assess the causes of delay. The study brought out that average delay on 126 public projects contractors' had undertaken was 34.6%, while the average delay was 43.65% in projects contracted out by public agencies. In 1975, only 22% of the public projects in Turkey were completed within their scheduled duration, while 18% were completed with as much as 4 years delay.

Mansfield et al. (1994) investigated the extent of delays in some of the highway projects in Nigeria and the time overrun in 9 highway projects was found to be ranging from 92% to as high as 343%.

Chan and Kumaraswamy (1995) observed that in 111 building and civil engineering projects completed in Hong Kong between 1990 and 1993, the average time overrun was exceeding 20%, and only 40% government buildings, 25% private sector buildings and 35% of civil engineering works were completed within schedule.

Assaf et al. (2006) conducted study on causes of delays in construction projects in Eastern province of Saudi Arabia through questionnaire survey of contractors & consultants. In their study, 76% of the contractors & 56% of the consultants specified a delay ranging between 10% to 30% and about 25% of the consultants specified a delay of 30% to 50% of original contract duration. Elinwa and Joshua (2001) found that degree of occurrence of time overrun in Nigeria is between 80% and 90%.

According to Sambasivan and Soon (2007), in 2005, about 17.3% of the 417 government projects in Malaysia experienced delays of more than 3 months or were abandoned & were considered sick. Koushki et al. (2005) in the study of 450 private residential housing projects in Kuwait, found that more than 56% of the projects did not complete on scheduled time, about

54% of the projects were delayed by four months or more, one-third of the projects were delayed by more than six months.

As per monthly flash report published by the Infrastructure and Project Monitoring Division (IPMD) of Ministry of Statistics and Programme Implementation (MOSPI) of Government of India, as on May 2016, out of 1076 projects (costing INR 1.5 Billion & more) from among 16 sectors, 330 projects (30.66%) are delayed. Figure 3 is prepared by the authors by taking out the data for respective months from the monthly flash reports (IPMD, n.d.). Figure 3 gives the trend of the project delays & cost overruns in India over the years from 2001. It is evident that there is no change in the trend of delays in India over the last 15 years.

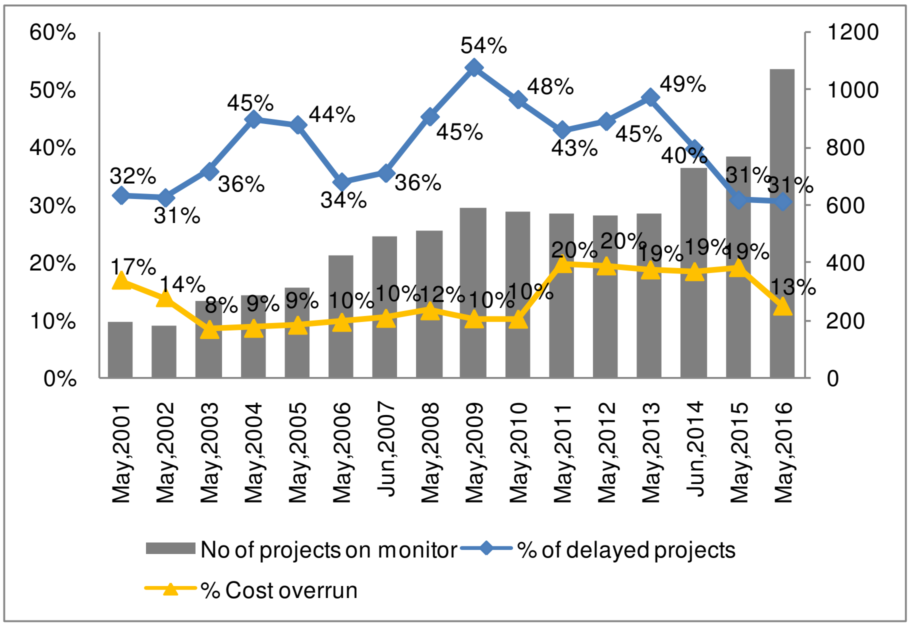

Figure 3. Trend of delay & cost overrun in construction projects in India over the years (Source of data: Flash report, MOSPI, Government of India)

Even the developed countries are not spared from the problem of construction delays. In a study of claims of contractors and subcontractors from 24 projects in Canada, Semple et al. (1971) observed that in several cases, delays exceeded the original contract duration by over 100%.

Bromilow (1974) observed that only one-eighth of the building projects in Australia completed on time and average time overrun on the projects exceeded 40%.

The average time overrun of government construction projects in UK during the period 1993-1994 was found to be 23.2% (Bordoli and Baldwin, 1998).

Eliis and Thomas (2002) in their study on root causes of delays in highway projects in USA observed that time overrun in 150 projects averaged 272 days or 25% of contract duration.

Ansar et al. (2016) from the study of 65 projects in rich democracies (Denmark, Germany, Japan, South Korea, Netherlands, Norway, Spain, Sweden, UK & USA) observed that average schedule overrun was 42.7%.

Largely research has focused on the causes of delays covering all phases of construction projects, barring a very few which have focused on the specifics which are mentioned below.

Marzouk et al. (2008) in their study on Engineering related delays in Egypt, identified 22 factors among four categories – design development, workshop drawing supervision, workshop drawing approval, & project parties' changes. Their study found that mistakes/changes in the design documents provided by the Employer, delay by Employer in responding to contractor's queries, delay by contractor in preparation of drawings due to lack of resources, experience, management and changes due to mistakes, constructability problems in the design documents generated by employer as some of the most critical factors of delay.

Rahman et al. (2009) from the study of financial related factors contributing to delay of projects in Malaysia found that late payment, poor cashflow management, insufficient financial resources & financial market instability as the most significant factors.

Yang and Wei (2010) brought out that changes in client's requirement, poor scope definition, unreasonable and unpractical initial plan, change orders by client and project complexity as main factors causing delay in planning & design phases of construction projects in Taiwan.

