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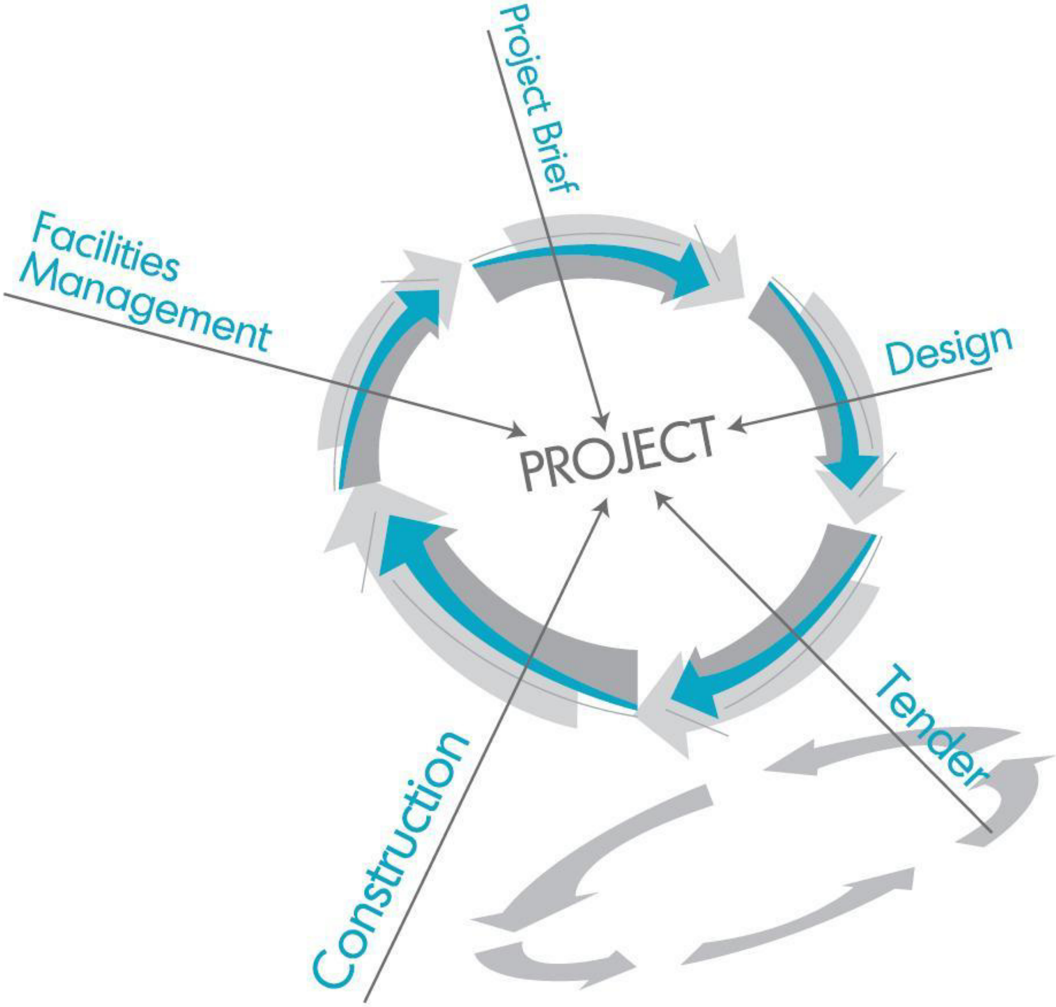

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Contents

Editorial Advisory Board

Editorial

Welcome from the Editors

Welcome to the sixteenth issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include another 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. It is hope that readers will find informative articles from this edition of MCRJ. In this issue;

Raza Ali Khan, ***et. al.*** present an empirical examination of Malaysian Construction Sector (MCS), through the development of a time series model equation under vector error correction (VEC) system. The estimated model is able to develop the impulse response functions (IRFs) for the purpose of examining the behavior and response of MCS against the positive shocks produced in other major sectors of the economy and vice versa. The results suggest that the MCS is relatively small in size and contribution to GDP; however, it has strong correlation and long and short run association with all major sectors of the economy.

M. Waris, ***et. al.***, through questionnaire survey, investigates the current awareness of onsite mechanisation, the advantages in its adoption, and the barriers for onsite mechanisation application in Malaysian construction industry. The paper reveals that there is a good understanding and application of mechanised practices among IBS contractors. However, for medium and small size contractors, the implementation of onsite mechanisation is largely inhibited due to budget constraints as it is considered an extra financial burden.

Mohd. Harris, ***et.al.*** explore the expectation of the stakeholders over the potential business value of Building Information Modelling (BIM) in the Architecture, Engineering, and Construction (AEC) industry through quantitative analysis. Despite of being reluctant to take up BIM into their process delivery, the professional personnel within the AEC industry are aware of the benefits and Return on Investment (ROI) gained from the BIM investment. The study proposed in-depth research with empirical study over ROI for BIM projects and the strategies for technological competencies development for a BIM user should be conducted.

Mastura Jaafar, ***et. al.*** study the level of women participation in the construction industry. The findings bring an important message to the industry, by identifying the barriers and challenges faced by women in this sector. It was found that the main barriers that caused low women participation in construction industry are due to inflexible working hours, mistreatment by others in the industry, and the strict recruitment processes.

Gan Hock Beng, ***et. al.*** propose a new housing design strategy enables retrofit and reconfiguration to be made quickly, economically, and repeatedly, without involving excessive site labour, time, and cost; as compared to the currently adopted one which is associated with rigid structure, interlocking plan, and predetermined function. By comparing these two design strategies, they authors demonstrate the potential of applying flexibility as an inherent design strategy for the modern urban mass housing. The paper, hence, suggests that only dwellings with high degree of flexibility may enable the integration of dual aims and principles of affordability and sustainability in mass housing, thereby facilitating the movement of the country's construction industry towards mechanisation, industrialisation, and standardisation.

Murnira Othman, ***et. al.*** provide an overview of construction activities in Malaysia and review the importance of applying Life Cycle Assessment (LCA) in building construction. Wide application of LCA in various types of building as well as among many countries suggests that this tool is important in evaluating building performance. The paper also suggests that the implementation and application of LCA in the building sector is a wise move towards energy saving, emission reduction, and natural resource conservation.

Editorial Committee

IMPULSE RESPONSE ANALYSIS FOR MALAYSIAN CONSTRUCTION SECTOR BY VECTOR ERROR CORRECTION MODEL

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Abstract
The Malaysian construction sector (MCS) is a significant sector of the Malaysian economy. It plays a pivotal role in the social economic development. This study focusses on empirical examination of MCS, and develops a time series model equation for MCS under vector error correction (VEC) system. The estimated model is used to develop the impulse response functions (IRFs) to examine the behavior and response of MCS against the positive shocks produced in other major sectors of the economy and vice versa. The results suggest that the MCS is relatively small in size and contribution to GDP; however, it has strong correlation and long and short run association with all major sectors of the economy. The speed of adjustment of MCS toward long run equilibrium is 30 %. It has positive response against the shock produced in other sectors of the economy except manufacturing sector. The most sensitive sector for MCS is mining and quarrying. The MCS economic activity is at peak in the third quarter of each year. This study is useful for government of Malaysia, economic planning unit, construction firms and other interested parties of the construction sector.

Keywords: *Impulse response function; Vector error correction model; Cointegration.*

INTRODUCTION

The Malaysian economy is the most successful growing economy in the world. Recently the World Economic Forum (WEF) ranked Malaysia 24 most competitive countries out of 148 countries, above than China and Korea. The high economic growth and development of Malaysia is due to its performance, structure, behavior, policies and good decision about the entire economy of a country. The Malaysian economy is comprised of five major sectors, namely agriculture and forestry (AGRF), manufacturing (MANF), mining and quarrying (MINQ), service (SERV) and construction (CONS).

This study focuses on behavior, reaction and influence of Malaysian construction sector in the Malaysian economy. The reason for selecting the construction sector is its significant role in socioeconomic development of a society. The image of socioeconomic development of any country can be measured or judge by the construction industry of that country. The role of construction sector in the social, economic and infrastructure development is very strong and it provides great support to develop other sectors of the economy as well through backward and forward linkages.

Malaysian construction sector is a significant productive sector and playing a pivotal role in the Malaysian economy. Malaysia realized the importance of construction sector since the early years of its independence not only for economic growth, but also for increasing the standard of living and quality of life for their people. The construction boom in Malaysia began in the early 1990s, just after the introduction of Vision, 2020 (Kamal, 2012).

Today the Malaysian construction sector is a significant productive sector of the Malaysian economy. It is more advanced, modernized and well equipped. It has a potential to deliver complex heavy infrastructure and skyscraper projects by using highly sophisticated mechanized techniques. This has resulted in rapid execution of many projects like high rise commercial and industrial buildings, highways, expressways, bridges and tunnels, housing schemes, schools and hospitals and sports and spa centers, monorail and mass rapid transit rail system, and power plants. Now the Malaysian construction sector is considered as a great source of economic development and micro and macroeconomic activities of Malaysia.

The purpose of this study is to develop impulse response functions for Malaysian construction sector (MCS) by using a vector error correction model (VECM) to analyze how the construction sector behaves and responses when positive shock is produced in other sectors of the economy. The study also examines the reaction of other sectors when positive shock emerged from construction sector.

LITERATURE REVIEW

After the World War II, the construction sector has grown rapidly and become a highly dynamic sector all over the world. It has become an important sector of the economy in terms of its contribution to gross domestic products (GDP), domestic gross fixed capital formation (GFCF) and employment generation (Hillebrandt, 2000). The activities of the construction sector have great significance in the achievement of national socioeconomic development goals in providing infrastructure, income generation and employment creation. It deals with all economic activities directed to the creation, renovation, repair or extension of fixed assets in the form of buildings, land improvements of an engineering nature. Besides, the construction sector generates substantial employment and provides a growth impetus to other sectors through backward and forward linkages.

Therefore, the construction sector has become a target of economic policy aimed at achieving price stability, low unemployment, and balanced growth since variation in construction sector activity may influence macroeconomic variables seriously. On the other hand, fluctuations in construction sector activity are affected by the implementation of monetary and fiscal policy (Ozcelebi, 2011). Virtually there is a strong link and great interaction between construction activities and the aggregate economy.

The number of studies has been conducted over the role of construction sector in aggregate economy, the relationship between construction sector and GDP and link between construction activities and macroeconomic variables such as Turin (1969) highlighted the significance of construction sector in the national economy and concluded that there is a direct relationship between construction output and economic growth and construction output grow faster than GDP, when the economy grow. Park (1989) confirmed that the construction sector generates one of the highest multiplier effects through its extensive backward and forward linkages with other sectors of the economy (Park, 1989).

This integration combined with high value added to output ratio indicates that construction provides a substantive stimulus throughout the economy and vice versa (Geadah, 2003). Field and Ofori (1988) stated that the construction makes a noticeable contribution to the economic output of a country; it generates employment and incomes for the people and therefore the effects of changes in the construction industry in the economy occur at all levels and in virtually all aspects of life (Chen, 1998; Rameezdeena, 2008). In this regard housing sector of construction industry plays a significant role. It is observed that the size and volume of overall construction sector largely depend on the housing sector. The prices of houses and housing demand and supply are significant factors in the fluctuation of macroeconomic variables such as inflation and investment. Therefore, it is important that the factors, which determine the housing demand and housing supply, are measured with great care (Ozcelebi, 2011). A study conducted by Apergies (2003) in Greece for determining the macroeconomic factor that influences the housing prices from 1981 to 1999 by using vector error correction approach. This study concluded that the housing mortgage rate produced more variation in real housing prices than employment and inflation.

It is also observed that the change in investment level in housing sector affects the housing supply that ultimately changes the volume of construction sector. Therefore, in available literature, there are some studies that analyze and discuss the dynamics of both housing demand and housing supply factors such as a study conducted by Barrot and yang (2002) to evaluate the dynamic of housing demand and supply for Sweden and United Kingdom by using an error correction model (ECM). The study concludes that on the supply side, the building cost and nominal house prices determined the housing investment in both countries, whereas, the housing demand influencing factors were common and similar on the basis of the estimated coefficient in each country (Ozcelebi, 2011).

In short the construction sector has become an indispensable factor for sustainable socioeconomic development and been playing a significant leading role in the aggregate economy of a country. Many studies, like Charles (2004), Bo (2006), Bon and Pietroforte, (1990), and Bon, (1992) uses the strong direct and total linkage indicator to explain the leading role of the construction sector in the national economy.

METHODOLOGY

The paradigm of research of this study is quantitative. Both descriptive and inferential statistical techniques are used to analyze the available data. In this regard quarterly output of all major sectors of the Malaysian economy, such as CONS, MANF, MINQ, AGRF and SERV in value term (RM million) are used. The required time series data starting from 1991Q1 to 2010Q4 are obtained from the published report 2011 by the Department of Statistics Government of Malaysia. The popular augmented Dicky Fuller and Philip Perron tests are conducted for each variable series, in order to remove the stationary/unit root problem from the data series. The VECM equation is constructed to develop the impulse response functions (IRFs) for MCS. The VECM is very sensitive to lag order; therefore optimal lag length is determined through likelihood ratio (LR), and Hunan and Quinn (HQ) criteria. In order to examine the long run association between variables Johansen co-integration test is used. The Johansen rank trace test and maximum eigenvalue rank test are used to know the number of co-integrating equations in the data set. After satisfying the basic requirements, non-stationarity of data series at the level and the existence of co-integration with concerned variable, the VECM equation for MCS is developed. The VECM equation is not only used to determine the long run and short run coefficients but also used to develop the impulse response functions. Finally impulse response functions are developed through estimated VECM for the construction sector.

EMPIRICAL ANALYSIS AND DISCUSSION

Descriptive Statistical Analysis

The descriptive statistical analysis was conducted to examine the basic properties of each variable. The results of descriptive statistics are presented in the Table 1. The service sector is the highest average quarterly output contributor to GDP with high standard deviation. The second highest contributor is manufacturing sector, whereas the average quarterly output contribution of the construction sector is small as compared to the other sectors. It does not mean that the MCS is not significant because the significance and importance of the sector in the economy does not measure through the volume and size of the sector. It measures through the linkage strength of the sector and potential to generate economic activities in the aggregate economy. Three sectors CONS, MANF and MINQ data series are negatively skewed while the two sectors AGRF and SERV are positively skewed. The value of kurtosis for all variables is less than 3, which implied that the all variables have platykurtic distribution and all uniform distributions are platykurtic.

Table 1. Results of Descriptive Statistical analysis

Description	CONS	MANF	MINQ	AGRF	SERV
Mean	3517	26032	9375	8289	46346
Median	3657	26391	9629	8056	44605
Maximum	4814	40328	11302	10831	84858
Minimum	1871	10603	6599	6422	18743
Std. Deviation	687	9152	1210	1133	18077
Skewness	-0.608	-0.065	-0.844	0.467	0.378
Kurtosis	2.989	1.718	2.707	2.319	2.074

Correlation Test

The Pearson correlation test was conducted to examine the strength of association between construction sector and other major sectors of the economy. Results suggest that there are strong correlations exist between MCS and other sectors of the economy. Hence the estimated correlation coefficient is greater than 0.5 for all studied variables.

Table 2. Correlation Test Result

	CONS	MANF	MINQ	AGRF	SERV
CONS	1				
MANF	0.746	1			
MINQ	0.748	0.821	1		
AGRF	0.557	0.819	0.512	1	
SERV	0.737	0.960	0.738	0.850	1

Output by Season

Figure 1 depicts the average output level of each variable by season or quarter. The construction and manufacturing sectors have more or less same trend, from Q1 to Q3 average output levels gradually increase and then constant between Q3 and Q4. In case of MINQ there is a negative trend between Q1 and Q2 and then increase in each quarter. The AGRF is reverse of MINQ. AGRF quarterly output gradually increases in the first 3 quarter from Q1 to Q3 and then decline in Q4, whereas the service sector has throughout positive trend in each quarter from Q1 to Q4.

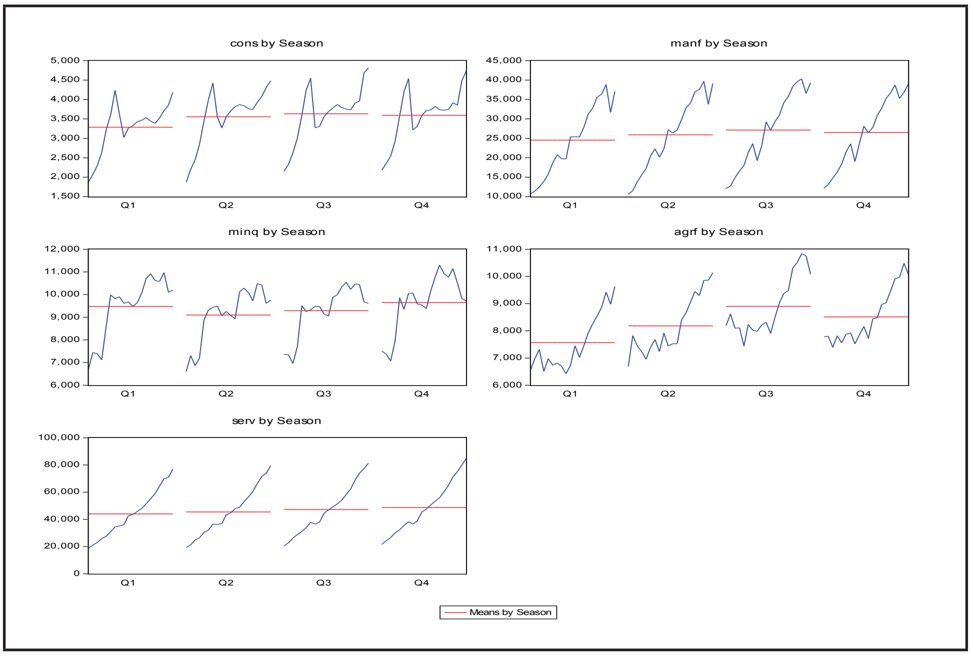

Figure 1. Mean output by Season (Quarter)

Unit Root Test

Most of the time series have a unit root/stationary problem, which leads to spurious regression results. The fundamental requirement of time series analysis in the variable series should be stationary. The unit root test is conducted to examine the stationary problem with the series. Equations 1 to 5 are developed for each variable on the basis of augmented Dicky Fuller model equation for unit root test.