Figure 4 & 5 present the details of the various research work carried out in developing & developed countries respectively by type of the projects investigated, research methodology adopted by the authors.

Figures 6 & 7 present the top five causes of delays as found out from the review of literature in various countries along with the frequency (%). Mostly, the studies and ranking of causes is based on the Relative Importance Index (RII), Frequency Index (FI), Severity Index (SI) and Importance Index (II). Table 2 provides the definitions of the statistical measures most widely used adopted by authors for ranking the causes of delay.

Table 2. Statistical measures adopted by various authors for ranking of delay causes

No	Statistical Measure	Equation	Parameters
1	Relative Importance Index (RII)	$\frac{\sum_{i=1}^{i=5} a_i x_i}{\sum_{i=1}^{i=5} x_i}$	i is the index of answer category with value between 0 and 4, a_i is the weight assigned to ith response, x_i is the frequency of ith response as a percentage of total responses for each cause
2	Frequency Index, (FI) (%)	$\sum a\left(\frac{n}{N}\right) * 100/4$	a is the constant expressing weighting given to each response, n is the frequency of the responses, and N is total number of responses.
3	Severity Index, (SI) (%)	$\sum a\left(\frac{n}{N}\right) * 100/4$	a is the constant expressing weighting given to each response, n is the frequency of the responses, and N is total number of responses.
4	Importance Index (II)	$\sum_{i=1}^{i=4} \frac{a_i x_i}{3}$	a_i - constant expressing weight of ith response, a_i=0,1,2,3 for i=1,2,3,4 respectively, x_i is the frequency of ith response as a percentage of the total responses for each cause
5	Relative Importance Weight (RIW)	$\frac{\sum_{i=1}^{i=5} a_i n_i}{\sum_{j=1}^{j=N} x_j}$	x_i is the sum of the jth factor; j=the factors 1, 2, 3, 4, . . .N; N is the total number of factors; a_i=constant expressing the weight given to the ith response: i=1, 2, 3, 4, 5
6	Mean Score (MS)	$4 - \frac{\sum f \times s}{N}$	f is the frequency of responses to each rating, s is the score given to each factor by the respondents and N is the total number of responses concerning that factor
7	Rank correlation coefficient (ρ)	$\frac{1 - 6\sum D^2}{N(N^2 - 1)}$	Where D is the difference between ranks given by one party and the rank given by another party for an individual cause and N is the number of cause or groups
8	Weighted Opinion Average (WA)	$\frac{1}{4} \times \frac{\sum_{i=1}^{i=4} F_i R_i}{\sum_{i=1}^{i=4} F_i} \times 100\%$	Where R_i is the response type on the Likert scale, i ranging from 1 to 4 on the Likert scale; F_i is the frequency or total number of respondents choosing response type i on the Likert scale
9	Importance Weight (IW)	$\frac{FI(\%) \times SI(\%)}{100}$	Where FI is the Frequency Index and SI is the Severity Index.

S No	Study	Country / Region	Type of projects investigated	Respondents / Tools	Research Methodology	Statistical analysis & tests
1	Arditi *et al.,* (1985)	Turkey	Buildings & Engineering projects	Clients & contractors for public projects	23 causes identified. Causes ranked on the basis of importance, arrived by relative weightage(%).	Relative Weightage (%)
2	Kazaz *et al.,* (2012)	Turkey	Generic	Representatives of contractors	34 factors identified from literature review categorised to 7 groups (Environmental, financial, labor, managerial, owner based, project based & resource based). Factors ranked based on RII of factors calculated from the responses.	Relative Importance Index (RII)
3	Gündüz *et al.,* (2013)	Turkey	Generic	PMs, managers (site, technical office) Engineers, & consultants	83 causes identified from literature review, categorized into 9 groups - consultant, contractor, owner, design, equipment, labor, material, project, externally related factors. Ranking based on RII.	Relative Importance Index (RII)
4	Dlakwa and Culpin (1990)	Nigeria	Generic	Public agencies, contractors & consultants	18 factors ranked on the basis of grand mean score of responses from all categories of respondents	Mean score for each factor Standard deviation for each factor
5	Mansfield *et al.,* (1994)	Nigeria	Generic	Contractors, Consultants & Clients	16 factors responsible for delay identified. Ranking of the factors is done on the basis of severity index (%) calculated as the sum of the percentage of respondents who strongly agree & who agree that a particular reason causes delay.	Severity Index (%)
6	Elinwa and Joshua (2001)	Nigeria	Generic	Architects, Surveyors, Engineers & Builders	23 factors responsible for delay identified. Ranking of factors on the basis of Severiry index (%) for individual categories of responses (Architects, Surveyors, Engineers & Builders) & on the basis of combined agreement factor for overall ranking.	Severity Index (%), Spearman rank correlation coefficient, One- tailed & Two-tailed tests, Combined agreement factor
7	Aibinu and Odeyinka (2006)	Nigeria	60 Nos of residential & office building projects	Construction managers	44 factors identified under two broad categories - 1. Factors relating to the various parties (client, quantity surveyor, architect, structural engineer, services engineer, supplier, contractor, sub contractor, supplier related factors) & 2. Factors not caused by design & construction participants (external factors). Ranking of factors based on RII	Kendall coefficient of concordance, Chi Square Test, Relative Importance Index (RII), One-sample t-Test
8	Assaf *et al.,* (1995)	Saudi Arabia	Buildings	Contractors, architects/ engineers & Clients	56 causes of delay categorized into 9 groups - material, manpower, equipment, financing, changes, Govt. relations, scheduling & controlling, environment, contractual relationships. The ranking of causes is based on importance index.	Importance Index Spearman rank correlation coefficient

Figure 4. Summary of construction project delay studies in developing countries

S No	Study	Country / Region	Type of projects investigated	Respondents / Tools	Research Methodology	Statistical analysis & tests
9	Al-Khalil and Al-Ghafly (1999)	Saudi Arabia	Water & Sewerage projects	Contractors, Consultants & Clients	60 causes of delay categorized into 6 major categories - contractor performance, owner administration, early planning & design, Govt. regulations, site & environmental conditions, site supervision.	Kendall coefficient of concordance, Chi Square Test, Frequency index, Severity index & Importance Index
10	Assaf and Al-Hejji (2006)	Saudi Arabia	Private & public projects completed / nearing completion	Contractors, Consultants & Clients	73 causes of delay categorized into 9 groups - project, owner, contractor, consultant, design-team, materials, equipment, manpower (labor), and external causes. The ranking of causes is based on importance index.	Frequency index (FI), Severity index (SI) Importance Index (II), Spearman's rank correlation
11	Ogunlana *et al.,* (1996)	Thailand	12 Nos of High-rise building projects	Construction managers & major contractors	26 causes of delay categorized into 6 categories - owners, designers, CM or inspector, contractors, resources suppliers & others. Ranking based on percentage of projects (out of a total of 12) affected by a cause.	Percentage of affected projects.
12	Toor and Ogunlana (2008)	Thailand	Airport construction project	Contractor, consultants & client	75 problems categorized into 10 categories - client, designers, project management/consultants, contractors, labour, finance, contract, communication, site and environment, other miscellaneous factors. Ranking of problems based on mean score	Cronbach's alpha test Analysis of Variance (ANOVA) Mean perception ratings for problems -overall & by category of respondent .
13	Al-Momani (2000)	Jordan	130 Nos of residential, office, admin & school buildings, medical facilities	Actual data from contract files of governement agencies	Actual causes of delay for 130 projects examined from the contract files of various state agencies and based on which the important causes of delay are brought out.	Simple regression between planned contract duration and actual completion time
14	Odeh and Battaineh (2002)	Jordan	Buildings, roads, water & sewerage projects	Contractors & consultants	28 delay causes delay causes categorized to 8 groups - client, contractor, consultant, material, labor & equipment, contract, contractual relationships and external factors. Ranking of causes based on RII	Relative Importance Index (RII)
15	Sweis *et al.,* (2008)	Jordan	Residential building projects	Contractor, consultants & clients	40 causes of delay categorized into 3 groups - input related (labor, materials, equipment), internal environment (contractor, owner, consultant) related & exogenous (Weather, Govt. regulations). Ranking of causes based on average score from responses.	Mean score by category of respondents & overall mean score for each cause of delay. Analysis of Variance (ANOVA)
16	Faridi and El-Sayegh (2006)	UAE	Generic	Contractors & consultants	44 causes of delay grouped into 8 categories - Contractor, consultant / designer, owner, financial, planning & scheduling, contractual relationship, Govt. regulations & unforeseen conditions. Ranking of causes based on RII.	Relative Importance Index (RII)

Figure 4 (Continued). Summary of construction project delay studies in developing countries

S No	Study	Country / Region	Type of projects investigated	Respondents / Tools	Research Methodology	Statistical analysis & tests
17	Alinaitwe *et al.,* (2013)	Uganda	Public sector projects	Contractor, consultants & clients	22 factors identified from literature review and pilot study. The causes of delays & cost overruns obtained through the questionnaire survey. The results were further examined through the case study of Civil Aviation Authority (CAA) projects.	Cronbach's Alpha Frequency Index (FI), Severity Index (SI), Importance Index (II), Spearman's correlation coefficient
18	Pourrostam and Ismail (2012)	Iran	Generic	Contractors & consultants	28 causes identified from literature review and questionnaire survey done. Ranking based on Relative Importance Index (RII).	Relative Importance Index (RII), Spearman's correlation coefficient
19	Kaming *et al.,* (1997)	Indonesia	31 Nos of High-rise building projects	Project managers	From literature review 11 delay causes identified and questionnaire survey of project managers of 31 projects done. The frequency index, importance index and severity index were computed for all causes based on the responses received. Ranking of the 11 causes is based on the severity index.	Frequency index Importance index and Severity index
20	Alwi and Hampson (2003)	Indonesia	Buildings	Contractors	31 delay causes grouped to 6 categories - People, professional management, design and documentation, materials, execution and external. The causes of delay were ranked separately for small and large contractors, ranking based on importance index	Importance index
21	Sambasivan and Soon (2007)	Malaysia	Buildings, infrastructure, electrical & mechanical, others	Contractor, consultants & clients	28 delay causes grouped to 8 categories - client, contractor, consultant, material, labour and equipment, contract, contract relationship and external factors. Ranking of causes based on RII	Relative Importance Index (RII)
22	Shehu *et al.,* (2014)	Malaysia	Public & private sector projects	Contractor, consultants & clients	84 factors of delay causes identified. Raking of causes based on the mean values of responses from mean value of responses from public sector and private sector separately and overall ranking is also determined	Kruskal Walis Analysis A Mann-Whitney U test Mean values from responses
23	Alaghbari *et al.,* (2007)	Malaysia	Buildings	Contractors, consultants & Govt bodies	31 factors grouped to 4 categories - owners, consultants, contractors and external factors. Ranking based on the Mean Score of the factor derived from the responses	Mean score for each factor Standard Deviation
24	Acharya *et al.,* (2006)	Korea	Buildings, roads, railway & water projects	Contractor, consultants & clients	85 factors identified from literature review grouped to 5 groups - owner related, consultant related, contractor related, project related & third party related factors. Ranking of factors based on mean score.	Mean score for each factor ANOVA

Figure 4 (Continued). Summary of construction project delay studies in developing countries