Construction Sector
$$\Delta CONS_t = \propto_0 + \alpha_1 T + \beta_1 CONS_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta CONS_{t-1} + \mu_t \quad (1)$$

Manufacturing Sector
$$\Delta MANF_t = \propto_0 + \alpha_1 T + \beta_1 MANF_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta MANF_{t-1} + \mu_t \quad (2)$$

Agriculture Sector
$$\Delta AGRF_t = \propto_0 + \alpha_1 T + \beta_1 AGRF_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta AGRF_{t-1} + \mu_t \quad (3)$$

Mining and Quarrying Sector
$$\Delta MINQ_t = \propto_0 + \alpha_1 T + \beta_1 MINQ_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta MINQ_{t-1} + \mu_t \quad (4)$$

Services Sector
$$\Delta SERV = \propto_0 + \alpha_1 T + \beta_1 SERV_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta SERV_{t-1} + \mu_t \quad (5)$$

Where, $\propto_0$ is constant, α_1 drift term and T is time trend and μ_t is the error term for the series.

These equations (1 to 5) are used to test the following null and alternate hypothesis for each variable series.

Null hypothesis: H_0: Series has a unit root problem, statically $\beta_1=0$
Alternate hypothesis: H_1: No unit root problem in the series, statistically $\beta_1 \neq 0$

The criteria for rejecting the null hypothesis ($\beta_1=0$) is, the estimated value of β_1 should be greater than the MacKinnon critical value at conventional significant level 5%. The results of ADF and PP tests for unit root are presented in Table 3. The results suggested that all variables have a unit root/ stationary problem at the level. This implies that all variables are non-stationary at level. However, just at first difference all variables converted into stationary variables. The estimated value of β_1 is greater than the critical value suggested by Mackinon at the first difference of the series. Hence, we statistically reject the null hypothesis and accept alternate (Series has not unit root problem) at the first difference of each variable series. Another important outcome of this test is, all data series have order of integration one I(1). This implies, there is a possibility of co-integration in the data set and the variables may have a long run relationship.

Table 3. Unit Root Test Results

Variables	Lag order	DF test at level with intercept	ADF test (first difference) with intercept	PP test (first difference) with intercept	Order of integration
CONS	4	-2.5901	-3.0777**	9.8436**	I(1)
MANF	4	-0.9901	-5.3748**	12.6824**	I(1)
AGRF	4	-2.2333	-3.5938**	9.6871**	I(1)
MINQ	4	-0.1020	-4.9525**	13.8359**	I(1)
SERV	4	-1.0530	20.9246**	73.2907**	I(1)

Mackinnon critical value for the rejection null hypothesis of 5%, the level of significance with, intercept is -2.932. (** denote rejection of the null hypothesis at the 5 % significance level)

Optimal Lag Length

The VECM is very sensitive to the lag order. The very small number of lags means the residual behavior is not like white noise, and model parameters and their standard error will not be defined well and accurately estimated. Alternatively, too many lags reduce the explanatory power of the model due to loss of degree of freedom.
This study uses the LR and HQ information criteria to select the optimal lag length for developing the model, results are presented in Table 4. The optimal lag length suggested by the both LR and HQ criteria is 6.

Table 4. Optimal Lag Order

Lag order	LR	HQ
0	NA	103.33
1	711.40	93.99
2	119.09	93.44
3	91.79	93.18
4	73.63	93.08
5	68.62	93.03
6	**62.26***	**93.41***
7	50.94	93.15

Cointegration Test

The order of integration in unit root test has already identified the possibility of co-integration between the studied variables. The existence of co-integration between the variables indicates that the variables have long-run association and long run causality exists between the variables (Johansen, 1988). The Johansen Rank Trace and Rank Maximum Eigen Value are conducted to examine the co-integration among the concerned variables. Equation 6 and Equation 7 is used for trace and maximum eigenvalue tests respectively.

$$\lambda_{trace}(r) = -\mathrm{N}\sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i) \quad (6)$$
$$\lambda_{max}(r, r+1) = -N\sum_{i=r+1}^{n} ln(1-\hat{\lambda}_{r+1}) \quad (7)$$

Where $\hat{\lambda}_i$ is the eigenvalue (estimated characteristic roots) obtained from the estimated long run relationship matrix. *N* is the number of observations that can be used.

The empirical test results are presented in Table 5 and Table 6. Both the trace statistic and maximum eigenvalue confirms the existence of co-integration among the major sectors of the Malaysian economy. Johansen co-integration, rank trace and maximum eigenvalue tests suggested that there is at most one co-integrating equation in the data set at the 5% significance level.

Table 5. Unrestricted Cointegration Rank Test (Trace)

Hypothesized number of co-integrating equations	Eigenvalue	Trace Statistics	5% critical value	Probability
None**	0.4912	90.7785	69.8188	0.0005
At most one	0.2369	41.4389	47.8561	0.1751

** denotes a rejection of the null hypothesis at the 5 % significance level

Table 6. Unrestricted Cointegration Rank Test (Maximum eigenvalue)

Hypothesized number of co-integrating equations	Eigenvalue	Trace Statistics	5% critical value	Probability
None**	0.4912	49.3396	33.8768	0.0004
At most one	0.2369	19.7435	27.5843	0.3591

** denotes a rejection of the null hypothesis at the 5 % significance level

The matrix of normalized co-integrating equations on the basis of co-integration tests are presented in Table 7.

Table 7. Normalized Cointegrating Equation

Cointegrating equations	CONS	MANF	MINQ	AGRF	SERV
Coint-1	1.0000	0.1232	-0.7949	0.0279	0.0554

Vector Error Correction Model (VECM) for MCS

The error correction model (ECM) is transformed into VECM, when more than one or a set of causality equations is involved in a system. The fundamental process of VECM is incorporating the co-integration information on the ECM. Thus the model is able to provide long run equilibrium association and short run adjustment to changes in independent variables through the estimated parameters. The mathematical formulation of general VECM can be described in Equation 8.

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{m-1} \Phi_i \Delta Y_{t-i} + \Gamma D_i + \mu_t \quad (8)$$

Where Y_t is a column vector of k observable endogenous variables, which are construction, manufacturing, mining and quarrying, agriculture and forestry, service sector output and gross domestic product (GDP), Π is the matrix of co-integrating vectors (long run parameter matrix). The matrix may be factored as α and β, where α represents the speed of adjustment toward long run equilibrium for specific variables, when they move out of long run equilibrium. Φ represents a matrix of coefficients of the endogenous variables. The first term in equation captures the long run impact over dependent variables and second term captures short run adjustments. The "m" is the optimal number of leg length included in the model. D_i is a matrix of a deterministic trend such as intercept, time trend in the series and Γ is a coefficient of the matrix of deterministic trend and μ_t is the vector error. The developed estimated model equation for MCS is presented in Equation 9.

$$D(CONS) = C(1)*(CONS(-1) + 0.12325944406*MANF(-1) - 0.794940209399*MINQ(-1) + 0.0279426995716*AGRF(-1) - 0.0554159338556*SERV(-1) + 3063.60113221) + C(2)*D(CONS(-1)) + C(3)*D(MANF(-1)) + C(4)*D(MINQ(-1)) + C(5)*D(AGRF(-1)) + C(6)*D(SERV(-1)) + C(7)*D(CONS(-2)) + C(8)*D(MANF(-2)) + C(9)*D(MINQ(-2)) + C(10)*D(AGRF(-2)) + C(11)*D(SERV(-2)) + C(12)*D(CONS(-3)) + C(13)*D(MANF(-3)) + C(14)*D(MINQ(-3)) + C(15)*D(AGRF(-3)) + C(16)*D(SERV(-3)) + C(17)*D(CONS(-4)) + C(18)*D(MANF(-4)) + C(19)*D(MINQ(-4)) + C(20)*D(AGRF(-4)) + C(21)*D(SERV(-4)) + C(22)*D(CONS(-5)) + C(23)*D(MANF(-5)) + C(24)*D(MINQ(-5)) + C(25)*D(AGRF(-5)) + C(26)*D(SERV(-5)) + C(27)*D(CONS(-6)) + C(28)*D(MANF(-6)) + C(29)*D(MINQ(-6)) + C(30)*D(AGRF(-6)) + C(31)*D(SERV(-6)) + C(32) \quad (9)$$

The model equation (9) has overall 32 coefficients. First coefficient C (1) is co-integrating equation coefficients speed of adjustment toward long run equilibrium of MCS. The coefficients C (2) to C (31) are short run causality coefficients. These coefficients capture the rate of change in the construction sector in the short run due to variation in the independent variable. C (32) is a constant term. The most important thing is the sign and the probability value of C (1), it must be negative and significant for correctness of the model and the existence of long run causality between the dependent and independent variables. The sign, value, t-statistics and the probability of these coefficients are displayed in Table 8.

Table 8. Estimated coefficient for VECM MCS

Coefficients	Coef. Value	Std. Error	t -statistic	Probability
C(1)	-0.297893	0.095416	-3.122046	0.0033
C(2)	0.441334	0.149338	2.955277	0.0052
C(3)	0.013665	0.028346	0.482089	0.6323
C(4)	-0.249449	0.075378	-3.309319	0.0020
C(5)	-0.013450	0.072373	-0.185845	0.8535
C(6)	-0.033623	0.025221	-1.333113	0.1899
C(7)	0.741741	0.171962	4.313392	0.0001
C(8)	-0.065765	0.030465	-2.158712	0.0368
C(9)	-0.012873	0.071544	-0.179934	0.8581
C(10)	0.096498	0.070501	1.368734	0.1785
C(11)	0.010496	0.029752	0.352763	0.7261
C(12)	0.115368	0.186167	0.619702	0.5389
C(13)	0.033956	0.028106	1.208165	0.2339
C(14)	-0.042438	0.074066	-0.572974	0.5698
C(15)	-0.149611	0.072930	-2.051442	0.0466
C(16)	-0.038529	0.026418	-1.458450	0.1523
C(17)	0.261893	0.173394	1.510393	0.1386
C(18)	0.070845	0.028878	2.453242	0.0185
C(19)	-0.128389	0.083585	-1.536029	0.1322
C(20)	-0.065146	0.078818	-0.826541	0.4133
C(21)	-0.051599	0.024100	-2.141010	0.0383
C(22)	0.203406	0.166222	1.223699	0.2281
C(23)	0.015789	0.024920	0.633605	0.5299
C(24)	-0.139849	0.085118	-1.643004	0.1080
C(25)	-0.172066	0.064521	-2.666835	0.0109

C(26)	-0.048681	0.025094	-1.939959	0.0593
C(27)	0.333307	0.179297	1.858963	0.0702
C(28)	-0.000809	0.025862	-0.031274	0.9752
C(29)	-0.119011	0.075153	-1.583584	0.1210
C(30)	-0.104409	0.063229	-1.651283	0.1063
C(31)	-0.074934	0.023030	-3.253796	0.0023
C(32)	167.9463	55.82580	3.008399	0.0045

The negative value (-0.2978) of C (1) and its corresponding probability (0.0033) ensure that VECM Equation 9 for MCS is desirable and has not any fundamental problem. There is a long run relationship between the construction sector and other key sectors of the Malaysian economy. The coefficient value informs that the speed of adjustment toward long run equilibrium is 30 % (correction) of the disequilibrium of the previous period.

Regression Results of VECM Equation 9

The estimated values of important parameters of VECM Equation 9 for MCS are presented in Table 9 below. The coefficient of determination (R^2) is 81.48 %, which suggests that the estimated model has strong explanatory power for MCS. The D.W value (1.9486) is much closed to 2 that indicate the model has not auto correlation problem and the probability of the F-statistic is significant. This implies that all included independent variables have combined effect over MCS. The estimated VECM for construction satisfied the all necessary and sufficient conditions so the estimated model Equation 9 for MCS is an efficient model equation that can be used for developing impulse response functions of MCS.

Table 9. Regression Results

Parameters	Value
Coefficient of determination (R^2)	0.8148
Adjusted R^2	0.6747
F -statistics	5.8190
Probability of F-statistic	0.0000
Durbin Watson statistic	1.9486

Impulse Response Functions

The vector auto regression (VAR) methodology offers a useful analytical tool to analyze the responses of a system's variable to the impulses of the system's shocks (Ronayne, 2011). The impulse response function defines the reaction of the whole system as a function of time under VAR system (Helmut, 2008). It is used to track the responses of a system‘s variable to the impulses of the system‘s shocks.

Figure 2 (A to I) depicts the response of construction sector for next 20 quarter against the positive shock produced in other sectors of the Malaysian economy and vice versa.

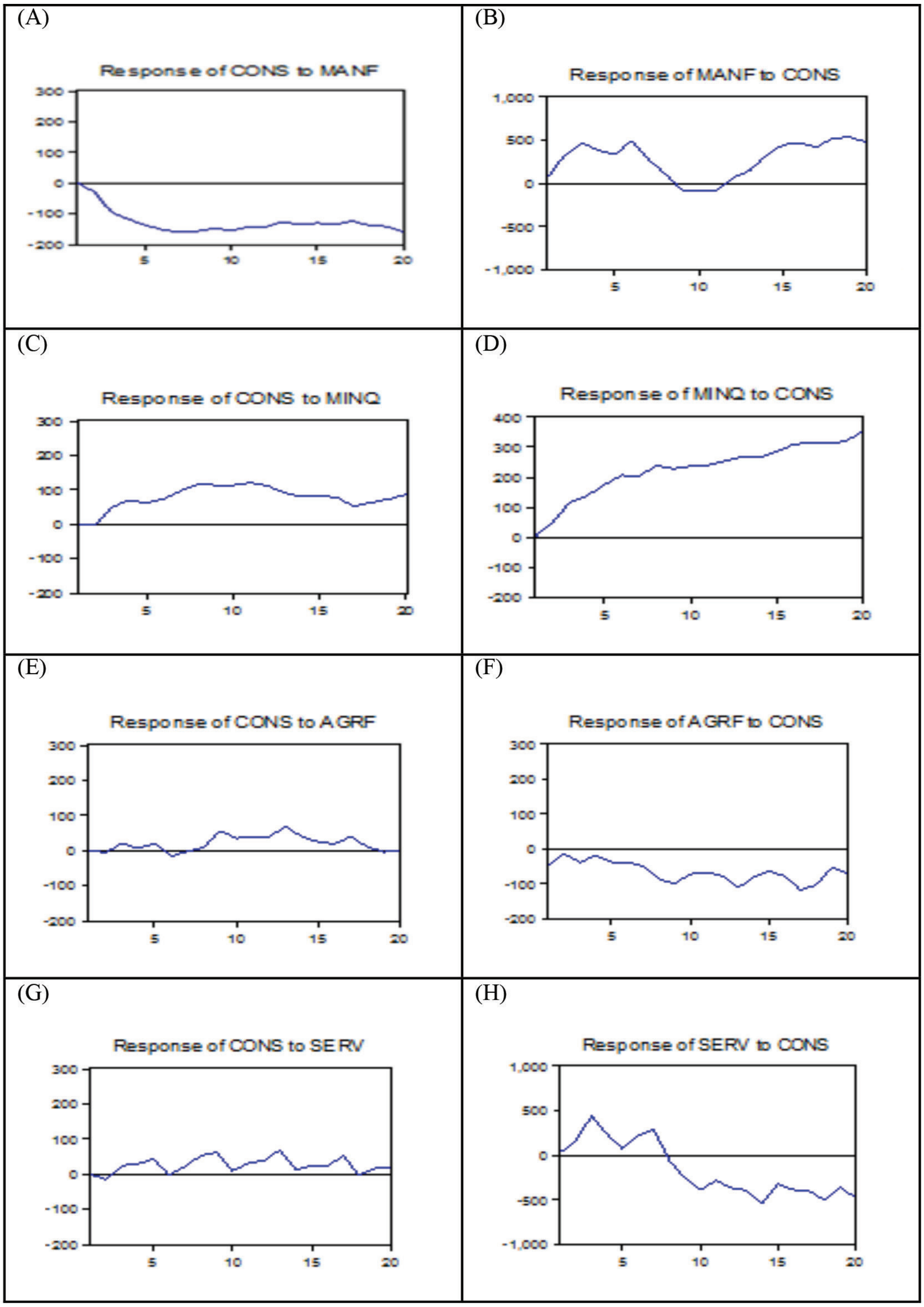

Figure 2. Comparative Analysis of Responses between Construction and Other Sectors

The response of construction sector against the one standard positive shock produced in the manufacturing sector is throughout negative in next 5 years (20 quarter), whereas the manufacturing sector has a positive reaction against the positive shock from the construction sector in first 10 quarter and then slightly negative for a small period and then bounce back in positive region. This is due to strong backward linkage of construction sector with the manufacturing sector.

Figure 2C and 2D show the response of construction against mining and quarrying shock and reaction of mining and quarrying if shock produced in construction sector respectively. Both sectors have throughout positive reactions against the shock. It can be seen that the mining and quarrying sector is more sensitive than construction sector. Its response is relatively more powerful than construction sector. There is a bidirectional relationship between the two sectors, construction and mining and quarrying.

The response of construction sector against the shock of agriculture and forestry is neither too strong nor sensitive. It gives positive response with low peak and in next 3-4 quarter enters into the negative area for a short period and then it come into positive region for next 8 to 10 quarters. Whereas, the agriculture and forestry sector response is throughout negative versus positive shock from construction sector. This implies that there is a one way relationship exists between construction and agriculture and forestry sector.

Figures 2 (G) and 2 (H) depict the responses of construction against service sector shock and response of service sector if shock is produced in the construction sector. It can be seen in Figure 2 (G) that the construction sector response throughout next 20 quarter is like a frog walk in positive region without so much variation except beginning of first 2 quarter where it has movement in the negative region. Figure 2 (H) shows the reaction of the service sector is positive in first 8 quarter and then negative. Which indicates that the expansion in the construction sector boost the service sector.

The conclusion of Figure 2 is that the construction sector has a relationship and link with all major sectors of the Malaysian economy and investment change in construction sector affect the other sectors and vice versa.

CONCLUSION

This study mainly focuses on the development of a VECM for the construction sector to empirically examine the long run and short run association of MCS with other major sectors of the Malaysian economy. It also analyses the response of MCS against the positive shock produced in other sectors and vice versa.

The descriptive analysis suggests that over the past two decades (1991-2010) the average contribution of MCS to GDP was 4 %. The average contribution of MCS to GDP is relatively small as compared to other key sectors of the Malaysian economy. However, it has a strong correlation with major sectors of the economy since the Pearson correlation coefficient is greater than 0.5 (50 %) for all major sectors. The seasonal output analysis shows that the construction sector activities are at peak in the third quarter of each year.

The VECM equation for MCS was successfully developed. The strength, efficiency and correctness of the model was examined by the various standardized tests and found satisfactory. The model equation suggests that the MCS has long and short run association with other sectors of the economy and speed of long run adjustment toward equilibrium is 30 %. The estimated long and short run coefficients are presented in Table 8.