S No	Study	Country / Region	Type of projects investigated	Respondents / Tools	Research Methodology	Statistical analysis & tests
25	El-Razek *et al.,* (2008)	Egypt	Buildings	Contractor, consultants & clients	85 causes identified from literature review grouped to 9 groups - financing, manpower, changes, contractual relationships, environment, equipment, rules & regulations, material, and scheduling & control factors. Ranking of causes by importance index	Importance index
26	Marzouk and El-Rasas (2014)	Egypt	Generic	Contractors	43 causes identified from literature review grouped to 7 categories -Owner, consultant, contractor, material, labor & equipment, project & external related. Ranking of causes by importance index.	Frequency index Severity Index and Importance index Probability of Error (P)
27	Aziz and Abdel-Hakam (2016)	Egypt	Road construction projects	Consultants, Site engineers/ designers & contractors	293 causes categorized into 15 groups - financing, owner, contractor, consultant, labor, design, site, contractual relationships, contract, project, equipment, material, scheduling & controlling, rules & regulations, external related causes. Ranking of causes based on overall RII	Overall Relative Importance Index (ORII)
28	Mezher and Tawil (1998)	Lebanon	Generic	Contractors, architects /engineers & Clients	64 causes of delay identified from literature review categorized into 10 groups - materials, manpower, equipment, financing, changes, government relations, project management, site conditions, environment, and contractual relationship. Ranking of the causes by Importance Index.	Importance index
29	Frimpong *et al.,* (2003)	Ghana	Groundwater projects	Contractor, consultants & clients	26 causes of delay identified from previous investigations on groundwater projects in Ghana. The ranking of causes is done by the Relative Importance Weight (%) of each factor	Kendall coefficient of concordance, Chi Square Test, Relative Importance Weight(%)
30	Koushki *et al.,* (2005)	Kuwait	450 Nos of Private residential projects	Owners & developers	Causes populated from the study and responses from owners of 450 sample residential projects investigated in the study. Ranking based on the extent of delay (in months) by a particular cause.	-
31	Shebob et al., (2012)	Libya	Generic	Contractor, consultants & clients	75 causes identified from literature review grouped to 4 categories - Contractor, Owner, Consultants and Others. Ranking based on Importance Index of each factor.	Frequency Index, Severity Index, Importance Index Importance Weight (IW), Average Weight (AW)

Figure 4 (Continued). Summary of construction project delay studies in developing countries

S No	Study	Country / Region	Type of projects investigated	Respondents / Tools	Research Methodology	Statistical analysis & tests
32	Chan and Kumaraswamy (1997)	Hong Kong	Building & Civil engineering projects	Contractor, consultants & clients	83 factors from literature grouped to 8 categories - Project related, client related, design team related, contractor related, material, labour, plant/equipment, external factors. Ranking of factors based on RII.	Relative Importance Index (RII) Rank Agreement Factor (RAF) Percentage Disagreement (PA)
33	Lo *et al.,* (2006)	Hong Kong	Generic	Contractor, consultants & clients	30 causes of delay categorised to 7 groups - client related, engineer related, contractor related, human behavior related, project related, external factor and resource related factors. Ranking based on Overall Mean Score	Mean score for each factor by respondent type & Overall Mean Score
34	Gardezi *et al.,* (2014)	Pakistan	Generic	Contractor, consultants & clients	27 factors causing delay are identified from the actual data of delays of 50 active construction projects in Pakistan. Causes are grouped to 7 categories - client, contractor, consultant, material, labor & equipment, contract related and external factors. Ranking based on RII	Relative Importance Index (RII)
35	Long *et al.,* (2004)	Vietnam	Generic	Contractor, consultants & clients	62 problems identified from literature review, grouped to 7 categories - financier, owner, contractor, consultant, project attributes, coordination & environment related factors. Factors ranked by occurrence and influence.	Mean score for degree of occurrence, Mean score for degree of influence, Standard Deviation & Factor Analysis
36	Kaliba *et al.,* (2008)	Zambia	Road construction projects	Contractor, consultants & clients	14 significant factors causing delay of road construction in Zambia identified through the responses of questionnaire survey. Ranking based on the weighted opinion averages.	Weighted Opinion Average
37	Doloi *et al.,* (2012)	India	Generic	Client, Contractors, designers / architects	45 delay attributes identified from literature under six categories - project related, site related, process related, human related, authority related and technical issues. The ranking of factors is based on RII. Further, factor analysis done on 27 out of 45 factors.	Relative Importance Index (RII) Factor analysis
38	Enshassi *et al.,* (2009)	Gaza	Generic	Contractors, Consultants & Clients	110 delay factors grouped to 12 major groups - project related, contractors' responsibilities, consultants' responsibilities, owners' responsibilities, professional management, design and documentation, materials, execution, labour and equipment, contractual relationship, government relations, and external factors. Ranking of causes is based on importance index.	Importance Index Cronbach's alpha
39	Mahamid (2013)	West Bank	Road construction projects	Contractors	45 factors identified and classified to 6 groups - project, managerial, consultant, financial, external and construction items. A risk map is developed based on the frequency and severity of the factors. The criticality of the factors is identified from the risk map.	Risk map

Figure 4 (Continued). Summary of construction project delay studies in developing countries