The series of IRFs successfully developed by the estimated model and analyzed the response of MCS against the one standard deviation, positive shock in other sectors and the reaction of other sectors against the positive shock in MCS. It was observed that the response of construction sector against the positive shock in the manufacturing sector is throughout negative; similarly the agriculture and forestry sector has throughout negative response if shock produced in the construction sector. It is also noted that the mining and quarrying sector is highly sensitive against the shock produced in the construction sector and the impact of shock was long lasting in this sector as compared to other sectors. The construction sector is relatively more sensitive against the shock of mining and quarrying as compared to the other sectors shock.

The results of the study are informative and useful for government of Malaysia, policy makers and planner. They can use this information in developing investment and expenditure plan for the construction sector and other sector as well.

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AN EXPLORATORY STUDY ON ENABLERS AND BARRIERS FOR ONSITE MECHANISATION IN THE MALAYSIAN CONSTRUCTION INDUSTRY

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Abstract
Onsite mechanisation in construction is characterized by the intensive deployment and usage of equipment. It requires different types of heavy equipment, vehicles and machineries for carrying out complex construction activities. The utilisation of heavy equipment increases construction productivity as well as reduces the dependency on intensive labour. Apart from this, the increasing trend of the Industrialised Building System (IBS) also needs greater mechanisation for erection and installation of large IBS components. This paper aims to investigate the current awareness of onsite mechanisation, the advantages in its adoption, and the barriers for the Malaysian construction industry. A questionnaire survey was conducted among a group of Construction Industry Development Board (CIDB) of Malaysia registered contractors. The important findings from the survey have indicated that there is a good understanding and application of mechanised practices among IBS contractors. It is further revealed that the need for onsite mechanisation has mainly come about to meet the timelines with a high speed of work and productivity. However, for medium and small size contractors, the implementation of onsite mechanisation is largely inhibited due to budget constraints as it is considered an extra financial burden. The findings of this study will provide relevant authorities with informed understanding to develop potential policies and regulations to encourage mechanised practices for the Malaysian construction industry.

Keywords: *Onsite mechanisation; Construction equipment; Onsite technology; Acquisition of onsite machineries; Mechanised construction*

INTRODUCTION

The term 'mechanisation' in construction is defined as the application of the plant, equipment and machineries for carrying out construction activities (Kamar et al. 2010). The growing need of infrastructure and industrialisation changed the manual methods with those that are mechanised and equipment-based in order to meet the shorter timelines and complexities of designs started after the World War II. As a result of this incremental development in construction technology, today's construction projects are highly mechanised and are becoming even more so every day (Idro, 2011). The roles of construction machineries are being increased to improve the performance, productivity, working standards and efficiency of contractors (Day and Benjamin, 1991). These require innovative and modern machineries to cater to the needs of the clients and contractors and achieve project objectives (Indoria, 2009). Furthermore, the growing industrialisation in construction leads to offsite prefabrication of concrete, structural and finished elements that are then installed or assembled rather than produced onsite. Consequently, production equipment is being replaced on the construction site by earth moving, transportation and other material handling equipment (Shapira et al. 2007). The typical construction site will employ several or all of the following equipment types: such as earthmoving and transporting equipment, material handlers, concrete pumps, hoists, lift cranes etc.(Arditi et al. 1997). Researchers have suggested that the adoption of mechanised practices speeds up the execution of site works, thus shortening the project completion time and cost. Many manual methods are getting obsolete and redundant in industrialised countries due to expensive and shortage of skilled labour (Seeley, 1996; Prasertrungruang and Hadikusumo, 2007; Indoria, 2009).

In the last 50 years, architects and civil engineers have delivered gigantic infrastructure around the globe. It can be stated without any doubt that such enormous achievements in modern civilisation cannot be possible without the aid of mechanised construction practices. However, there are inadequate references and research with regards to mechanisation practices in Malaysian construction industry that can aid the relevant authorities to develop any potential policies and regulations that encourage onsite mechanised practices. In order to provide some useful information to these purposes, this paper investigates the current awareness of Malaysian contractors towards onsite mechanisation and its enablers and barriers.

NEED OF MODERN MECHANISED CONSTRUCTION AT THE POLICY LEVEL

The Malaysian economy is based on agriculture, forestry, fishing, mining, manufacturing, construction and services sectors. In the last decade, the Malaysian construction industry has played an important role towards the growth of the national economy and it is accounted for almost 4.6% of the country's GDP in 2011 (EPU, 2012). The industry is also great source of providing job opportunities to the local and foreign people. About 6.3% of the country's workforce was involved in construction related jobs (EPU, 2012). This sector accounted for 18.5% of the total sectorial distribution of privatized projects (1983 – 2011) and remained highly attractive for private investment. The industry is comprised of thousands of contractors who are classified by the CIDB into G1, G2, G3, G4, G5, G6 and G7 categories. G1 is the smallest group among these categories and are low volume contractors (worth- wise) whereas G7 are the high volume contractors with no limit of works (EPU, 2011). According to the CIDB (2006), the total numbers of registered contractors as of the 1st quarter of 2006 were 63, 875. This sector is fragmented in nature and involves a number of stakeholders such as consultants, developers, clients (government and private), contractors, manufacturers, material and equipment suppliers etc. The government, its associated Ministry of Works and other departments like the Public Works Department (PWD), CIDB, Contractor Service Centre, the Board of Engineers, Board of Architects and Board of Surveyors are important players and exert influence. All these organisations are actively involved in the expansion and advancement of the Malaysian construction industry.

During the early years of post-independence, the Malaysian construction industry was a low-tech, labour intensive and craft-based industry. However, the implementation of National Economic Policy in 1970 acted as a catalyst to speed-up the public sector development mainly in public infrastructure. During this era, a rapid growth had been observed and the industry increased from 3.38 percent in 1970 to 10.71 in 1971 and 10.84 in 1973 resulting in the increase of residential, commercial and industrial buildings. The enhancement of the Foreign Direct Investment (FDI) in the 1970s further expand the annual growth from 2.13 percent in 1978 to 17.18 percent in 1979 (Abdulllah et al. 2004). Due to the international recession in the mid-1980s, there was a noteworthy deceleration in overall construction activities which led to negative annual growth rates. After the recessionary years of the mid-eighties, the industrialization program of the country had changed the construction demands. Now, the clients were demanding more complex architectural and civil engineering works with shorter completion timelines. As a result, there was a continuing shift from traditional construction techniques towards modern construction activities.

The embarking of Vision 2020 in 1994 propelled the construction boom in the country at an annual average rate of 14 percent till 1996. During this period, highly mechanised production techniques were seen in projects such as the PETRONAS Twin Towers, Kuala Lumpur International Airport (KLIA) and Sepang Formula 1 racing circuit (Kamal and Flanagan, 2012). The East Asian economic crisis drastically affected the growth of the construction industry to the lowest level of -24% in 1998 and slowed down the country's economic growth. Although, the country's economy resumed due to the government supporting initiatives during the 7th and 8th Malaysian Plan (CIDB, 2006), the industry remained under continuous pressure to deliver and to tackle issues on performance, productivity and affordable public infrastructure. The availability of cheap and skilled workforce has also remained a critical issue for the industry. Currently, the local construction industry is highly dependent on foreign labours which generally create immigration and legal issues for the authorities. Besides, modern methods of construction such as IBS has also emphasized on greater utilisation of onsite mechanisation and automation techniques for carrying out the massive jobs. Therefore, in order to overcome these issues and foster the modernisation of the construction industry, the Malaysian government has emphasized the adoption of mechanisation, automation and robotics in construction practices (EPU, 2012).

ACQUISITION OF ONSITE MECHANISED EQUIPMENT

It is a customary practice that all contractors formulate stringent polices for acquiring construction equipment as it is directly concerned with productivity and profitability. Additionally, it has been observed that the construction equipment acquisition policy comprises financing modes, operational and maintenance strategies, equipment standardization and the process needs that are of mandatory compliance for the contracting firm (Tavakoli et al. 1989). In many scenarios, there is no unique method for the financing of heavy equipment. Due to this, the acquisition practices include many financing options and alternatives.

Usually there are three basic methods which are adopted to finance the procurement of construction equipment. These methods are buying or 100% ownership, lease agreement and rental (Gransberg et al. 2006). Each of these methods has their own advantages and limitations. Many large contractors are willing to own equipment because they can deduct the related depreciation, insurance, repairs, taxes and interest, which lowers their tax bills. However, large down payments can strain their resources. In addition, buying equipment also requires operation, maintenance, storage and transportation costs. And last but not least, the owner must deal with disposing of the equipment after achieving its useful life service period (Cudworth, 1989).

In contrast to the above, smaller construction companies often can't afford to own every piece of equipment they need, but they can't afford to be without them either. The big advantage to renting equipment is that a user pays only when using it. The user can always return the equipment to the rental company if business slows down or if a project falls through.

Equipment rental offers many of the same benefits as leasing, with three distinct differences. First, rental contract periods provide total flexibility. Equipment can be rented for any length of time — for example, from one day to as long as one year. Second, rental equipment usually includes maintenance provisions. And, third, if users are not satisfied how a rental operates after actually using it, they can return the item. In this way, the users are not locked into a long-term commitment with the supplier. Renting also gives convenient access to the newest and best equipment. Rental companies typically upgrade their inventories regularly. They also provide specialized mechanics to keep their pieces in top condition. A larger rental company may even be able to dispatch a mechanic to a project site quickly or, if necessary, deliver a replacement piece of equipment.

Many contractors lease their equipment to conserve capital (Gransberg et al. 2006). Equipment leasing is essentially a loan. The lender buys and owns the equipment and then leases it at a flat monthly rate for a set number of months. At the end of the lease, users have the option to purchase the equipment, return it or lease new equipment. It is a usual practice that many leasing firms offer flexible payments modes that can help small scale contracting firms to better manage their payments during the hectic months and allow no payments during slow periods. Most leases are structured so that payments are made with operating rather than capital funds, which can eliminate or reduce capital budget delays. As an additional benefit, a contractor can generally deduct monthly payments as an operating expense (MacManamy, 1991).

ADVANTAGES OF ONSITE MECHANISATION

The lesson learned from the 9th Malaysian Plan indicates that the construction sector did not grow at 6% per year during the 5 year plan period. There are many underlying causes for this slow growth rate; the most notable is due to slower construction activities in the civil and non-residential sub-sectors (EPU, 2010). During the 10th Malaysian Plan (2011 – 2015), the government has allocated RM 138 billion for the development of physical infrastructure. During this period, 52 mega projects are being take-up from various sectors, such as highways, power stations, double track train project, LRT expansion, Iskandar development, Greater Kuala Lumpur etc. (EPU, 2011). The timely and successful completion of these projects requires enhanced productivity, quality, efficiency and high class workmanship. Besides this, the implementation of the IBS agenda under the 10th Malaysian Plan also needs speed, quality and safety to meet the local and global standards (Kamaruddin et al. 2013).

In order to achieve these goals and optimize cost, the local construction industry needs to adopt mechanisation, automation and robotics methods. The use of heavy construction equipment is directly correlated to the megaprojects for meeting-up the heightened demands of mechanisation and industrialisation. The 7th Malaysia construction sector review and outlook seminar highlights the successful execution of construction projects and improvement of the construction industry through the enhancement of process and technologies. Keeping this in view, the government has initiated new policies on embracing new technologies and mechanisation in the construction sector. The government is envisaged to take all of the necessary measures and provide support through its encouraging policies and regulations for the adoption of mechanisation in the industry (EPU, 2012). The implementation of the free flow of workers within the ASEAN countries by 2015 will bring a pressure in the construction job market of the country. Moreover, the government is determined for the realisation of free market strategies through liberalising regional economic accords. With these polices and reforms, it is not possible for the construction industry to flourish by relying on cheap labours. The dependency of foreign skilled labour also acts as an inhibitor for the growth of the construction sector during the 10th Malaysian Plan period. According to CIDB (2006), *"Labour intensive industries such as the construction industry must shed their traditional dependency on labour and focus on alternative production inputs that can boost productivity"*. A report published by Experian (2008) in the context of the UK 2020 vision for the construction industry has also supported this statement. According to this report, specialised and intelligent onsite mechanised equipment and vehicles will reduce the dependency of onsite personnel. Thus, it will positively affect safety and decrease construction cost. Another important aspect of onsite mechanisation is to reduce the scaffolding and workers at a high altitude. In this scenario, mechanisation and other technological methods must be encouraged in order to achieve the maximum yield of the construction workers.

BARRIERS FOR THE ADOPTION OF ONSITE MECHANISATION

Researchers have classified the heavy equipment practices into four categories; procurement, operation, maintenance and disposal stages (Prasertrungruang and Hadikusumo, 2007). Somehow, the barriers of onsite mechanised practices are well associated with all these phases. Firstly, the procurement of heavy construction equipment is very much capital intensive for construction firms. It is also considered as a major financial burden during the construction phase besides other expenditures. The past research has shown that the acquisition of heavy equipment constitutes 36 percent of the total project cost and possesses high risk and uncertainties for the owners (Yeo and Ning, 2006). Another research by Vorester (2005) indicated that construction equipment is worth 30 percent of the total company assets. According to Bahaman (2011), the current import duties and sales taxes on heavy construction machinery and spare parts are also hindering local contractors in adopting more options for mechanisation. Beside this, contractors have to face long time lags to acquire the desired heavy machinery and import the heavy machinery from other countries and bear the import duty which increases the cost of construction. This situation is becoming more apparent since the rollout for the 9th Malaysian Plan. In this scenario, local dealers that import heavy machinery from other countries are also facing deterioration in their sales because they have to increase their prices due to the import duties. This will create a difficult situation for both the suppliers and the contractors. A similar research work by Mahbub (2012) has concluded that cost and the financial commitments in acquiring and maintaining the technologies are the main barriers towards the implementation of automation and robotics in developing countries.

During the operation phase, it has been observed that the problems associated with machine breakdowns and accidents due to the improper handling of equipment adversely affected the flow of work (Stewart, 2000; Edward and Holt, 2002; Edward and Nicholas, 2002). In most of the cases, it was mainly due to the improper handling of the equipment by the unskilled labourers (Gann and Senkar, 1998). Therefore, greater onsite mechanisation implies the need for new skills and abilities from the site supervisors and labour to understand the modern techniques and terminologies. This will require a proper training scheme for the site personnel to do their jobs in a safe and efficient way (Experian, 2008).

The equipment maintenance phase needs a lot of attention as it is directly related to its utilization. It not only enhances the working life of the equipment but also ensures the machine's availability (Tavakoli et al. 1990; Shenoy and Bhadury, 1998). For achieving proper maintenance, the contractor has to spend a sufficient amount of the project budget in terms of either corrective maintenance, preventive maintenance or predictive maintenance (Gopalakrishnan and Banerji, 1991; Sutton, 2001). The research work of Kamaruddin et al. (2013) has highlighted the prominent features of mechanisation and automation in IBS projects in Malaysia. Their research work has ranked a number of influencing factors such as capital, maintenance and operational costs, the inadequacy of the market size, site arrangements, upgrading cost of machines or equipment, availability of machines in the local market, location of site, training cost of operators and transportation cost of equipment to the site. All of these factors can be taken as the implications of mechanisation and automation in the construction industry.

METHODOLOGY

This research was conducted by using both the qualitative and quantitative research methods. The qualitative research approach was required to develop a basis to establish the background knowledge about the mechanisation and its enablers and barriers for the Malaysian construction industry. The primary data required for this study was collected through the questionnaire survey. This methodology has been considered as cost effective and time saving in order to achieve better results in a shorter duration. The traditional techniques for collecting responses from the targeted respondents are postal, fax and emails. However, for this research work a web-based survey tool was used effectively for getting feedback from the respondents. This has helped the research team a lot in achieving momentum and a good data base of the survey participants. For the purpose of achieving the desired research objectives, a structured or close-ended questionnaire was designed to gain the views from the industry practitioners. A total number of 400 (Grade G7) civil contractors (Kuala Lumpur and Selangor based) were randomly selected from the CIDB database. Grade G7 are large contractors and usually engaged in heavy and complex construction activities. Hence, they are more familiar with the phenomenon of mechanisation. Before sending the questionnaire, it was dully confirmed and assured that all the targeted respondents were doing construction business and engage in civil and infrastructure works. This is due the fact that despite there being a high percentage of contractors in Malaysia only 12% were actually running construction businesses (Bahaman, 2011).

RESULTS AND ANALYSIS

A total of 123 completed questionnaires were received giving an overall response rate of 30.75%. This response rate was well acceptable in view of past research (Akintoye, 2000; Dulami, 2003). The findings of the survey are as follows;

Respondents Background and Experience

Figure 1 shows the pie-chart distributions of the respondents. The data analysis indicated that the feedback from project managers were relatively higher (35%) as compared to the other categories of respondents.

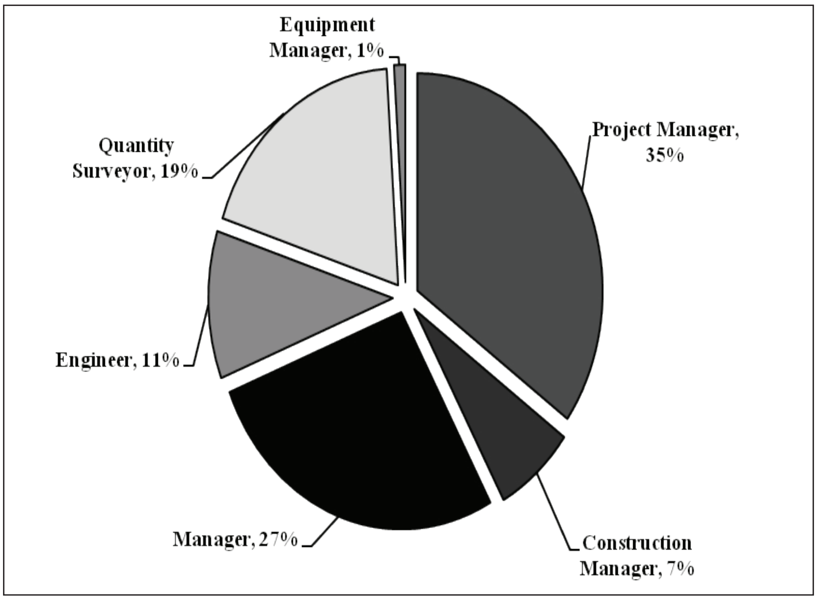

Figure 1. Distribution of respondents' primary job function

Figure 2 shows the involvement of construction firms in different infrastructure projects. It has been observed that the majority of the respondents i.e., 60.5% were participating in roads and highway projects (It is to be noted that respondents were provided more than one option to select in this question of the survey).

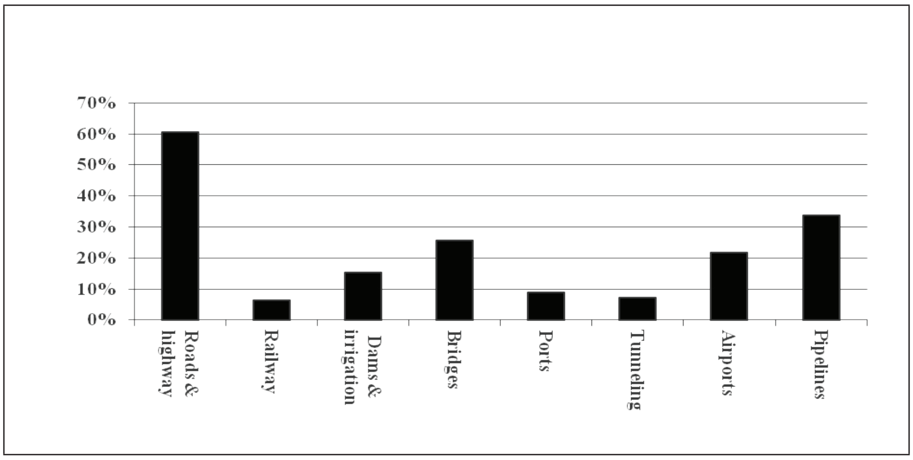

Figure 2. Respondents' participation in infrastructure projects

The respondents' experience in construction projects is also shown in Table 1. It was found that 30.8% of the respondents had working experience within the range of 11 to 20 years. Whereas, 24.3% had more than 20 years of field experience. These statistics represent that the questionnaires were mostly filled by the senior professionals having vast experience in construction projects.

Table 1. Distribution of respondents' construction experience

S.No.	Construction Experience	Frequency	Percentage
1	Less than 5 years	30	24.3%
2	6 to 10 years	25	20.3%
3	11 to 20 years	38	30.8%
4	More than 20 years	30	24.3%
	Total	123	100%

Understanding of the Mechanisation in Construction Projects

The response of the questionnaire survey indicated a good understanding of Malaysian contractors towards mechanised construction practices. The current level of understanding and awareness with the mechanisation is shown in Figure 3 as pie-chart distribution. It shows that 23% of the respondents had high level of acquaintance with the mechanisation where-as 45% had moderate understanding with this phenomenon. Apart from that, 20% of the respondents were 'somewhat aware' with the mechanisation.

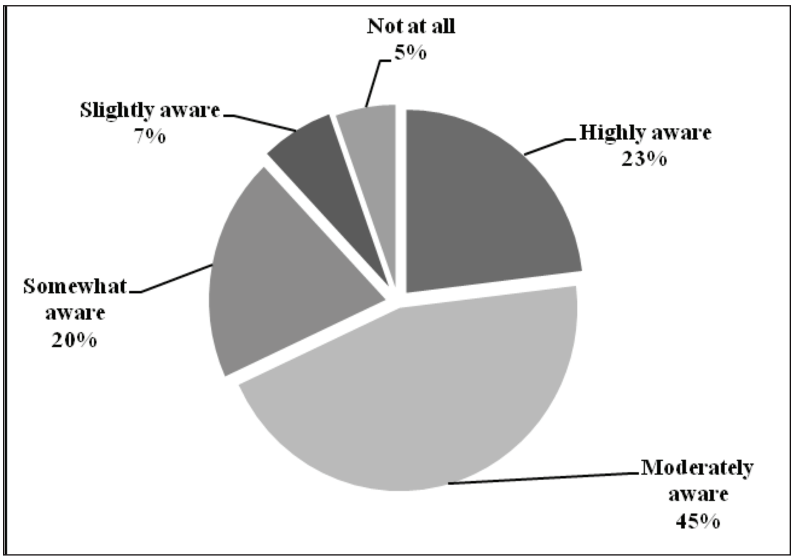

Figure 3. Understanding of mechanisation in the Malaysian construction industry

The results of the survey also depicted that those firms who were using the IBS in Malaysia were more inclined towards mechanisation as compared to those who were still using conventional construction techniques. A total of 46% respondents were using IBS components and had also adopted mechanised practices. From the survey, 63% of the respondents (including IBS adopted firms) were using heavy mechanised equipment at the site. Hence, there is a correlation between the usage of IBS and mechanisation. The more the usage of IBS, the higher will be the rate of the mechanisation.

Mechanisation of Onsite Activities

The above survey result shows that 63% of the contractors in Malaysia have been adopting mechanisation for onsite activities. However, a more useful approach for finding its usage is by looking at areas within which the machines and equipment are mostly used. The measurement of usage is analysed via the Likert scale of 1 to 5 (with 1 = never, 2 = seldom, 3 = sometimes, 4 = regularly and 5 = highly). The reliability of the 5-point Likert scale was determined by using Cronbach's alpha coefficients. Ideally, the Cronbach alpha coefficient of a reliable scale should be greater than 0.70. A reliability test for the eight onsite construction activities as shown in Table 2 was conducted by using the SPSS. The Cronbach alpha here is 0.831, indicating that the data collected for the analysis was interrelated and consistent.

Table 2. Mean score and ranking of onsite mechanised construction activities

Heavy Construction Activities	Overall Mean Score	Rank
Excavation, earthworks and pilling work	4.05	1
Structural works	4.03	2
Demolition, site clearance and alterations	3.72	3
Concreting and formwork	3.59	4
Assembly and installation works	3.55	5
Road making, flooring and pavement	3.54	6
Plumbing and drainage	3.17	7
Brickwork and masonry	2.88	8

Refer to the Table 2, eight main onsite construction activities were identified as the potential areas for the application of mechanised equipment and machineries. It shows the overall mean score and the corresponding ranking based on their level of usage and importance. The comparison of the Mean Index with the Average Index Assessment scale (as shown in Table 3) indicated the mechanisation assessment of each heavy construction activity.

Table 3. Average index assessment scale

Scale	Assessment
1.00 – 1.80	Very Low
1.81 – 2.60	Low
2.61 – 3.40	Average
3.41 – 4.20	High
> 4.20	Very High

Table 4 shows the details of the mechanisation assessment of each construction activity. Out of these eight onsite construction activities, Activities No. 1 to 6 had high mean index values; hence it was found that these activities had high utilisation of mechanised construction equipment. Activities No. 7 and 8 had average utilistation of equipment and machineries.

Table 4. Comparison between the mean index and average index scale

Heavy Construction Activities	Mean Index	Average Index Indicator
Excavation, earthworks and pilling work	4.05	High
Structural works	4.03	High
Demolition, site clearance and alterations	3.72	High
Concreting and formwork	3.59	High
Assembly and installation works	3.55	High
Road making, flooring and pavement	3.54	High
Plumbing and drainage	3.17	Average
Brickwork and masonry	2.88	Average

Enablers of Onsite Mechanisation

The primary data collected for the enablers of onsite mechanisation were analysed from the perspective of the contractors. The relative importance index method was used for determining the relative importance of various enablers. The Relative Importance Index (RII) is a non-parametric technique widely used by construction and facility management researchers for analysing structured questionnaire responses for data involving an ordinal measurement of attitudes (Kometa et al. 1994). For this part of the questionnaire, the 5-point Likert scale (with 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree) was adopted and the relative importance indices (RII) for each of the enablers was calculated by using Equation (1).

$$RII = \frac{\sum w}{A \times N} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5 \times N} \tag{1}$$

Where w showed the weighting that is assigned to each variable by the respondent, A is the highest weight and N is the total number of respondents. The RII value ranged from 0 to 1 with 0 not inclusive. It showed that the higher the value of RII, the more important the enabler of the onsite mechanisation. Table 5, shows the relative importance index (RII) for the enablers that were identified from the respondents' feedback. The enablers were also ranked based on the RII values.

Table 5. Overall ranking of enablers

Enablers of Onsite Mechanisation	RII	Rank
Large quantity of materials can be handled	0.968	1
Work can be done speedily	0.876	2

Increase productivity	0.849	3
Work can be done in time	0.834	4
Magnitude and complexity of work	0.830	5
High quality standards can be obtained	0.819	6
Labour reduction	0.812	7
Optimum use of material	0.779	8
Satisfy client specifications	0.789	9
Increased safety	0.768	10
Cost effectiveness	0.749	11

Refer to the Table 5, the ranking assigned to each enabler of the onsite mechanisation identified the most important advantages which were perceived by the respondents. Based on the ranking, the five most important enablers were: (1) large quantity of material can be handled (RII = 0.968); (2) work can be done speedily (RII = 0.876); (3) increase productivity (RII = 0.849); (4) work can be done in time (RII = 0.834) and (5) magnitude and complexity of work (RII = 0.830).

Barriers of Onsite Mechanisation

The barriers of onsite mechanisation were also analysed by using the RII. Table 6 shows the RII and overall ranking.

Table 6. Overall ranking of barriers of onsite mechanisation

Barriers of Onsite Mechanisation	RII	Rank
B_1: Budget constraints for small and medium size firms	0.842	1
B_2: Government import duties and sales taxes on construction machinery	0.814	2
B_3: Mechanisation is expensive and extra financial burden	0.810	3
B_4: Availability of skilled operators	0.772	4
B_5: Inadequate information about mechanisation techniques	0.757	5
B_6: Proper maintenance of equipment	0.753	6
B_7: Equipment are difficult to acquire locally	0.751	7
B_8: High training needs for operators	0.751	7
B_9: Low technology literacy of staff and workers	0.745	8
B_{10}:High delivery time which may affect project deadline	0.717	9
B_{11}: Low equipment utilization by operators	0.661	10
B_{12}: High equipment accidents and breakdown	0.657	11

Based on the above table, the important barriers of onsite mechanisation as ranked by the respondents were: budget constraints for small and medium sized firms (RII = 0.842); government import duties and sales taxes on construction machinery (RII = 0.814); expensive and an extra financial burden (RII = 0.810); availability of skilled operators (RII = 0.772) and inadequate information (RII = 0.757).

The barriers to onsite mechanisation were also analysed through correlation analysis by using Spearman's correlation test. It is a non-parametric measure of the strength and direction of association that exists between two variables measured on at least an ordinal scale. It is denoted by the symbol r_s (or the Greek letter ρ, pronounced rho). As shown in Table 7, all independent variables B_1 to B_{12} (i.e. barriers of onsite mechanisation) were significantly related to each other and have high degree of correlations and agreements.

Table 7. Spearman's rho correlation test for onsite mechanisation barriers

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}
B_1	1.000	.590**	.494**	.305**	.379**	.190**	.169	.225	.205	.178	.132	.175
B_2	.590**	1.000	.691**	.385**	.505**	.372**	.295**	.341**	.353**	.238**	.235**	.334**
B_3	.494**	.691**	1.000	.560**	.517**	.556**	.266**	.332**	354**	.363**	.381**	.332**
B_4	.375**	.385**	.560**	1.000	.665**	.564**	.344**	.501**	.311**	.443**	.485**	.398**
B_5	.379**	505**	.517**	.665**	1.000	.625**	.286**	.449**	.388**	.319**	.487**	.360**
B_6	.190	.372**	.556**	.564**	.625**	1.000	.438**	.536**	.513**	.496**	.557**	.531**
B_7	.169	.295**	.266**	.344**	.286**	.438**	1.000	.578**	.514**	.343**	.430**	.481**
B_8	.225*	.341**	.332**	.501**	.449**	.536**	.578**	1.000	.520**	.477**	.524**	.474**
B_9	.205*	.353**	.354**	.311**	.388**	.513**	.514**	.520**	1.000	.582**	.610**	.542**
B_{10}	.178	.238*	.363**	.443**	.319**	.496**	.343**	.477**	.582**	1.000	.654**	.513**
B_{11}	.132	.235*	.381**	.485**	.487**	.557**	.430**	.524**	.610**	.654**	1.000	.701**
B_{12}	.175	.334**	.332**	.398**	.360**	.531**	.481**	.474**	.542**	.513**	.701**	1.000

** Correlation is significant at the 0.05 level (2-tailed).*
*** Correlation is significant at the 0.01 level (2-tailed).*

DISCUSSION

The previous sections have discussed about the onsite mechanised practices and its associated enablers and barriers. Their respective ranking and correlation analysis make it possible to categorize them for further investigation. In this regard, the findings are summarised as:

i. The data analysis showed that excavation, earthworks, pilling and structural works were the high ranking activities where machineries and equipment were mostly used by the contractors. As these activities are intensive in magnitude and complexity, so the technology driven approach is a more viable solution for handling them. But still, there is room to increase the level of mechanisation for these construction activities. In Malaysia, the availability and abundance of cheap foreign labour is a priority option for the contractors and it surpasses the use of mechanised equipment. It is due to this phenomenon that Activities from serial No. 7 to 8 (Ref. Table 4) had relatively low average index indicator values in terms of mechanisation. Among these activities, plumbing, drainage, brick work and masonry had low demand for mechanisation.

ii. Mechanisation is the second level of industrialization and its main aim is to modernise the conventional construction process. With reference to IBS, the technical efficiency of the entire process could be achieved by utilising appropriate machines and equipment. As, prefabricated components are massive in size and weight, thus require specialised equipment for transportation, erection and installation (Kamaruddin et al. 2013). The current research has highlighted that onsite mechanisation can help in handling large quantity of material with high speed of work which will ultimately increase productivity. Hence, work can be completed in a scheduled time and as well as it will help in doing high magnitude and complex work in case of IBS.

iii. A number of barriers may affect the contractors to adopt appropriate technology for performing construction activities. This study further investigated the main barriers that inhibited the use of mechanised equipment. It is a general perception that technology driven approach is quite expensive and considered as a financial burden for the contractor (Mahbub, 2012). The survey results have also shown that a budget constraint is a high ranking concern for the small and medium sized firms and largely influence the purchasing or renting decision. It is due to this reason that these firms are more willing for renting and leasing options rather than to own or purchase equipment. Similarly, vice versa is the case for large size firms as there is a more trend for buying equipment due to their financial capability. Beside this, government import duties and sales taxes on construction machinery is the second important barrier as identified by the respondents. In comparison to other ASEAN countries, its ratio is high in Malaysia (Kamar, 2012). Due to these, contractors are reluctant for adopting innovative methods of mechanised construction.

FUTURE SUGGESTIONS

The survey results reveal the inclination of construction industry practitioners for implementing onsite mechanisation. Majority of the respondents are well aware and had a good knowledge of mechanised construction practices. Based on the enabling aspects of the studied phenomenon, it can be anticipated that the adoption of onsite mechanisation could provide a practical option to do the schedule compression beside ‘crashing’ and ‘fast tracking’ techniques currently used in construction project management (PMBOK, 2008). The subsequent deployment of suitable machines and equipment accelerates the construction process and shorten the project timelines. Beside this, the greater dependency of Malaysian construction industry on foreign labour is considered as a prevailing hindrance for its growth and expansion. With the enhancement of mechanisation, this issue will also be demoted and illegal foreign labour issue could be addressed.

Nevertheless, mechanisation is still a financial burden for contractors due to the major capital investment require for procuring and maintaining a suitable fleet of equipment. In order to overcome this barrier, it is proposed that the government could devise techno-economic policy that will encourage local contractors (from grade G1 to G7) to increase the level of mechanisation in their existing practices. This can be stimulated by offering procurement incentives in terms of lowering taxes, levies and import duties on construction machineries. Moreover, government bodies such as CIDB, Construction Research Institute of Malaysia (CREAM) along-with Master Builder Association of Malaysia (MBAM) can play a vital role by developing new working standards and guidelines for modern and mechanised methods of construction. These autonomous entities in collaboration with technical colleges and institutes could also propose training programs for increasing the skills of mechanised practices among site staff and workers.

Above all, the future of mechanisation in Malaysia is linked with the effective collaboration of government and private sector that led the construction industry to achieve higher level of industrialization.

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BUSINESS VALUE OF BIM IN MALAYSIA'S AEC INDUSTRY: PRELIMINARY FINDINGS

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Abstract
Building Information Modelling (BIM) has been embraced by the Architecture, Engineering and Construction (AEC) industry to capitalise on the benefits it presents. BIM offers an innovative way of leveraging the business, augmented with the use of technology as a means to provide an opportunity to carry out projects more efficiently. Indeed, BIM is making construction more attractive to the clients and more profitable to participants. Despite its benefit, there is a need for relevant practice to evaluate the expected benefits of BIM in conjunction with a valid baseline. The purpose of this study is to explore the expectation of the stakeholders over the potential business value of Building Information Modelling (BIM) in the AEC industry. This research method consists of quantitative data analysis gathered from surveys conducted among 27 respondents, draw from the Construction Industry Development Board (CIDB) through a series of workshop. The findings of this research demonstrate that professional personnel within the AEC industry are aware that they will gain benefits and ROI from the BIM investment. However, besides this awareness, the AEC industry are still reluctant to take up BIM into their process delivery. The study also revealed that a majority of respondents agree that the staff capabilities and competencies to operate BIM will influence the decision and choice for its adoption. The study proposed in-depth research with empirical study over Return on Investment (RoI) for BIM projects and the strategies for technological competencies development for a BIM user should be conducted.

Keywords: *Business Value; Building Information Modelling; BIM; Malaysia; Return on Investment (ROI)*

INTRODUCTION

AEC organizations have aggressively embraced new technology to remain competitive in the current market (Alshawi et.al. 2010). Digital construction is here to stay, and it is becoming increasingly difficult to ignore this emerging technology that could produce a high impact in the construction industry. Building Information Modelling (BIM) is a new term in the Industry and is considered to be an innovate idea and benchmarking technology in the global construction industry (Liu et. al., 2013). For instance, BIM could be considered revolutionary in the way it transforms architectural thinking by replacing drawings with a new foundation for representing design and aiding communication, construction, and archiving based on 3D digital models.

BIM is evolving rapidly and leading construction industry in stimulating an unprecedented construction revolution. Recent research shows that BIM is a philosophy, not just the software itself (Zhu et. al., 2010); indeed BIM is more than a technology (Ashcraft, 2009). The BIM technology provides a platform to illustrate both graphical and non-graphical information of the building projects during its life cycle (Shen et.al., 2012). Through the realists lens, BIM will create competitive advantages through increased delivery speed, better coordination, decreased labour costs, greater interconnected productivity, high-quality work output; and the most important BIM create new revenue and business opportunities (Eastman et al. 2008).

BIM is becoming pervasive in the industry; several studies have shown that its rate of adoption in the AEC industry still seems at 'infant stage' among stakeholders and in the different phases of a project's lifecycle. As the Industry embraces the revolution, participants are at different adoption and experience levels. Although technology plays a vital role in implementing BIM and could bring benefits to the organisations, the process of selecting the technology is vital to ensure its support to the organisation's business. Therefore, BIM cannot be viewed simply as application of software; but it integrates human activity with software application that ultimately induces broad process changes in construction (Wang, 2009). However, there are still many challenges in adopting BIM in the traditional work processes, especially for those smaller players in the AEC industry who have limited resources and are reluctant to embrace new technology (Chua, 2011). The demarcation lines going to be stretched between advocates and opponents of the burgeoning technology, as well as those who can afford to invest in BIM and those who cannot. Hence it demonstrates the need to improve BIM-based change management systems for effective coordination of multi-disciplinary models throughout the dynamic process of building design and construction (Langroodi & Staub-French, 2012).