Study	Country / Region	Type of projects investigated	Respondents / Tools	Research Methodology	Statistical analysis & tests
Baldwin *et al.,* (1971)	USA	Generic	Architects, Engineers & Contractors	17 causes of delay were examined in the study. The most important causes are described to suggest ways to reduce delays.	-
Bordoli and Baldwin (1998)	USA	Buildings	Contractors, PM practices, architectural practices, quantity surveyors, law firms	The research work discussed the various methods for assessing delays in construction methods and proposed a method for delay analysis. The proposed method was tested on a building project. The causes of delays are brought out through this case study.	-
Ahmed *et al.,* (2003)	USA	Buildings	Contractors	50 delay causes identified from review of literature and used in the questionnaire survey. Causes of delays are classified to 6 categories - acts of God, design related, construction related, financial/economic, management/administrative, & code related causes. Ranking of causes on the basis of chance of occurrence of causes as perceived by respondents.	-
Eliis and Thomas (2002)	USA	Highway	Clients, contractors, design consultants & professional organisations	Questionnaire survey conducted on State Highway Agencies, Contractors. The most frequent causes as indicated by the agencies and contractors are brought out by the study.	-
Semple *et al.,* (1994)	Canada	Buildings & Engineering projects	Claim documentation	The study is based on the investigation of the claim documentation of contractors and subcontractors in Canada. The important causes are identified from the study of 24 claims of contractors and subcontractors.	-
Ayudhya (2011)	Singapore	Buildings	Contractors, Consultants & Clients	35 delay causes identified from literature review. The causes were ranked by Severity Index.	Severity Index Spearman's rank correlation coefficient
Hwang *et al.,* (2012)	Singapore	Buildings	Contractors, Consultants & Clients	18 factors were identified from literature review and responses sought from industry experts. 13 factors were grouped under Player-related category and 5 factors under resource related category. The ranking of the factors is done on the basis of criticality index of each factor	Impact index Frequency index Criticality index
Wong and Vimonsatit (2012)	Australia	Generic	Clients, contractors & consultants	48 factors identified from review of literature and categorised into eight groups - financing, manpower, changes, contractual relationship, environment, equipment, materials and scheduling & controlling. Causes ranked on the basis of Relative Importance Index (RII).	Relative Importance Index (RII) Cronbach's alpha

Figure 5. Summary of construction project delay studies in developed countries

S No	Study	Country / Region	Type of projects	Respondents / Tools	Research Methodology	Statistical analysis & tests
9	Love *et al.* (2010)	Australia	Commercial, Industrial, Engineering construction	Clients and contractors	The database of disputes in Australia were filtered for diputes in commercial, industrial & engineering construction projects excluding domestic building disputes. The causes of disputes were further ascertained by the responses from focus groups of contractors and clients	-
10	Orangi *et al.* (2011)	Australia	Pipelines	Clients and contractors	The study identified the root causes of delays in pipeline projects in Australia through the case studies of three projects. The causes are ranked based on the extent of impact on the three projects as perceived by the respondents.	-
11	Larsen *et al.* (2015)	Denmark	Generic	Architects, Engineers & Building surveyors	26 factors identified from literature reviews. The factors are grouped to 5 categories - External complications, complications related to the contract, project management complications, project change complications and finance & scheduling complications. Factors ranked on the basis of RII.	Relative Importance Index (RII) Cronbach's alpha Friedman's test
12	Sullivan and Harris (1986)	UK	Buildings & Engineering projects	Clients, consultants & contractors	The research objective was to identify the factors leading to unanticipated delays and cost overruns in large projects. The factors were ranked on the basis of frequency of occurrence (proportion of the projects 'experiencing the factors.	-
13	Olawale and Sun (2010)	UK	Generic	Contractors & consultants	The research objective was to identify the time control practices in UK, time & cost control inhibiting factors of projects and mitigating factors. Ranking of the factors is based on RII.	Relative Importance Index (RII) Spearman Rank Correlation
14	Shebob *et al.* (2012)	UK	Generic	Contractor, consultants & clients	75 causes identified from literature review grouped to 4 categories - Contractor, Owner, Consultants and Others. Ranking based on Importance Index of each factor.	Frequency Index, Severity Index, Importance Index Importance Weight (IW), Average Weight (AW)
15	McCord *et al.* (2015)	Ireland	Buildings	Academicians, Contractors, Clients and consultants	75 delay attributes identified from literature and used for the survey. The attributes were grouped to 10 categories - Client, consultant, contractor, design, equipment, external, labour, management, material & project related attributes. The attributes are ranked on the basis of RII	Relative Importance Index (RII) Kendall's coefficient of concordance

Figure 5 (Continued). Summary of construction project delay studies in developed countries

Country / Study Major causes of delay (Top 5 Causes)	Turkey			Nigeria				Saudi Arabia			Thailand		Jordan			UAE	Uganda	Iran	Indonesia		Malaysia			Korea	Egypt			Lebanon	Ghana	Kuwait	Libya	Hong Kong		Pakistan	Vietnam	Zambia	India	Gaza	West Bank	Frequency(%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	
A. Owner /Consultant /Architect related																																									
Delay in monthly payments / payments for completed work	✓	✓		✓	✓	✓		✓	✓	✓				✓			✓	✓			✓				✓	✓	✓		✓							✓			✓	46%
Design & drawings related (delays in approvals, design changes, errors etc.)		✓	✓			✓	✓	✓			✓	✓	✓			✓			✓	✓				✓	✓			✓			✓			✓			✓			44%
Change orders/Variation orders/Changes in scope/Extra work										✓			✓		✓		✓	✓								✓				✓		✓					✓			23%
Slow decision-making process / owner interference / delayed approvals														✓		✓		✓		✓								✓				✓								15%
Owner's financial constraints / inadequate budgets / cashflow problems				✓			✓																							✓				✓		✓				13%
Deficiency in owner' organisation / lack of experience	✓											✓																		✓										8%
Delay in site clearnace, failure to provide construction site																								✓											✓					5%
Poor contract management / non-compliance to contract / modification					✓	✓																							✓							✓				10%
B. Contractor related																																									
Deficiencies in planning & scheduling			✓	✓		✓				✓					✓	✓			✓	✓	✓	✓				✓	✓													31%
Contractor's financial difficulties	✓	✓		✓			✓		✓						✓			✓				✓	✓		✓				✓						✓		✓			33%
Delay - delivery of materials, imported materials & plant items, procurement			✓					✓															✓		✓				✓	✓	✓					✓	✓	✓		26%
Poor supervision, site management			✓											✓		✓		✓			✓		✓				✓					✓		✓						23%
Inadequate experience and lack of control over project			✓									✓		✓							✓												✓							13%
Shortage of manpower										✓	✓					✓			✓																					10%
Poor labour productivity		✓								✓				✓					✓							✓														13%
Preparation and approval of drawings / shop drawings								✓																				✓												5%
Unrealistic project schedule / Inaccurate time estimating						✓						✓												✓											✓					10%
Deficiencies in contractors' organisation / project team	✓			✓							✓				✓																				✓					13%
Subcontractor & supplier related (delay, incomptence)					✓		✓					✓									✓	✓						✓												15%
Poor coordination, poor monitoring & control											✓									✓		✓																		8%
Equipment breakdown & maintenance problem, inadequate equipment							✓										✓										✓												✓	10%
Shortage / Availability of construction materials					✓						✓								✓				✓															✓		13%
Shortage of resources of due to contractor / lack of capital																																	✓							3%
Improper technical study contractor during bidding stage/low bids																																	✓							3%
Rework due to errors / mistakes during construction																							✓								✓									5%
Cashflow problems		✓						✓	✓													✓																✓		13%
C. External																																									
Weather / Ground conditions													✓													✓				✓		✓	✓							13%
Unqualified / Inadequately experienced workforce / low skill															✓					✓											✓									8%
Changes in site conditions					✓								✓											✓																8%
Inflation, interest rates, escalation, political instability, economy, law & order													✓				✓												✓					✓		✓		✓	✓	18%
Bid related - system of selection of lowest bidder / high competition									✓																														✓	5%
External work due to public agencies / link with other utilities																															✓		✓							5%
Shortage / difficulties in obtaining resources from market	✓																																					✓		5%
Other external causes									✓								✓							✓	✓		✓	✓						✓	✓		✓		✓	

Figure 6. Major causes of delays in construction projects in developing countries
*Numbers under respective countries in the above Figure are as per studies in Figure 4

Country / Study Major causes of delay (Top 5 Causes)	USA				Canada	Singapore		Australia			Denmark	UK			Ireland	Frequency(%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
A. Owner /Consultant /Architect related																
Delay in monthly payments / payments for completed work /project financing						✓					✓				✓	20%
Design & drawings related (delays in approvals, changes, complexity, errors)	✓		✓	✓						✓		✓	✓		✓	47%
Change orders/Variation orders/Changes in scope/Extra work			✓		✓				✓			✓		✓		33%
Slow decision-making process / owner interference / delayed approvals			✓							✓		✓			✓	27%
Evaluation of completed works						✓										7%
Delay in site clearnace, failure to provide construction site, restricted access					✓				✓							13%
Poor contract management / non-compliance to contract									✓							7%
B. Contractor related																
Deficiencies in planning & scheduling				✓							✓					13%
Contractor's financial difficulties						✓		✓							✓	20%
Poor supervision, site management							✓									7%
Inadequate experience and lack of control over project													✓			7%
Availability of staff to manage project							✓									7%
Shortage of manpower / Availability of laborers on site	✓						✓	✓								20%
Unrealistic project schedule / Inaccurate time estimating								✓					✓			13%
Subcontractor & supplier related (delay, incomptence)	✓	✓								✓		✓	✓	✓		40%
Poor coordination, poor monitoring & control							✓									7%
Shortage of materials / Availability of materials	✓						✓									13%
Lack of identification of needs											✓					7%
Rework due to errors / mistakes during construction											✓					7%
C. External																
Force Majeure / Acts of Gods		✓				✓										13%
Weather / Ground conditions	✓	✓			✓	✓		✓		✓		✓		✓		53%
Unqualified / Inadequately experienced workforce / low skill								✓								7%
Changes in site conditions/ Poor site conditions				✓					✓					✓		20%
Inflation, interest rates, escalation, political instability, law & order														✓		7%
External work due to public agencies / link with other utilities				✓											✓	13%
Shortage / difficulties in obtaining resources from market		✓														7%
Changes in laws, regulations, legislations			✓													7%
Building permits /Approvals from Governement / Authorities / Other stakeholders			✓							✓	✓					20%
Risk and Uncertainity associated with projects									✓				✓			13%
Other external causes				✓												

Figure 7. Major causes of delays in construction projects in developing countries
*Numbers under respective countries in the above Figure are as per studies in Figure 5

Recommendations & mitigation strategies to control delay

Table 3 presents details on the recommendations and mitigation strategies for controlling delays in construction projects, provided by the researchers.

Table 3. Recommendations/mitigation strategies for control of delays proposed by the researchers

Recommendations / strategies	Study
Owners to pay progress payment on time, appropriate funding levels to be determined at the planning stage of project	Assaf and Al-Hejji (2006); Enshassi et al. (2009); Aziz and Abdel-Hakam (2016); Frimpong et al. (2003); Koushki et al. (2005); Gardezi et al. (2014); Mansfield et al. (1994); Sambasivan and Soon (2007)
Owner to minimize change orders during construction, comprehensive strategies to be formulated for minimizing variations, effective scope definition	Alinaitwe et al. (2013); Assaf and Al-Hejji (2006); Chan and Kumaraswamy (1997); Kaliba et al. (2009)
Owner to check for the availability of resources and capabilities of contractor before awarding the contract to the lowest bidder, chose a contractor with good reputation and sufficient experience	Assaf and Al-Hejji (2006); Koushki et al. (2005); Aziz and Abdel-Hakam (2016); Enshassi et al. (2009); Odeh and Battaineh (2002); Sambasivan and Soon (2007)
Contractor to manage his financial resources and plan cashflow, contractors to have enough cash before beginning project	Assaf and Al-Hejji (2006); Enshassi et al. (2009); Sambasivan and Soon (2007)
Contractor to have proper planning & schedule, to match with resources, monitoring and control	Assaf and Al-Hejji (2006); Gardezi et al. (2014); Koushki et al. (2005); Mansfield et al. (1994)
Contractors to be more aware about construction materials and logistics, purchase materials at beginning of work, effective and efficient material procurement systems	Enshassi et al. (2009); Frimpong et al. (2003); Mansfield et al. (1994)
Continuous work training programmes for personnel in the industry, updation of knowledge and skills	Frimpong et al. (2003); Mezher and Tawil (1998); Odeh and Battaineh (2002)
Owners to employ experienced designers / consultants	Aziz and Abdel-Hakam (2016); Koushki et al. (2005)