Implicitly, in Malaysia, the National BIM Steering Committee had defined BIM as *Modelling technology and associated set of processes to produce, communicate and analyse digital information models for construction life-cycle*. The private sectors primarily drive BIM's adoption in Malaysia since 2009 (CIDB, 2012; Haron, 2013). The government participation begins through the first government's BIM project officially announced in 2010, which is the National Cancer Institute, Sepang (CIDB, 2014). Following this, CIDB currently complementing the efforts of the BIM implementation by providing sustaining environments where BIM will survive and thrive (CIDB, 2012).

This paper is specifically designed to explore the expectation of the stakeholders on the potential of business value of BIM in Malaysia AEC industry. It addresses the questions of what organization expectations of the monetary return and what is the critical expectation of the organization's decision maker to accept BIM. In order to answer these questions we have focused on two sets of the variables, return on investment and competency acquiring. It should be noted that this paper is based on the preliminary findings of an ongoing research on development of model on business value of BIM in Malaysia AEC industry.

PHILOSOPHY OF BUILDING INFORMATION MODELLING (BIM)

BIM is a new way of approaching the information in the design and documentation of building projects. BIM models were first developed and originated in 1975, based on "Building Description System" of Chuck Eastman, the "father" of BIM (Eastman et al., 2008). Since then, the definitions of Building Information Modelling (BIM) vary widely depending on organisations and professions (Haron, 2013).

Fundamentally, BIM is not simply a thing or a type of software but an integrated approach between human activity and the relevant software that ultimately involves broad process change in construction (Eastman, 2011). In a BIM workflow, BIM is a digital representation of physical and functional characteristics of a building to create shared knowledge resource for information, forming a reliable basis for decisions during its life cycle, from earliest conception to demolition (CPIC, 2011). It is also defined as the parametric Modelling of a building by NIBS (2007). However, BIM can exist either in collaboration environment or in isolation depending on the objectives of the organisation (Haron, 2013). The frequency and variety of the definitions of BIM illustrate the confusion in defining and quantifying BIM and putting it in terms of potential benefits rather than the original philosophy of BIM (Barlish & Sullivan, 2012). Hitherto, BIM had been defined differently by various people due to their perceptions, background and experiences (Khosrowshahi and Arayici, 2012). Whatever the definitions, it is noteworthy that the original conceptual frameworks of BIM should remain unchanged, which is the methodology of practice that carries the philosophical stand based on the availability of information about building (or building project) within the technology to support its lifecycle processes (Roberts, 2013). The differences are only the evolution of technology from the 2D CAD with lines and alphanumeric spreadsheet to the 3D object with elemental information and a relationship database (Haron, 2013).

As the BIM concepts continues to grow, the term ''Building Information Modelling (BIM)'' was coined in 2002 to distinguish the next generation of Information Technology (IT) and Computer-Aided Design (CAD) for buildings from traditional CADD (Computer-Aided Drafting and Design), which focused on drawing production (Lee et al., 2006). The BIM Handbook provides a three part characteristics of BIM: (1)"a more integrated design and construction process that results in better quality buildings at lower cost and reduced project duration, (2) a model that "contains precise geometry and data needed to support the construction, fabrication, and procurement activities through which the building is realized", and (3) "accommodates many of the functions needed to model the life cycle of a building, providing the basis for new design and construction capabilities and changes in the roles and relationships among a project team" (Eastman et al. 2007).

Through BIM methodology, it is possible to improve coordination, enhances information accuracy, reduces waste, and enables better-informed decisions earlier than conventional methodologies that are used to create constructed assets (Love et.al., 2013). Building Information Modelling has great potential to facilitate better communication and collaboration among project participants. It has emerged as a very powerful system that allows users to create visual simulation of a project and provide a virtual prototype of a building prior to construction. Structured approaches have been utilized in most advanced countries to ensure that their industry players systematically adopt the use of BIM (CIDB, 2012). Furthermore, projects that are planned, designed and constructed using BIM methodology have proven to fully meet the client's requirement, in terms of cost, quality and completion time. BIM technology can also provide a more streamlined business process, associated project and site management methodologies, including complete facilitation of construction knowledge during the full lifecycle of a building project (Arayici and Aouad, 2010).

In a distributed team environment, the result from other portions of the research indicates that the Industry use of BIM is currently focused more internally than on its ability to help them interact with other players (Bernstein and Jones, 2012). This is strengthened through the survey by McGraw-Hill (2012) where the findings show that the factor of multi-party communication is no longer favourable by contractors in the United States compared to the year 2009. The factors that now take precedence include those most closely related to improving productivity, increasing prefabrication and the time and cost savings, rather than using it as collaborating tools.

BUILDING INFORMATION MODELING: ACCEPTANCE AND BUSINESS VALUE

The acceptance of any new technology requires a strategic approach as it is a behavioural-based managerial practice requiring a clear assessment of decision makers' state of mind, actions and conducts (Zakaria, 2010). It involves a number of individuals including both, supporters and opponents in the organisation, each of whom plays a role in the decision to accept the technology (Oliveira and Martin, 2011). Therefore, to identify the acceptance of BIM, the need to understand the benefits and value of BIM seems obvious.

With all of these BIM-enabled opportunities, the concept of BIM business value aligned with the theory that an organisation could be best view as a network of internal and external relationships. Hence, each relationship of the network creates entities and contributes to the overall organisational performance in implementing BIM. One of significant BIM of value is the development of centralized project databases, which require full participation from the network of project team. Contractor can utilize these databases to analyse and configure site planning and logistics such as location of machineries and temporary access point (Khanzode et.al., 2008).). It is also used to simulate and analyse the sequence of construction activities to reduce project time up to 7% (Azhar et.al. 2008). Meanwhile, Howard and Bo-Christer (2008) indicated that approximately 2% cost saving are achievable during the construction phase. Even though it seems as small, it is still substantial for a multi-million projects.

With this growth in use and interest of BIM, Contractors in United States started to obtain the value of BIM in their organisation and becoming the leading users of BIM, which has leapfrogged the architect by 4% (McGraw-Hill, 2012). More than 50% of contractors indicated that BIM could generate strong benefits in terms of reducing error, reducing rework and omissions in documentation, perhaps those benefits seems to be closely associated with BIM throughout the industry (Bernstein and Jones, 2012). The McGraw Hill report (2012) also suggested that contractors are finding ways to incorporate BIM into their existing capabilities more than using it to revolutionize their businesses. This trend is also projected to be seen in Malaysia's AEC industry within the next few years.

The business value of any new technology comprises both monetary and intangible outcomes (Barlish & Sullivan, 2012). Therefore, business value to BIM is prevalent, but it is not insurmountable. From the implementation of BIM, some will lose from this whilst others gain, and the entire sector will progressively reshape in near future. BIM technology can facilitate improvements in many business practices related to the building industry (Jensen & Jo, 2013). BIM technology has been identified as a boundary object in business and social interactions between construction professionals as well as facilitates organizational change (Forgues et al. 2009). Rather than trying to embark on it alone, Sebastian (2010) stated that BIM can be applied without radical changes to the information and communication technology systems or to the business organizations. Organisations engaged in small-scale projects could adopt relatively simple working methods with basic BIM for direct tangible impacts, without any radical change to their ICT systems or putting their business organizations at stakes. The BIM as a 'truly game-changing technology', eliminates a huge amount of cost, time and increases the productivity of staff. That, in turn, means projects get delivered faster, which is helpful to the billing cycle of small firms. Ultimately, implementing BIM in an organisation will bring higher business value to all types of AEC organisation with a lesser investment and risks.

PROBLEM STATEMENT

Where the remarkable success story of BIM exist, there is also evidence that a large contingent of AEC organisation that are not getting on board towards in implementation of BIM. AEC industries still relatively conservative about how they estimate return from BIM and augmenting slow progress (Alshawi et.al., 2009; Khosrowshahi and Arayici, 2012; Bernstein and Jones, 2012). The problem, however, Davis & Songer (2008) and Hartman & Fischer (2008), argued that performance of project will suffer when implementing BIM because the technology is difficult to learn, taken too long to be skilful which will disturbed the established workflow in the project. While the perception that implementing BIM in construction project could suffer project performance due to the transition process (Regan & O'Connor, 2000).

The full potential of BIM has not been realized as it is hindered by a lot of business issues and owner's expectations while implementing BIM (Merschbrock & Munkvold, 2012). One of the vigorous reasons for this predicament could be the difficulty to learn how to use the BIM software and the adoption incur additional cost (Khosrowshahi and Arayici, 2012). As with any revolution, though, there will always be some workers who are not resistant to new ways of working. Hence, this paper seeks to investigate the expectation of the AEC industry on the return on investment (ROI), either in economic value or values that may not directly measured in monetary terms.

RESEARCH METHODOLOGY

This study was conducted by Construction Industry Development Board (CIDB) through a series of workshop. The respondents consist of various professional with different background in construction industry. A total of 32 targeted respondents were invited to a briefing on BIM prior to answering a semi-structured questionnaire, which is distributed at the end of the briefing session. A comprehensive literature review was conducted to set a foundation for this study and to support the survey questionnaire development. The data collected from this question was used for stratifying the responses and then analysing them.

THE FINDINGS

This preliminary study consists of 32 respondents; 27 had completed the process and answered all questions. Meanwhile, five respondents do not complete the whole process; therefore, their response is excluded from the analysis. Anderson (1998) suggested the numbers of respondent for pilot study is 6 to 12. Hence, 27 respondents for this pilot study is suffice for this study. Table 1 presents the distribution composition of respondents according to the age, organisation, experiences and industry background.

Table 1. Profile of Respondents

Variables	Frequency	%
Gender		
Male	19	70.4
Female	8	29.6
Years of Experience		
Less 5 years	8	29.6
5 to 10 years	3	11.1
11 to 15 years	6	22.2
Above 15 years	10	37.1
Organisation		
Government Bodies	3	11.1
Architecture Firms	4	14.8
Engineering Consultant	9	33.3
Quantity Surveyor Firms	4	14.8
Contractors	6	22.2
Academician	1	3.8

The highest respondent is from the engineering consultants which represents 33.3% of the sample. Followed by the contractors (22.2%), Architecture and Quantity Surveyor firm represents 14.8% each, 11.1% represents by government bodies while the academician is 3.8%. Meanwhile, the respondents are targeted well, where 33% had experienced BIM in their work, while 52% are at the learning stage and 15% at introductory level, as illustrated in Figure 1.

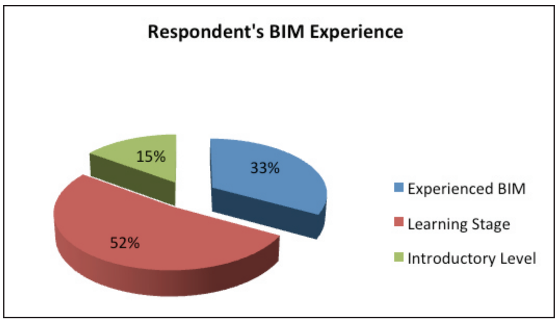

Figure 1. Respondent's Experience of BIM

Table 2. The Organisation Expectations of the ROI period

ROI Expectation (year)	Percentage	Remarks
1 to 2 years	70	General expectation of ROI across all organisations
3 to 5 years	22	Some Architect firms, Engineering consultants and Government bodies
More than 5 years	8	Government bodies and Academician
TOTAL	100	

Table 2 shows the organisation expectations of a monetary return based on BIM software and training investment. From the results of the study, it appears that 100% of the respondents believed that they would gain return from the investment of BIM. 70 of organizations believe that ROI to be gain within 1 – 2 years period, 22% are willing to wait between 3 - 5 years. Meanwhile the government bodies and academician (8%) are ready to have a long term investment on BIM with the ROI exceeding 5 years.

It shows that even though the resistance may come from a high initial cost to implement BIM as stipulated by Takim et. al. (2013), the industry is ready to invest and aware that they will gain benefits and ROI from the investment. Unfortunately, in spite the awareness of BIM benefits and potential returns, AEC industries still yet to adopt it aggressively (Alshawi et.al., 2009; Khosrowshahi and Arayici, 2012). However, based on this survey, cost issue are not the predetermining factor for BIM acceptance.

Table 3. Critical Expectation of the Organisation's Decision Makers

QUESTIONS	ORGANISATION EXPECTATION		ACTUAL
	Scores	Results	
Do you agree that your current staff capability and competency will influence your choice to accept BIM	81.5%	Agree	
How long can you allow for your staff to be away for BIM training?	61%	1 to 3 days	Tools A: 3 to 5 days Tools B: 5 to 10 days Tools C: 3 to 5 days
Do you expects your staff able to immediately implement BIM upon completion of the training	63%	Yes	No
Do you expect full BIM advantages can be utilized immediately after completion of the training	63%	Yes	No
If your staffs require further practice prior to implementation, how long can you allow your staff to continue practicing (on the job) and be ready to optimized full BIM potential?	76%	Up to 1 week	2 to 3 months and for some tasks, will take up to 6 months

Table 3 above described the critical expectation of the organization's decision making to accept BIM and to withdraw the advantages from BIM adoption. The survey questions focus on the factors of decision to implement BIM into the organization. Surprisingly, as high as 81.5% of the respondents agree that the staff capabilities and competencies to operate BIM will influence the decision and choice for its adoption. It indicates the importance of training and competency development prior to acceptance of BIM into the organisation's workflow.

Meanwhile, comparison is established on the BIM competency development, between the organisation's allowances over the period to attend training with the actual effort offered by the major BIM's software providers namely in this study as Tools A, Tools B and Tools C. The results shows that 61% of the organization allows their staff to be away for training to a maximum of only 3 days, while Tools A and Tools C will require a minimum of 3 days to train the basic function and taking another 2 to 3 days for the advance function. Hence, it taken at least 5 to 6 days to complete learning the available functions within the BIM software. On the other hand, 63% of the organization expects the trained staff immediately able to implement BIM and achieve its full potential upon completion of the training. Whereas, Lange (2013) stipulated that the trainee will require further practice and assistance on real-life project, in order to be skilful and achieve full BIM's potentials.

On this account, the survey further enquires the additional period allowed by organisations for the staff to practice the BIM software further in order to be competent. The result shows that as high as 76% of the organization able to give an additional allowance of only 1 week to practice prior to expecting full advantage of BIM to be easily withdrawn from BIM implementation. Meanwhile, Haron (2013) and CIDB (2013) stated that the actual time taken for the on-job practice could be within 2 to 3 months, or even up to 6 months depending on the tasks needed by the organisations before any benefit could be utilised effectively. These are one of the major gaps identified during the survey that may contribute to the resistance of BIM for its wider acceptance by the decision makers, which is the stakeholder's expectation and the actual software capability offered by the relevant principles.

CONCLUSION

One of the most prominent functions of BIM is to do more with less. Without a doubt, the benefits to BIM appear obviously and BIM's future is a ballpark' in the hands of AEC industry. One of the most significant findings to emerge from the above study is that the AEC professional is cognisant that BIM will provide business value in changing the face of the global AEC industry. The results of the above study show that there are challenges with the commercial issues and enfold significant gaps between the stakeholder's expectation and the offer of technology in the form of implementation of BIM in organisation. Taken together, it all looks a bit difficult. However, with this landslide of information over the business value offered by BIM, it is not surprising to see more organisations are willing to invest on BIM to augment their business value. To the very nature of the dynamic, complex and sometimes unpredictable industry, BIM continues to substantiate itself as a well-executed business strategy for construction business not only for organization's long-term success, but to get them success within competitive AEC industry. The demand for BIM is there, while the latent potential is enormous. It is thus suggested that, for AEC organisation that willing to rethink its business strategy and taking advantage with technology, shifting to BIM considered being as the best option.

RECOMMENDATION

There is a need for a relevant methodology to evaluate the expected benefits of BIM on any project, from a business perspective, in conjunction with a more comprehensive baseline. As a precursor to future research in this area, future studies should also address the user's expectation during the training in terms of ease of learning, as a comparison with the current application available in the market.

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WOMEN'S CONSULTANT PARTICIPATION IN THE MALAYSIAN CONSTRUCTION INDUSTRY

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Abstract
It has been over a decade that the number of women entering construction related programmes in Malaysian higher education has outnumbered men. However their numbers of involvement in the industry is very much lower compared to men and has not been extensively documented. The aim of this paper is to establish the level of women's participation in the construction industry and to identify the barriers and challenges faced by women in this sector. A questionnaire survey has been administered to 45 women working in consultancy firms in the construction industry through simple random sampling. Majority of the respondents were in the category of having 1-10 years of industry experience. Their decision to enter the industry has been influenced either by parents, themselves or friends and motivated by financial gains and good career opportunities. The main barrier to remain in the construction industry is the inflexible working hours and the most challenging factors faced are mistreatment by others in the industry and strict recruitment processes. The findings bring an important message to the consultant organizations, to continue their support on this cohort, especially those with family obligations, by developing flexible work schedules and looking at cases of mistreatment seriously. In anticipation of the industry recruiting higher number of women workers in the future, it is thus timely that the industry should formally acknowledge their existence and contribution. Adopting flexible working arrangements would greatly facilitate in the development and enhancement of this potentially important asset to sustain in the industry.

Keywords: *Barriers; Challenges; Women's participation; Construction industry and Malaysia*

INTRODUCTION

In reality, female representation in the workplace has increased enormously during recent decades in most developed countries; furthermore, women have begun to enter traditionally male-dominated jobs owing to economic reasons and organizational changes in worksite settings (Lin et al., 2011). In the US, women make up approximately one half of the US workforce (U.S. Department of Labor, 2011). Female employment rates in the UK are "*inching closer to men's employment rates all the time"* (Li et al., 2008). Malaysia, on the other hand, was reported to have the lowest women labor participation rate in East Asia (Labor Force and Social Trends in Asean, 2008). Compared to the neighbouring Asean countries, Malaysian women participation stood at 40% compared to Indonesia and Philippines (52%) and Singapore (60%).

The construction industry is one of the most male-dominated industries in the world, with a male representation rate of more than 90% (Fielden et al., 2010). Although the opportunities for women in the construction industry appear to be increasing, these are still extremely limited (Fielden et al., 2010). According to the Construction Industry Training Board (CITB, 2003), women only account for 9% of the construction work force. Women are confronted by a significant number of barriers, including difficulties in joining the construction industry and gaining the most senior positions in the organization's hierarchy; there are growing interests for women in the industry to better negotiate and define their professional identities (Powell et al., 2006).