INFERENCE FROM LITERATURE REVIEW

Critical causes of delay

Review of literature and causes as depicted in Figures 6 & 7 has helped us narrow the critical factors responsible for construction project delays. Top ten causes of delay based on frequency (%), in developing countries and developed countries are as in Figure 8.

Developing countries	Developed countries
• Delay in payments by clients	• Weather / Ground conditions
• Delay in drawings, changes & errors in designs	• Delay in drawings, changes & errors in designs
• Contractor's financial difficulties	• Subcontractor & supplier related causes
• Deficiencies in planning & scheduling	• Change orders / increase in scope of work
• Delay in delivery of materials	• Slow decision making / approvals from client
• Change orders / increase in scope of work	• Delay in approvals / permits from other authorities
• Poor site supervision and management	• Changes in site conditions / poor site conditions
• Economy, law & order, inflation, political instability	• Contractor's financial difficulties
• Slow decision making by owner	• Delay in monthly payments from client
• Subcontractor & supplier related causes	• Force majeure / Acts of Gods

Figure 8. Top ten causes of delays in construction projects in developing and developed countries

It must be noted that causes of delay vary from country to country and especially causes for delay in developing country are different from that of developed country.

Characteristic of delays in developing and developed countries

It is noticeable from Figures 6 & 7 that in the case of developing countries causes of delays are mostly weighing around client & contractor related factors, while in the case of developed countries, the delays in projects are governed by the external factors in addition to the client & contractor related factors. This can be reasoned that in developed countries, with sophisticated technologies, and implementation of best in class project management systems & practices the internal factors associated with client & contractor are mitigated or eliminated.

The above inference is further strengthened by the fact that two of the most frequent causes of delay in developing countries as identified in literature - deficiencies in planning & scheduling, inadequate experience of the contractor both of which does not feature at all in the Top 10 causes of delay in developed countries.

The criticality of delay causes in developing countries as against developed countries is a reflection of the financial status / fund availability with implementation agencies as well as the contractors in developed countries as against those in the developing countries. This is visible and evident as two of the highly ranked causes of delays in developing countries – delay in payments from clients and contractor's financial difficulties rank lowest in developed countries. This finding is in agreement with Ogunlana et al. (1996) who opined that contractors working in developing economies work under special constraints which are not as serious in developed countries.

It is noticeable from Figure 6 that subcontractor related factor is ranked high as a cause in developed countries. This is a reflection of the project execution strategies in developed economies where the contracting companies practice outsourcing as a concept and subcontract large volume of work in different packages, enabling the companies to be lean, and focus on multiple projects.

Irrespective of the type of economy, two of the causes feature in both and are ranked high – delay in approvals of drawings, design changes & errors, change orders / increase in scope of work.

Research Gaps & Scope, direction for further research

Type of project

The characteristics & challenges in construction projects vary from one type of project to another type. In the case of hydro power projects, which are usually set up in the remote locations & cut off from access, the challenge is to have a mechanism that ensures logistics for uninterrupted supply of resources, & to adequately rehabilitate the locals. In case of a highway project, acquiring land for construction is the challenge. In case of a nuclear power project, meeting the stringent quality and safety norms, technical specifications and getting the skilled labour, achieving productivity is the challenge. Studies in the past either in India or anywhere across the world have been able to compare the reasons for delays for different type of projects in one single study. As evident from Figure 4, 43% of the research in the past has focused on buildings, while 37% of the studies have been generic without reference to any type of project.

Causes responsible for delays in specific type of projects if identified can be dealt separately with a meaningful solution by the respective implementation agencies within the Government. Hence, research identifying causes by the type of the project in a country can be done.

Type of contract

Type of the contract (Design Build / Design Bid Build (DBB) or Traditional contract) through which the project is executed has not been captured at all in the delay studies. From the inferences of literature review summarized in Figure 7, critical causes of delay are design changes by owners, changes during construction by owners, client initiated variations, occurrences & impact of which are reduced in the EPC/ Design Build contract by its basic & most essential characteristic of vesting the design responsibility with the construction contractor. There have been many research works on the performance of Design Build (DB) contracts. Research on time performance of DB projects have indicated that DB projects perform better in terms of schedule performance, have higher delivery speed and are easier to commission. (Molenaar et al., 1999; Ling & Kerh, 2004; Hale et al., 2009; Shrestha et al., 2012; Chen et al., 2016). Design and Build is seen to be providing the missing integration of the design and construction of the project (Dulaimi and Dalziel, 1994). There are studies with contradicting views also. Dissanayaka and Kumaraswamy (1999) concluded that time-overruns appear to be greatly influenced by non-procurement related factors. Ling and Poh (2007) found that owners face significant problems in the whole development process of DB projects, especially during tender preparation and evaluation stages. Lam et al. (2003) found frequent & late changes, delay of design approval, burden of tendering on contractor & misinterpretation of client's requirements as some of the problems in DB contracts. This invites for further research on this topic.

EPC model is going to be the preferred mode of project execution in the near term (Ernst & Young, 2014). Research on causes of delays in different type of contracts – EPC, traditional contracts can be done which will bring a different dimension to the studies and also enable recommend the type of contract for a specific type of project.