In Malaysia, although the participation of women in the academic side of the construction sector is still low, the percentage has increased from 30% in 2001 to 33% in 2005 (Eaton and Morton, 2008). It is also predicted that the percentage will increase by the year 2020. The higher enrolment of women compared to men in public universities in Malaysia over the past decades may lead to the future phenomena where a construction project handled 100% by women becomes a reality (Department of Statistics Malaysia, 2013). Based on the Department of Statistics Malaysia (2013), the rate of female employment population has increased to 47.9% in 2011 compared with 30.8% in 1957 (Peninsular Malaysia). These figures show the ever increasing female employment population in the construction industry in Malaysia, even though it is still lower than that of the male population (Sihi, 2012).

There are some barriers that prevent women from participating in the construction industry, the biggest being those related to entry, development and retention (Amaratunga et al., 2006). Moreover, women also encounter physical barriers, such as on-site environmental hurdles and perceived emotional support barriers that can even lead to hostility from colleagues or from the environment (Geertsema 2007). In Malaysia, safety and health problems in the construction industry create further barriers to women entering and remaining in this field (Sarkar 2002). The working environment is generally not conducive to the sustained employment of wives and mothers. The Occupational Safety and Health Administration (OSHA) (1999) found that, in a one year period, 41% of female construction workers suffered from gender harassment and 88% reported sexual harassment.

Previous studies on women's participation in the construction industry have focused on barriers that prevented women from achieving managerial-level positions (e.g., Ginige et al., 2007; Greed, 2000) and have all been conducted in Western countries (e.g., Gale, 1994; Sommerville et al., 1993). Furthermore, according to Fielden et al. (2010), the construction industry itself has not, until recently, formally acknowledged that the under-representation of women is an important issue. Besides construction organizations, studies on women in the construction industry have been covered on women consultants such as Lingard and Lin (2004), Loosemore and Galea (2007) and Enshassi et al., (2008). There is an obvious lack of study conducted covering professional women's participation in the construction industry, such as quantity surveyors, engineers, architects and project managers, especially in Malaysia. Focusing on professional women in the industry, this study thus aims to establish the level of women's participation in the construction industry and identify the barriers and challenges encountered by them.

The next section contains a review of literature related to women in the construction industry. The literature review is followed by a description of the research methodology with the research findings reported in the next section. The discussion section reports the findings on participation, barriers and challenges met by professional women in the industry. Finally, the conclusion identifies implications of the findings and contributions of the research.

LITERATURE REVIEW

Women in the construction industry

The issue of women's underrepresentation in the construction industry has been of great concern since the early 1980's. Women in this industry are perceived as the wrong gender to be in construction occupations that require manual dexterity and physical strength (Aulin and Jingmond 2005). A recent survey of 81 female construction workers by the Ucatt Union in the UK found that 41 (51%) believed that they were treated unfairly at work because of their gender and 34 (42%) reported that bullying and harassment by managers was a problem (The Construction Index, 2012).

According to the National Women's Law Center (NWLC, 2012), the construction industry generally employs less than 10% of female in the workforce with even lower participation in specific crafts and trades. Many of the European Union countries today are suffering shortages in skilled labor, but project-based companies are more interested in seeking external resources, such as immigrant workforces, instead of looking at local resources (i.e., female workforce) to cover the increasing demand (Clarke et al., 2005). In relation to this, women need to be aware that the industry does not guarantee high-paying jobs with benefits (Bakar, 2012). Enshassi et al., (2008) argued that women would rather choose a 'softer' option for their career paths rather than gain employment in the construction industry with the frequency of relocations to new construction sites and working long hours.

Barriers against women's entry to the construction industry

Image of the industry

The construction industry is typically portrayed as promoting adversarial business relationships, poor working practices and environmental insensitivity, and has a reputation for under performance (CITB, 2003). The predominant industry image is one that is male-dominated, requiring brute strength and a good tolerance for outdoor conditions, inclement weather and foul languages.

One assumption on which some arguments are based states that a woman is physically not strong enough to endure the strenuous tasks involved. In fact, when entering gender-segregated occupations, women must prove their competence, despite their qualifications and experiences (Clarke et al., 2005). Dainty et al. (2000) found that women may not remain in the industry after completing a related degree due to the incorrect picture of the industry portrayed by recent recruitment initiatives.

Culture and environment

Women often choose a career in the construction industry if the work environment is challenging, provides good working conditions and fosters a sense of responsibility (Geertsema, 2007). Most women who join the construction industry are willing to take on certain challenges and are motivated to adapt to the environment, and by taking on construction roles, such as being an environmental consultant, while seen as a greater good, is still dependent upon an individual's decision (Williams, 2013).

The construction industry has a macho culture where relationships are characterized by argument, conflict and crisis (Gale, 1994). Consequently, employees (male and female) find that they are exposed to an extremely hostile environment. In the UK, the construction workplace has been described as amongst the most chauvinistic, with an extremely macho culture that is hostile and discriminatory towards women (Bagilhole et al., 2002), resulting in gender-differentiated career opportunities, leading to the inevitable consequence of high staff turnover of women in construction companies (Amaratunga et al., 2008).

According to Michael Romans, past president of the Chartered Institute of Building, the construction industry is characterized by *"a boy's own culture,"* which is overtly fostered on language and behavior (Amaratunga et al., 2006, p.564). Davey et al. (2005) highlighted that male values are the norm in the construction industry. These include long working hours, competition, independence, full-time work and high expectations for rewards and career advancement. Invariably, such male-dominant culture can be especially destructive for women's entry to the industry and their subsequent career development and retention.

Health and safety

A hostile workplace presents health and safety concerns on several levels, ranging from a lack of training and safety information to physical assault (Occupational Safety and Health Administration [OSHA], 1999). Distractions while working can lead to the improper practice of precautions that, in turn, lead to on-site injuries. The effects of a hostile workplace can be reflected in acute and chronic stress reactions (OSHA, 1999). According to a survey conducted by OSHA (1999) on women in the industry, 41% responded that they had been mistreated by co-workers or supervisors because they were female. The findings also showed that harassment by co-workers or supervisors served as an important predictor for symptoms of increased psychological and physiological distress (Bennett et al., 1999). In an industry already fraught with obvious dangers, this serves only to exacerbate the problems of female workers.

Sexual harassment

Sexual harassment is a serious problem for female construction workers. According to a 1996 USA Today analysis of the U.S. Equal Employment Opportunity Commission and Bureau of Labor Statistics data, female construction workers had the second highest rate of sexual harassment complaints per 100,000 employed women. Sexual harassment violates laws prohibiting sex discrimination in employment (Lan, 2011). There is growing evidence that sexual harassment, at a minimum, is a stress inducer that, in its more extreme forms, can pose a danger as a result of distraction, fear and assault (Shukor, 2012).

Marital status

It is hypothesized that women do not reach the top echelons in the construction industry management structure because their active careers are shorter than those of men due to family obligations and motherhood, as well as the lack of education and skills (Baksh, 2012). A declining number of women resign from their work for reasons related to marriage and or children. For those who choose to leave, a majority returned when the children were already of school-going age (Aziz and Marrison, 2001).

Women, being child bearers, have to address issues of initially caring for a baby, and the requirement to take leave from work. In fact, Harriet stated that "*One of the barriers in employing women is the assumption by society and industry that they will leave and have children*" (Harriet, 1999, p.70). For some women however, this is not necessarily true. By choice, some women can decide not to have children or may be physiologically unable to do so (Kellerman and Rhode, 2007). Sometimes, employers are reluctant to employ women who have babies; this phenomenon is not particular only in the construction industry but also in other industries (Kenya-SDN, 2010). Factors such as returning to work, maternity leave, long hours, and confidence are all part of the mix, which makes this a troublesome area (Wilson, 2012).

Level of Education

Women are more likely to face more complex career choices than men. Their career patterns tend to move through phases when other aspects of life take priority. According to Srivastava (1996), there is a large pool of women employees who lack the necessary qualifications in the construction industry because they have opted out so early in their lives.

Glover and Fielding (1997) reported that although the percentage of women with degrees in science, engineering and technology has doubled in the last 15 years, the proportion that used their qualifications professionally has not increased. A feminist theory and its critique of science offer insights as to how scientific investigations and practices within the scientific community, discriminate against females; discrimination, therefore, obstructs female representation in the construction field (Bennett et al., 1999).

The average percentage of females studying degrees related to the construction industry in South Africa is still low compared with that of their male counterparts (Hatipkarasulu and Roff, 2011). If women do not further their education in the construction industry, hence unable to acquire technical expertise and mechanical competence, would consequently result in their lack of technical ability or other means by which to advance their careers (Harriet, 1999).

Challenges faced by women in the construction industry

Compensation

One of the challenges of the construction industry is the issue of financial discrimination. Discrimination in terms of compensation is widespread, and according to Kaganas and Murray's (1994), 1991 census in South Africa showed that less than 10% of women employed in the construction industry earned over R300,000 annually and 53.6% had smaller incomes of as low as R100 per month or less. Needless to say, these values are far less than those received by male workers. Similarly, Shrum and Geisler (2003) found that women doing the same work as men earned significantly less. A survey of 2,600 construction workers found open inequality in pay, with women earning 10% to 20% less than men for doing similar work (Wells, 2001).

Recruitment

When applying for positions in the industry, many women have reported being subjected to unacceptable comments during interviews (Aziz and Marrison 2001). In a study by Hossain and Kusakabe (2005), the challenges identified by women in the construction industry in Thailand and Bangladesh were all related to the recruitment process.

Patriarchal behavior among colleagues

In striving for self-improvement, it is usual to look for a role model to imitate, and this can be difficult in the construction sector if a woman looks for another female to look up to (Aulin and Jingmond, 2011). The lack of role model, poor career advice, gender-biased recruitment literature, peer pressure and poor educational experiences have all been cited as factors that prevent women's entry to the industry; such factors have an overall effect on the career aspirations and development of women in this field (Dainty et al., 2000).

Promotion and recognition

Restricted promotional opportunities within the organizations occur within divisions that prevent lateral staff mobility among operating divisions, which sustain sub-cultural environments that restricts opportunities for women and maintains existing hierarchy and work practices (Dainty et al., 2000). Women are also considered threats to the limited promotional opportunities available within the organizations (Aulin and Jingmond, 2005).

The promotion of female engineers, for example, has increased considerably in recent decades, from less than 1% to more than 8%. Nevertheless, when they have the same educational qualifications, duration of employment and occupational attitudes, women are less likely than men to achieve high-status positions or move towards a career in management (Lauer, 1995).

RESEARCH METHODOLOGY

Sample and data collection

A sample survey was the type utilized in this research because the time frame only allowed data collection from select participants within a specific period of time (Tan, 2001). In this research, the questionnaire was the sole instrument employed to collect and record data. Simple random sampling method was applied given that each sampling element had an equal chance of being selected. About 250 questionnaires were distributed to various companies by email. Personal emails were also sent to all women consultant working in the construction industry. Of these, 45 respondents sent back the forms.

The sample size must be 10% of the total population or at least 50 samples in this study (Hoinville and Jowell, 1978). However, in some studies, a minimum of 30 samples is required (Black and Champion, 1998). In this study, 75 female architects were randomly selected from a sampling of 150 architects, 90 female quantity surveyors were randomly selected from a sampling of 120 quantity surveyors, 35 female engineers were randomly selected from a sampling of 80 engineers and 50 project managers were randomly selected from a sampling of 78 project managers. All the personal contact numbers, email addresses and other information from samples were obtained from the list of registered professional consultants in Malaysia.

Based on previous studies (Geertsema, 2007; Hatipkarasulu and Roff, 2011; Bennett and Davidson, 2006), a total of 7 items were used to determine the levels of women's participation in the construction industry; a total of 12 items regarding barriers against women's entry to the construction industry, and 8 items regarding challenges faced by women in the construction industry.

Reliability

Cronbach's alpha is the most common measure of internal consistency or "reliability". It is most commonly used in studies that employ Likert-type scales and multiple questions in a survey/questionnaire. The Cronbach's alpha value of barriers against women's entry to the construction industry is 0.837, while that of the challenges faced by women is 0.876. Kline (1999) noted that cut-off point of 0.7 is more suitable. As a result, none of the main variables are deleted.

ANALYSIS

Demographic data

The majority of the respondents were from 25 to 30 years (42.2%), followed by those under 25 years (39.4%), from 31 to 40 years (31.1%), from 30 to 35 years (17.8%) and 35 years old and above (8.9%). Most of the respondents were single (53.3%); 42.2% were married and only 4.4% were widowed. Majority of the respondents were degree holders (46.7%), followed by graduate/post-graduate degree holders (Master's or PhD), both of which have an equal amount of percentage (26.7%). For the salary range, most of the respondents' salaries are below RM 3,000 (57.8%), while 17.8%, 11.1%, and 13.3%, reported salaries between RM 3,001 to RM 6,000, between RM 6,001 to RM 8,000 and more than RM 8,000, respectively.

Participation of women in the construction industry

For work duration, most of the respondents (57.8%) had work experience of less than 5 years, 17.8% worked for 5 to 10 years, 11.1% worked for 10 to 15 years and 13.3% worked for 15 years or more. This indicated that almost 80% of women who participated in the industry have less than 10 years of experience. According to 31.1% of the respondents, the main reasons why they chose careers in the construction industry were financial gains and having a good career, with both factors recording the same response rate. This is followed by other factors that included passion or interest (22.2%), peer or parental influence (11.1%) and work environment (4.4%). Most of the respondents chose family as their motivator to enter the construction industry (42.2%), 35.6% made the decision to work in the industry by themselves and 22.2% based their decisions on their friends' inputs.

Since the questionnaires were distributed to all active women in the construction industry, the job titles were different. Thus, 40% of the respondents were quantity surveyors, 20% project managers, 15.6% architects, 13.3% engineers, 6.7% company directors and the rest administrative staff in the construction industry.

Almost all of the respondents (95.6%) answered in the affirmative when asked whether they intended to stay longer in the construction industry, while only 4.4% answered in the negative. For the employment status, 66.7% were permanent employees, 31.3% temporary employees and 2.2% self-employed (they own the company). As for time spent in the office, most of the respondents (48.89%) stayed in the office for more than half of their working days, 26.67% stayed in the office for less than half a day and 24.44% spent equal time at the office and at the construction sites.

Barriers against women's entry to the construction industry

From the descriptive analysis, the major barrier preventing women from entering the construction industry was inflexible working hours (mean=4.02, SD=0.94). This was followed by unsuitable working conditions (m =3.87, SD=0.92), family commitments (m=3.78,SD=0.99), forced to act like men (m=3.69, SD= 1.26), having a baby (m=3.67, SD=0.95), lack of education and practical skills (m=3.64, SD=1.11), presence of macho culture (m=3.64, SD=0.93), male dominance in the industry (m=3.62, SD= 0.93) and mindset (m=3.55, SD=1.12). There are only two factors that elicited neutral or uncertain responses, namely, hostile and discriminatory environment (m=3.47, SD=0.99) and sexual harassment (m=3.33, SD= 3.33).

Table 1. Item Statistics for Barriers against Women's Entry to the Construction Industry

	Mean	Std. Deviation	Ranking No
inflexible working hours	4.0222	0.94120	1
unsuitable working conditions	3.8667	0.91949	2
family commitments	3.7778	0.99747	3
women must act like men	3.6889	1.25811	4
child-bearing responsibility	3.6667	0.95346	5
macho culture	3.6444	0.93312	6
lack of education and practical skills	3.6444	1.11101	6
male-dominated industry	3.6222	0.93636	7
Mindset	3.5556	1.11916	8
hostile and discriminatory	3.4667	0.99087	9
sexual harassment	3.3333	1.18705	10

Scale: >1.49= strongly disagree; 1.5 to 2.49 = disagree; 2.5 to 3.49 = neutral;
3.5 to 4.49 = agree; 4.5 to 5.0 = strongly agree

Challenges faced by women in the construction industry

From the descriptive analysis, the most challenging experience faced by women in the construction industry was being mistreated (mean=3.69, SD= 1.06), followed by strict recruitment (m=3.60, SD=1.13) and underrepresentation and unfairness (m=3.57, SD= 0.94). Meanwhile, their opinions regarding other factors were reflected in the following values: limited promotion opportunity (m=3.46, SD=0.94), inequality (m=3.46, SD=0.99), feeling of vulnerability (m=3.44, SD=1.19), low compensation (m=3.31, SD=1.01) and uncomfortable situation (m=3.27, SD=1.17).

Table 2. Item Statistics for Challenges Faced by Women in the Construction Industry

	Mean	Std. Deviation	Ranking No
mistreatment	3.6889	1.0622	1
strict recruitment	3.6000	1.1361	2
underrepresentation and unfair treatment	3.5778	0.9412	3
inequality	3.4667	0.9908	4
limited promotion opportunities	3.4667	0.9438	4
Vulnerability	3.4444	1.1976	5
low compensation	3.3111	1.0185	6
uncomfortable conditions	3.2667	1.1751	7

Scale: >1.49 = strongly disagree; 1.5 to 2.49 = disagree; 2.5 to 3.49 = neutral;
3.5 to 4.49 = agree; 4.5 to 5.0 = strongly agree

DISCUSSION

The current paper explores women professional consultants in practice in the construction industry of Malaysia. Consultant firms are considered by scholars in construction industry research due to their operational characteristics which almost mirrors conventional construction organizations. These parties need to cooperate in realizing and implementing projects and their involvement focuses on similar project objectives identified by the client. It is interesting to note that majority of women consultants in the Malaysian construction industry were in the middle age category with less than ten years of experience, and many entered the industry because of financial rewards and the desire for a good career in the industry. Women seemed to be more independent in making decisions regarding their future career. For example, Geertsema (2007) mentioned that people often choose a career in the construction industry if it provides good working conditions, a sense of responsibility and a set of worthwhile challenges. Women also felt that their new found ability to earn money should translate into economic freedom as reflected in their status in society e.g., the ability to buy a house (Enshassi et al., 2008).

Family also plays a significant role in a woman's career. Most respondents said that their involvement is strongly supported by their family, consistent in fact, with a study which found that the family's influence was indeed important for women (Construction Sector Council [CSC], 2010). The study also supported Enshassi et al.'s work (2008) which stated that most women engineers' decision to study civil engineering and architecture was supported by their family, further reinforcing their personal interest to gain employment in the field of construction. Besides that, respondents who were permanent employees indicated their willingness to stay longer in the industry due to their interest, congruent with Enshassi et al.'s findings (2008). They found that majority of women refused to change their opinion regarding their engineering careers, despite the difficulties women engineers may face in construction sites. As for time spent in the office, most of the respondents spent more than 50% of their working hours in the office and the balance on the construction site. Lower hours at site may effectively contribute to the reason why respondents are willing to stay in the industry, as it would be fair assumption for women consultants to prefer to remain in the office, rather than be exposed to the difficult conditions experienced on project sites. This result might be different with women in construction organizations, where their tasks would require more commitment to do on-site work.

Barriers against women's entry to the construction industry

Inflexible working hours is the main barrier preventing women from entering the construction industry. Marriage, and taking on the responsibility as a wife, usually entails bigger responsibility in taking care of a family compared to the husband. Inflexible and long working hours can therefore lead to unproductive and inefficient work outputs for women. The problems increase as the family numbers grow over time, requiring even more time taken for family and leisure pursuits. Raising a family therefore, becomes an overriding priority for some women, and the prospects of long and inflexible working hours become decidedly unattractive. Based on a study by Talent Corp and the Association of Chartered Certified Accountant, in general, Malaysian women strongly desire flexible work arrangements that accommodate family commitments, support, maternal needs, optimum work-life balance and equal opportunities and rewards (New Straits Times, 2013). In the construction industry, women are required to fit into men's culture, but Ginige et al., (2007) argued that as woman is physiologically weaker than man, they may feel more tired and unable to work in the same capacity as her male counterparts.

Unsuitable working conditions form a second barrier against women's entry to the industry. Inadequate information and the lack of education and training concerning workplace health and safety are major concerns among women workers. The culture and attitudes of construction workers, supervisors and companies regarding health and safety often condone risk taking and unsafe work practices, passing "bad" habits from one generation of workers to another. Research conducted in the USA by Robinson and Burnett (2005) to determine the effects of working conditions on the health of women in the construction industry found an elevated mortality percentage for specific cancers and other diseases for women deployed in construction trades.

Family commitment and the responsibility of being a child bearer are other barriers against women's entry to the construction industry. The conflict between work and family obligations experienced by many construction professionals is more acute for women than for men. While men and women both need to balance the demands of work and home life, women still bear the primary responsibility for managing domestic duties in most households (Amaratunga et al., 2008). All of these are related to a woman's child-bearing roles (being pregnant, giving birth, taking care of the children and so on).

The lack of education and practice also serves as another barrier. This is because they are not being exposed to the construction environment and do not have any knowledge of the practical aspects of construction. Parents, teachers and school children believe that jobs in the construction industry are limited to bricklaying, joinery and painting and decorating. School students, undergraduates and graduates also perceive career teachers and careers' advisor as being unable to provide accurate and adequate information on the construction industry (Amaratunga et al., 2008).

The macho culture that prevails in the male-dominated industry also results in the development of a vulnerable mindset among women in the industry. However, in this study, the sense of vulnerability and that of being a victim of discrimination had the lowest response rates. This could be due to the fact that women are able to take care of themselves and exhibit higher levels of confidence. Moreover, women who do enter the construction industry in professional capacities tend to fill technical specialist positions rather than general managerial posts (NWLC, 2012).

Finally, the prospects of relocation and working on shifts can be tenuous for women, especially when required to work long hours and on weekends if a project has to be completed, or if they are required to travel long distances on a daily basis (Baksh, 2012). The construction industry makes extreme demands and expects commitment on time, due to its highly competitive nature. The practice of sequencing has not been proven to work for some women because they often lose their jobs or are replaced.

Challenges faced by women in the construction industry

As mentioned, the major factors faced by women in the industry is mistreatment, followed by strict recruitment, underrepresentation and unfair treatment, limited promotional opportunities, inequality, vulnerability, low compensation and uncomfortable conditions. Women have always been mistreated by male co-workers in the construction industry. Given that mistreatment is a sign of disrespect, such acts can be considered a form of disregard shown by male colleagues for their female coworkers (United Nation Development Program [UNDP], 2003). That apart, women also face the problem of strict recruitment. As women attempt to achieve a greater degree of equality in career advancement, they may face numerous problems such as the tendency of people to evaluate jobs and careers in terms of gender, educational level, income and position (Baksh, 2012).

Other challenges for women include underrepresentation and unfair treatment. Research indicated that women are offered fewer opportunities to develop and grow compared to men (Amaratunga et al., 2008). Although increasing numbers of women have appropriate educational qualifications, the perception that women are generally unqualified or unsuitable for senior management positions still exists.

Women also suffer from limited promotional opportunities and inequality in the workplace. Women who have been in the industry for a length of time inevitably want to move up the corporate ladder, but most are unable to find enough promotional opportunities (Geertsema, 2007) and receive lower compensation than men. Our respondents had the lowest response rate for this item. However, given their lower qualifications, this can indicate that either qualification dictates compensation or the expectations of our respondents were too high.

CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

The construction industry is unique in the Malaysian labor scenario. The statistical data showed that Malaysian women have progressed at a slower rate in the industry while confronting many barriers and challenges. The project based implementation allows many consultants such as architects, engineers, quantity surveyors and project managers to get involved in the industry. Actual practice allows consultants to prepare documents or drawings in the office, while progressively participating with on-site operations during construction stage. Unlike working in construction organizations, women consultants indicated their fairly balanced involvement between office and site works. The findings and implications of this study can be very useful to various parties involved in the Malaysian construction industry as well as future researchers who wish to deeply explore on the participation, barriers and challenges faced by this minority gender in the industry.

It is suggested that women consultants in the construction industry will enter the industry after graduation, but most likely leave after attaining certain age limit. This is a normal scenario, where fresh graduates feel eager to work for the attendant financial rewards and interests stimulated by knowledge gained during studies. However, various barriers such as inflexible working hours, unsuitable working conditions, family commitments and a raft of challenges such as mistreatment, strict recruitment and underrepresentation, and unfair treatment pose major obstacles for them staying in the industry. Malaysia's current economic development pursuits offer many channels for women consultants to enhance their career with flexible working hours, encouragement towards becoming self-entrepreneurial, join the academic sector or venture into firms espousing work from home programmes. Compiling knowledge gained throughout their career years in industry becomes an invaluable asset for the companies. Thus, after securing a career in the organization, consultant organizations must continue to support the sustainability of this cohort for the benefit of the business and industry. Managing and maintaining the talent of this group should be one of the main focuses of organizations in the construction industry. This endeavor should be prioritized towards ensuring that women's involvement in the industry will increasingly and significantly improve over the coming years, given the comparatively high number of entrants at university levels.

This paper also call for various parties in the industry to include within the industry strategic plans special suggestions and initiatives on how to retain women in the industry, specifically those proven capable with good and excellent track record with family obligations, perhaps by developing flexible work schedules and work-hours and by seriously addressing issues of gender mistreatment in the working environment, especially weeding out undesirable elements of sexual chauvinism, harassment and bullying. The industry needs to be proactive and make the first move by creating a fair working environment where women are treated with due respect and fully encouraged to stay in their career track. Initiatives to work from home are good, workable options allowing opportunities for women consultants to contribute their expertise whilst at the same time able to take care of their family. However, the implementation of this programme should be done with specific performance measures agreed by both individuals and organizations.

The basic findings of the study offer some possible recommendations for future works. This research might offer more interesting findings if the respondents were interviewed to get their actual response on each barriers and challenges based on their age factor. Besides only focusing on women, perceptions from men would be an interesting point to be explored as well, for example the study on establishing women's performance and their work commitment. The comparisons between male and female perceptions would lead to comprehensive results to develop an agenda on future women's involvement in the industry. Other than that, future research could also be conducted using a more specific sample population. A limitation in this research was that the study only randomly focused on women in the construction industry and did not cover specific groups such as age, expertise and designation differences. The findings were thus able to offer only general conclusions on women consultant participation in the construction industry, as it ignored the above segmentation.

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UNLEASHING THE POTENTIAL OF TRADITIONAL CONSTRUCTION TECHNIQUE IN THE DEVELOPMENT OF MODERN URBAN MASS HOUSING

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Abstract
The provision of adequate quality housing for the mass population has always been the major challenge for a rapidly developing country like Malaysia. As the country heads towards higher level of urbanization, it is expected to face accelerated demand on housing and the associated environmental impacts. Only by encouraging the development of more efficient buildings or through implementing a holistic construction approach that addressed right from the onset of the design stage, harmful environmental impact to the surroundings can be mitigated. This paper highlights the potential of applying flexibility – a design approach which has been widely adopted in the traditional construction – as an inherent design strategy for the modern urban mass housing. The proposed design strategy entails open plan that enable retrofit and reconfiguration to be made quickly, economically, and repeatedly, without involving excessive site labour, time, and cost; as compared to the currently adopted design strategy which is associated with rigid structure, interlocking plan, and predetermined function. It makes possible the creation of dwellings which may grow old yet without becoming obsolete; incorporating the latest design ideas and technologies, yet have a sense of history on the Malaysian housing design (the *rumah kampung* design); allowing the communities to live for generations, yet incorporating the potential of adaptation. By examining the background research and the fundamental design principles, the paper suggests that only dwellings with high degree of flexibility may enable the integration of dual aims and principles of affordability and sustainability in mass housing, thereby facilitating the movement of the country's construction industry towards mechanization, industrialization, and standardization.

Keywords: *Divergent dwelling deign, sustainable, affordable, housing, flexibility, tropical country*

INTRODUCTION

Housing industry today are overshadowed by two major problems: (i) short supply of adequate housing to mass population as a result of increasing demographics, and (ii) significantly contributing to CO_2 emission, caused not only by activities during the construction period but also after housing is completed and being occupied. While moving towards higher level of urbanization, Malaysia is of no exception in facing mass housing problems that require a solution with the integration dual aims and principles of affordability and sustainability. Keen architects, urban planners, and engineers might have achieved advances in generating single meaningful buildings, but most of them fail to come up with effective sustainable mass housing design when dealing with concentrated urban populations (Gan, 2013). Among the identified major impediments are the lack of research in the field of sustainable mass housing and the challenges of meeting public's affordability level with the fast rising construction cost (Zaid and Graham, 2011; Gan et al., 2013[a]). Based on the Real Estate and Housing Developers' Association's (REHDA) estimation, the price of an eco-friendly house is about 15% higher than the conventional one (REHDA, 2013). Given that the profit hovers around 5% to 10%, coupled with the nature of construction industry which is rather competitive and with extremely high risk, incorporating sustainable or green features into mass housing development is thought of as not cost-effective (Gan et al, 2013[b]). Hence, sustainability features were rarely seen as a mean of achieving affordability. Any movement towards embracing the green cause or promoting a wider notion of sustainability in mass housing is not in the preferable mode of housing design and construction, not to mention the adoption of an unfamiliar system or design principle that requires a major change to the existing housing construction process.

As the era of sustainability is taking its stand, unsustainable construction practices in the building industry are getting increasing attention from the public (Gan, 2013). Issues such as excessive energy and electricity consumption, consuming more raw materials than other industrial sector, generating large amounts of wastes, using heavy materials subject to wear and tear, disruption to nature etc. have become the main topic of public concern. Questions also arise whether mass population is being accommodated in suitable dwellings, and are homes now being developed capable of adapting to occupant's ever-changing requirements. Studies show that residents of mass housing in Malaysia are generally not satisfied with their housing conditions, in terms of construction activities, materials used, aesthetic value, amenities etc. (Karim, 2012; Isnin et al., 2012). Most of them end up renovating houses to tailor-suit their needs before occupancy (Rostam et al., 2012; Nurdalila, 2012; Erdayu et al., 2010). This is largely due to the nature of the current mass housing architectural strategy, namely the convergent design system (Figure 1), which is a "one fits all" design initiative where housing is likely to be designed around the capability of a given product, instead of around the end-user. Thus, houses designed for the average family are deficient in meeting the mass housing sustainability objectives as they are leading to further compromise the occupant's needs.

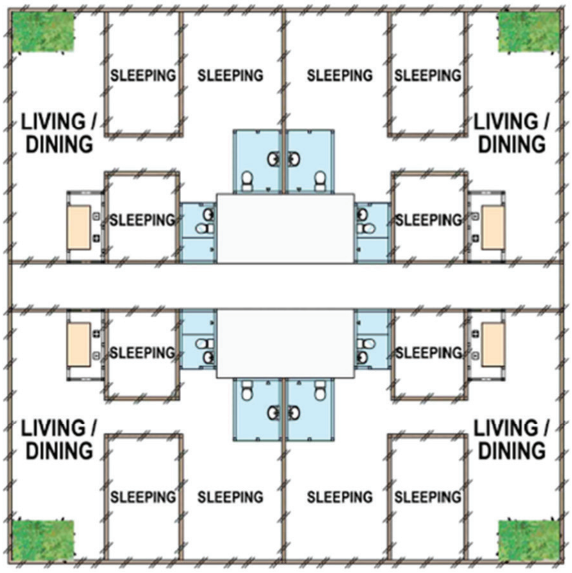


Figure 1. Typical layout of convergent design system

Besides, convergent design system implies to extreme compartmentalization and dissociation of internal elements, where service spaces such as kitchen, bathroom, etc. are built internally by interlocking with space, making the said service spaces difficult to interchange.

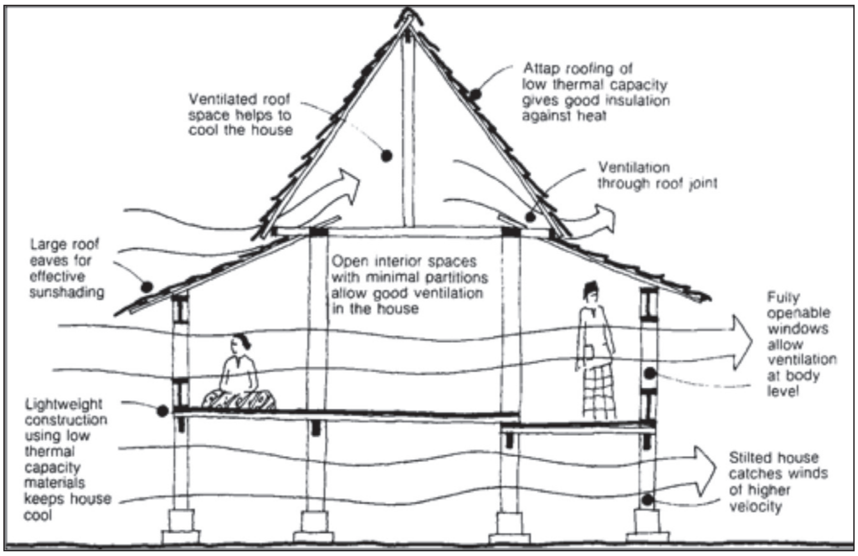
Houses designed and built with this system are solely based on the economic concepts of housing that only measure affordability, ignoring the potential of sustainable housing design that offers social and environmental benefits. The design features can be characterized as rigid structure, interlocking plan, and predetermined function, where very few of them are open plan that enable retrofit and reconfiguration to be made quickly, economically, and repeatedly (Gan, 2013). Even though the convergent dwelling design offers a reasonable alternative of housing needs for the general population, it is found to consider more on the physical development of housing rather than on the sustainable inhabitation. If Malaysia is to negate itself from locking in for an unsustainable future with detrimental construction that disregards environmental issues, a housing design approach that can create greater impact of sustainability to the dwellers, while improving the overall environmental performance is essentially needed. As such, how will the dwelling adapt to changes of a household over its lifecycle, and how can it adapt to suit different households or changes in external social and physical context becomes a tough challenge waiting for a holistic solution.

In this paper, the potential of applying flexibility – a design approach which has been widely adopted in the vernacular architecture – is proposed as an inherent design strategy for the modern urban mass housing. The aim of this paper is to explore how vernacular architecture grant insights to produce flexible mass housing design that will respond to changing demands of the users during occupancy. Within this framework, the paper focuses on the following topics of discussion: (i) what are the features of flexibility offered by the vernacular architecture; (ii) what is the scope of flexible housing in Malaysia; and (iii) how does the proposed design system address the issues of affordability and sustainability within the context of modern mass housing?

DESIGN FOR FLEXIBILITY – INSIGHT FROM THE VERNACULAR ARCHITECTURE

Flexibility refers to the idea of accommodating changes over time (Siddharth and Ashok, 2012). It is an innovative approach to architectural design that enables facilities to be retrofitted quickly, economically, and repeatedly. The concept of flexibility has long been a hallmark of the office and commercial spaces design. In-line with the new trend of residential housing design, the concept of flexibility is further intensified in the design of housing, as housing in the present day required to consider not only about housing one family or group of occupants over their lifecycle, but also allowing new residents to adapt the dwelling to their needs, or to allow a suitable mix of dwelling exists in an ever-changing environment. Flexibility, in the context of housing represents a comprehensive research on cases in the European context beginning from the early twentieth century (Siddharth and Ashok, 2012). According to Schneider and Till (2007), who introduce "flexible housing" by providing a criticism on the current condition of housing in the UK, housing flexibility addresses a number of issues related to the current and future needs of the users as it: (i) offers variety in the architectural layout of the units; (ii) includes adjustability and adaptability of housing units over time; and (iii) allows buildings to accommodate new functions.

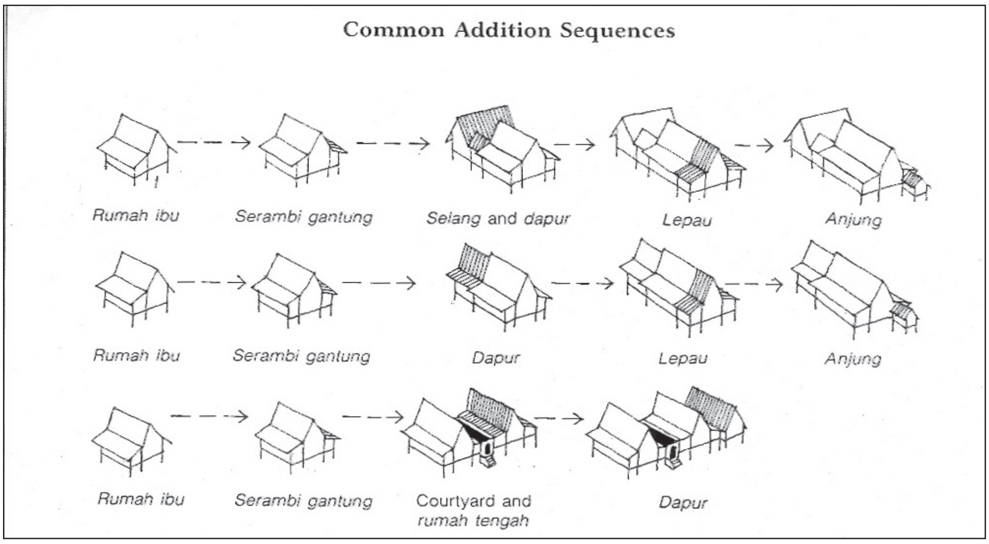
In Malaysia, the idea of flexibility has long been the key feature of design in the vernacular architecture. This is well reflected in the traditional Malay house, where the residential environment is not only designed to respond to the occupant's living demands, but also fully integrated with the tropical climate and the uses of local resource (Figure 2). The traditional Malay house is constructed by employing sophisticated architectural processes that has been proven to be harmony and successfully maintaining the capacity of the rainforest ecosystem (Che Amat et al., 2009; Nordin et al., 2005). Its design approach is ideally established based on the accumulated local knowledge, way of life, culture, and the deep understanding of natural environment. Apart from being the richest component of the country's cultural heritage, traditional Malay house is also recognized as the most sustainable building in the past, even until today, due to its design and construction process that takes into account energy efficiency, indoor environmental qualities, sustainable site planning, and the uses of local materials and resources. Typical example can be seen from the house orientation, where high-pitched roof not only encourages stack effect function but also acts as solar shading devices (Ramli, 2012). Besides, building on stilts allows cross-ventilating breezes beneath the dwelling to cool the house whilst also mitigating the effects of occasional flood as well as ensuring safety from possible attack by wild animals (Amad et al, 2007). Plenty of windows and openings allow more natural lighting while capturing high-velocity of air movement (Ramli, 2012). All these features have been proven to be the most effective passive design for a tropical building, as it increases the overall building's thermal comfort and energy efficiency. The application of Malay house's features into the design of low energy building can be seen from the Ministry of Energy, Green Technology & Water (MEGTW) Building, where among the features to be re-adapted are such as the consideration of building orientation, fenestration design, the application of natural lighting system, natural air ventilation system, and the arrangement of interior spaces (Ramli, 2012).