Indian context

Although construction projects share common characteristics across the world, the projects are influenced & governed by some country specific conditions, which needs to be factored and looked into (Olawale and Sun, 2010). The groups and factors causing delays are country, location and project specific and that there are no root causes that can be generalized (Ramanathan et al., 2012). Although there have been many studies to assess the causes of delays in construction projects, there has been very limited research work carried out on this topic in India in the recent times, except - Doloi et al. (2012). The trend and extent of delays invites for further research on this topic in India.

Root causes for the problems / factors

It is noticeable from Figure 6&7 that some of the causes of delays in construction projects have very high frequency such as delays in payments from client, deficiencies in planning & scheduling, delays in drawings, change orders etc.

These critical and high influence problems need to be investigated in detail with research focusing on the root causes for these problems and mitigation for these problems. While some work has been done with this attempt – Ramachandra and Rotimi (2015) investigated the payment problems in New Zealand, Yang and Wei (2010) investigated the causes of delays in planning & design phase of construction projects, more of such specific studies on relevant critical causes in a country can be done and will help in control the problem itself.

Research approach

As evident from Figures 4&5, almost all of the research and evaluation of causes of delay is based on the statistical analysis of questionnaire responses. The responses from a questionnaire can at times have biased opinions, as delay is a subject where each party will keep their interests protected and blame the other party for delay.

Research work to identify the causes can also be taken up through the review of actual documentation of Extension of Time (EOT) claim applications submitted by the contractors and EOT related arbitration awards or court awards. Alternatively, research work integrating both the methods can be taken up wherein the causes as identified from analysis of questionnaire responses can be compared with causes that emerge out from the study of claim documents, which will negate the effect of any biased opinions and strengthen the findings.

Mitigation for causes

Most importantly, while many researchers & studies have brought out the causes of delays, the research mostly has ended without providing any meaningful, fruitful solutions to mitigate the problem. Figure 9 presents the recommendations provided by researchers. It can be seen most of the recommendations are very generic and lack vigor. Most existing studies stopped at the identification of the influencing factors, but did not progress on to finding ways of mitigating the identified problems (Olawale and Sun, 2010). This was further reiterated by AlSehaimi et al. (2013) criticizing all previous research on three grounds – no recommendations made to correct or mitigate a particular cause of delay, recommendations do not match findings and recommendations provided are not practical. The study (Olawale and Sun, 2010) provided an exhaustive set of mitigating measures for problems in UK.

Studies investigating the causes of delay along with identification of mitigation measures to overcome the causes and control the delays in construction projects are essential to address the problem and can be done in India and other countries.

CONCLUSION

There has been extensive research in many countries to explore the causes of delays in construction projects. The paper has brought out the salient findings of previous literature in both developing and developed countries and the gaps in previous research and the scope for future research. With the objective of closing the gaps identified in previous literature, the authors intend to undertake research work considering all the factors with focus on causes of delays in EPC projects, along with identification of mitigation factors, results of which hopefully will aid in improving the construction project delivery in India and globally.

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GUIDE TO AUTHORS

Aims and Scope:

The Malaysian Construction Research Journal (MCRJ) is the journal dedicated to the documentation of R&D achievements and technological development relevant to the construction industry within Malaysia and elsewhere in the world. It is a collation of research papers and other academic publications produced by researchers, practitioners, industrialists, academicians, and all those involved in the construction industry. The papers cover a wide spectrum encompassing building technology, materials science, information technology, environment, quality, economics and many relevant disciplines that can contribute to the enhancement of knowledge in the construction field. The MCRJ aspire to become the premier communication media amongst knowledge professionals in the construction industry and shall hopefully, breach the knowledge gap currently prevalent between and amongst the knowledge producers and the construction practitioners.

Articles submitted will be reviewed and accepted on the understanding that they have not been published elsewhere. The authors have to fill the Declaration of the Authors form and return the form via fax to the secretariat. The length of articles should be between 3,500 and 8,000 words or approximately 8 – 15 printed pages (final version). The manuscripts should be written in English. The original manuscript should be typed one sided, single-spacing, single column with font of 11 point (Times New Roman). Paper size should be of Executive (18.42 cm x 26.67 cm) with 2 cm margins on the left, right and bottom and 3 cm for the top. Authors can submit the manuscript:

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

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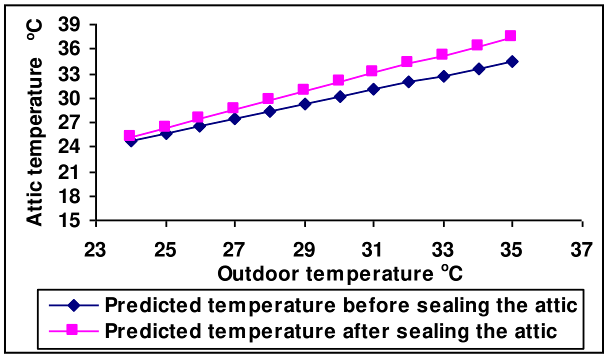

Figure 8. Computed attic temperature with sealed and ventilated attic

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Table 1. Recommended/Acceptable Physical water quality criteria

Parameter	Raw Water Quality	Drinking Water Quality
Total coliform (MPN/100ml)	500	0
Turbidity (NTU)	1000	5
Color (Hazen)	300	15
pH	5.5-9.0	6.5-9.0

(Source: Twort et al., 1985; MWA,1994)

Reference: Times New Roman, 11pt. Left indent 0.64 cm, first line left indent – 0.64 cm. Reference should be cited in the text as follows: "Berdahl and Bretz (1997) found…" or "(Bower et al., 1998)". References should be listed in alphabetical order, on separate sheets from the text. In the list of References, the titles of periodicals should be given in full, while for books should state the title, place of publication, name of publisher, and indication of edition.

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