(Source: Lim, 1991)

Figure 2. Climatic design of the traditional Malay house

In terms of construction, the Malay traditional house utilizes the technique of housing components prefabrication, which has permitted flexibility in the development of the house form. All the components that make up the structural framework, roof trusses, stairs, wall and floor panels, and roof surfaces, are made before erection of the house begins (Hassan, 2001). Structural framework such as columns (*tiang*), beams (*rasuk*), secondary beam (*gelegar*), primary roof beam (*alang panjang*) and secondary roof beam (*alang pendek*) are assembled on site to form the primary framework. Through this flexible housing construction approach, the traditional Malay house is capable of expanding from time to time, based on the occupant's affordability level and demographic concerns. With the basic type (i.e. *rumah ibu*) forms the 'core house', the house size is changeable along with the occupant's future requirement. Whenever additional finance is available or as the family grows larger, the house is capable to evolve, not only in terms of configuration and appearance, but also in respond to the explicit need through accommodating a wide diversity of users and household types (Figure 3).



(Source: Lim, 1991)

Figure 3. Possibility of expansion – the flexibility of traditional Malay house.

SCOPE OF FLEXIBILITY IN RESIDENTIAL HOUSING

Today's Malaysian residential housing does not incorporate the concept of flexibility in its design. The present mass housing design is said to have lost its build form identity in terms of rainforest and tropical landscape. This is largely due to the country's planning pattern and construction system, which adopt planning laws, building codes, and regulations borrowed from the West that promoting heavy weight construction using bricks and reinforced concrete as the main materials, has forbidden housing development based on traditional concepts (Hassan, 2001). Besides, the practicing housing construction method which is derived from system used since 1700s (the period of Industrial Revolution in Europe) is outdated. It is unlikely taking environmental concern as a primary consideration. What makes the condition even worse is that almost all housing programmes that initially aimed to tackle the country's housing shortage, is simply to augment the housing supply with minimum concern for social tradition issues (Hassan, 2001). For example, the housing industry is required to construct at least 100,000 affordable housing units per year (or 274 units per day) following the launching of 1 Malaysia People's Housing Scheme (PR1MA). Question arises concerning how far these programmes have succeeded in providing physical and social wellbeing of the population, considering the country's current housing design strategies are unable to cope with the incredible demands on such massive scale in sustainable manner.

For mass housing to be an attractive option for the average family, the provision of architectural flexibility is essential (Singh et al., 1999). Since each dwelling unit is a primary structure that would contribute to the quality of life through its flexible organization, and the root causes leading to housing quality problem are identified as issues related to housing layout and design, surrounding environment, maintenance, location, amenities, and building material (Živković and Jovanović, 2012), flexibility should be reflected, as much as possible, within all aspects of the housing type. According to Friedman and Krawitz (1998), elements to be considered for a flexible housing should include: (i) the composition of the varied households within the single structure; (ii) the choice of components that are available; and (iii) the ability to make future modifications with minimal inconvenience. In other words, each dwelling unit should be designed, in such a way that it is economically and easily adjustable, while adheres to the context of contemporary technology, tropical adaptation, and cultural responses. The key design element is the realization that lifestyle – as one of the defining characteristics of peoples' lives as citizens, consumers, and householders – is a feature that shifts in accordance with a dynamic lifecycle process. A home that can be altered with minimum effort and expense at a time of change in the lives of its owners, whether through such a minor intervention as the rearrangement of furniture in a non-restrictive space or through more vigorous modification such as the relocation of living or storage spaces, is a home that evolves with the lifecycles of its household rather than becoming rigidly obsolete in the conventional manner (Friedman and Krawitz, 1998).

DIVERGENT DWELLING DESIGN (D3) – PROPOSED MASS HOUSING SYSTEM FOR TODAY AND TOMORROW

The proposed mass housing design system – Divergent Dwelling Design (D3) – is an inherent design strategy of sustainable development that fully utilized the idea of flexibility. It is inspired by the traditional Malay house design approach that accommodates freedom for change of preference even after the structure is built. Each function unit (*rumah ibu, dapur, serambi, anjung* etc.) combines divergently to reduce the immense intricacy of architectural phenomenon to simple constant units and bring about an effective formation of a flexible dwelling system (Figure 4). By having the same models, structures, and constructions, D3 can produce millions of combinations, where each of which is of high level of flexible form and function in architectural organization with sustainable manner – capable of continuous modification, renewal, and redesign (Figure 5).

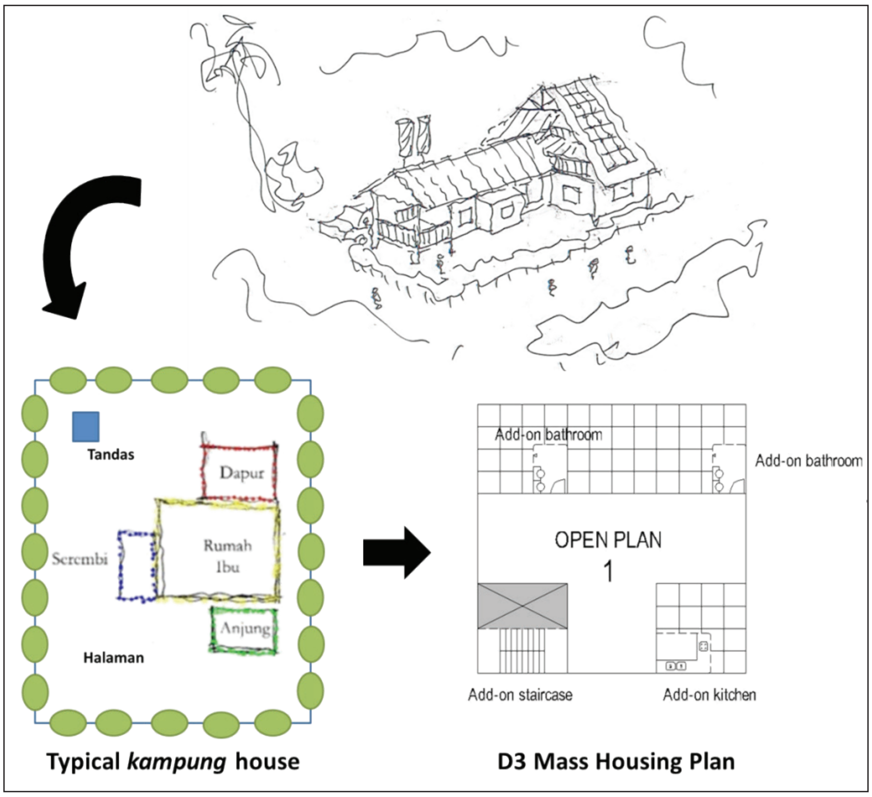


Figure 4. D3 design process

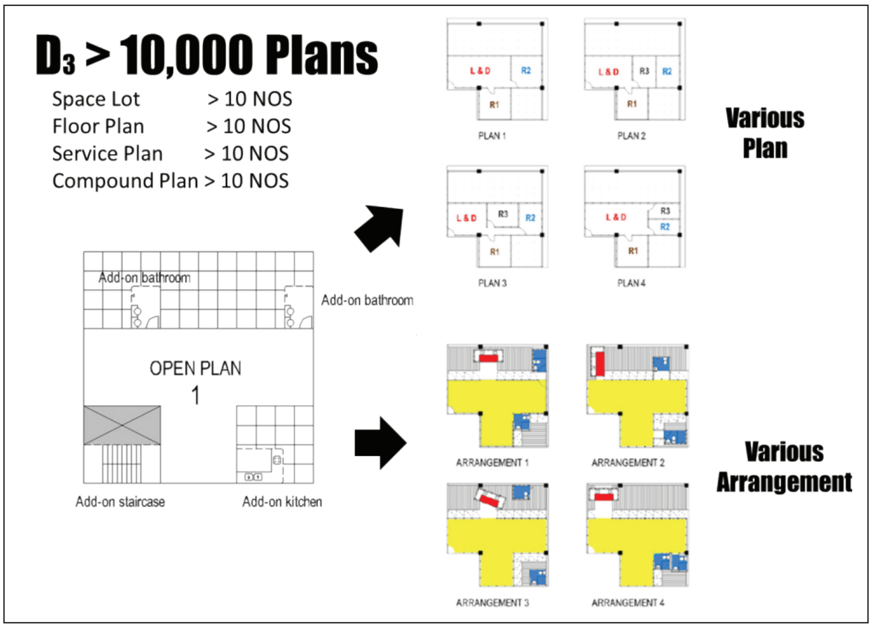


Figure 5. Possible combination of D3

In layman terms, D3 is an architecture where service spaces are attached externally to form dwelling of which the service spaces can be changed to accommodate different functions with minimum or no disturbance to the core structure (COR) (Figure 6). The concept is similar to the other existing facilities in modern industry (automotive innovations, electrical appliances, furniture, etc.) where each individual functional unit is freely bonded with the COR to serve different occupants' requirement. The COR, as a module, houses every independent functional unit of the dwelling and also forms the space for further expansion. The sustainability focuses on providing spaces to be used for a variety of purposes over time, be it the changes of household demography or the changes of resident's living satisfaction. Since this kind of functional change can be done by merely switching of the independent units within the configuration through a simple process, the function of the dwelling unit can be cultivated and adapted to the occupant's need whenever it is required. For example, a residential space can be converted into a café by just incorporating a larger kitchen and more toilets; a laboratory or playroom or computer room when added with a unit space for teaching can be used as an educational institution. So similarly the kind of unit space or constant space can change its function from residential to commercial, without ever needing to change the basic unit. As such, D3 system makes possible the creation of dwellings which may grow old yet without becoming obsolete; incorporating the latest design ideas and technologies, yet have a sense of history on the Malaysian housing design (the *rumah kampung* design); allowing the communities to live for generations, yet incorporating the potential of adaptation.

Another feature of D3 is that the system utilizes amply science, technology and industrialization in the formation of a unit. For example, bathroom and kitchen dimensions are fixed for mass production. The occupant has wide spectrum of choice with regards to products in the market. Since each unit is independently constructed by machine production, the development entails the use of technology and innovation, without the involvement of excessive site labour, time, and cost. In this sense, divergent design concept comprehends the advances of science and technology over time, thereby resulting in faster production at economical rates. More crucially, it helps to boost a greater productivity, better quality, and an assurance of a growing and interested housing market in the 21st century. Once the design system is in tandem with serial production and standardization, there will be no bounds for the development of sustainable community (Figure 7). It is because every detail can be perfected – just like the automobile and telecommunications industry, has seen continued advancement in technological innovations that have benefited consumers in the long run.

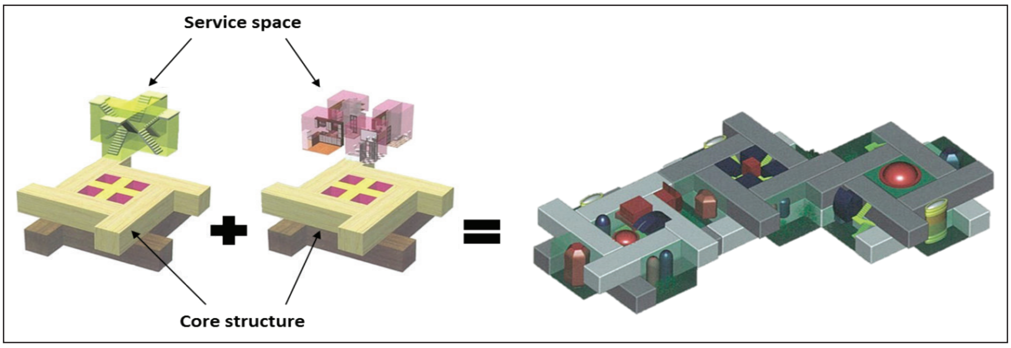


Figure 6. The concept of Divergent Dwelling Design (D3)

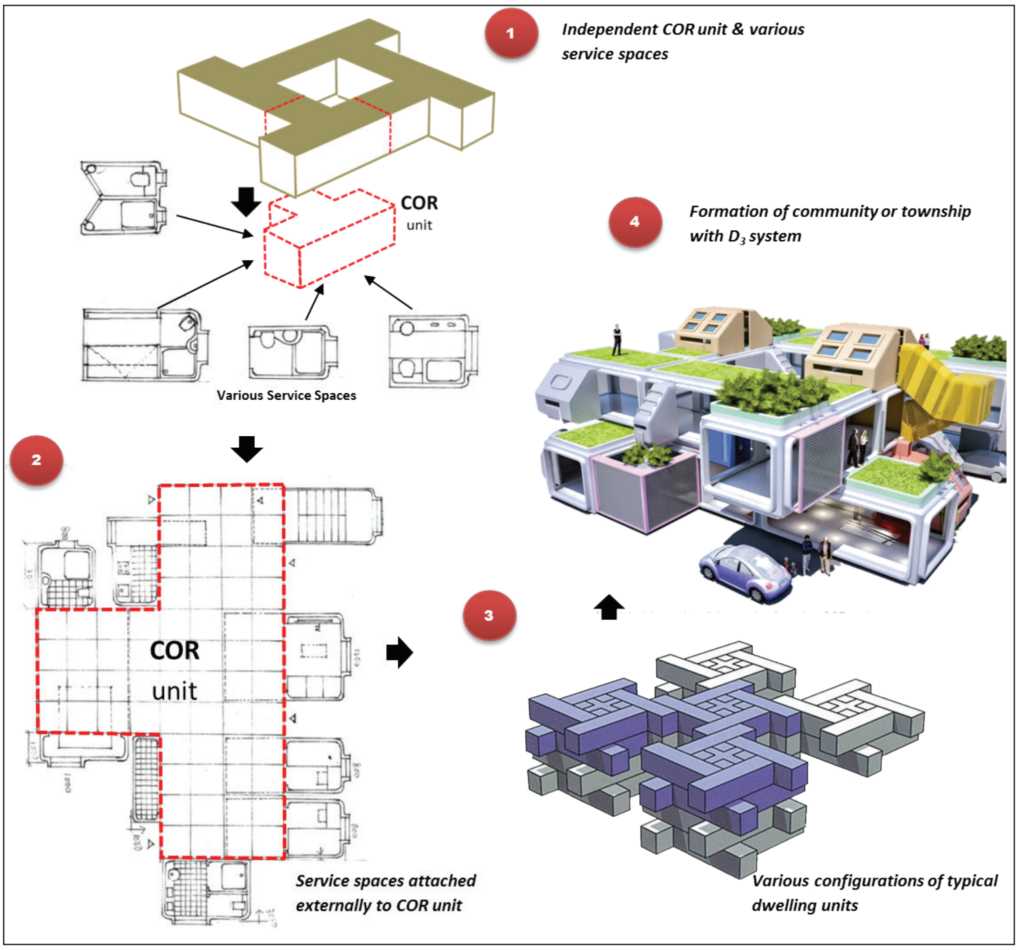


Figure 7. The application and evolution of Divergent Dwelling Design (D3) system

DESIGN PRINCIPLES OF D3

D3 directly responds to the fundamental demographic and economic pressure that have recently heightened the need for a new housing alternative that appropriately integrates affordability and sustainability. To ensure mass housing populations could enjoy eco-housing with affordable price, affordability is designed in at the beginning by adopting a simple design layout. This is to avoid the use of unnecessary technology which is costly to buy or repair, so that the house is easy for maintenance in the future. Besides, defining affordability in relation to housing within the ambit of sustainability broadens its scope by involving the social and environmental perspectives. The element of sustainability in D3 is ensured through a flexible design prototype that suits to the climatic condition in Malaysia, using environmental friendly method, contribute to the sustainable development of the construction industry, offers what people demand from a house and that they can live how they want to within it, by taking into account (i) the spatial and functional arrangement, (ii) the potential to expand spaces for increased occupant's usage, (iii) maximizing natural lighting and ventilation, (iv) the continuity of the traditional housing concepts into a modern contemporary residential development.

In general, D3 system utilizes four level of housing design principles: (i) the design of unit plan; (ii) the design of unit configurations; (iii) the design of sustainable strategies; and (iv) the design of structure and construction.

The Design of Unit Plan

In D3 system, the unit plan is designed to respond to the demand for more space and the changing circumstances of the occupants. It allows the flexibility in forming the basic unit configuration which then responds to the nature of the site conditions as well as the improvement of living environment quality (Figure 8). Internal space is adjustable according to the requirement of the user through adopting an open plan design. The dwellers are able to choose the interior components to tailor the design to their individual lifestyles and budgets, and can easily modify these initial parameters as the need arises. By enabling the floor plan to be adapted to the future users and the changing needs of families, D3 unit plan is also said to take into account different family types: (i) dynamic family which is likely to have more children in future, and is thus requires a high degree of space flexibility to cater for continuously changing and increasing needs; (ii) stable family which is not going to have any more children (either the children have left home or are too small to leave home) and thus requires a relatively lower degree of space flexibility; (iii) stagnant family which is expected to live in the same dwelling for a long time and thus has sufficient opportunity to benefit from flexible building elements, which provides for lower life-cycle cost of such elements. With dwelling unit built according to this flexible design principle, users are not only given the chance to choose the floor plan they want to live before moving in, but are also able to achieve harmony between the basic structure and the various sizes of dwellings in the long term, in accordance with rising space standards and the possibility of new family members in the future.

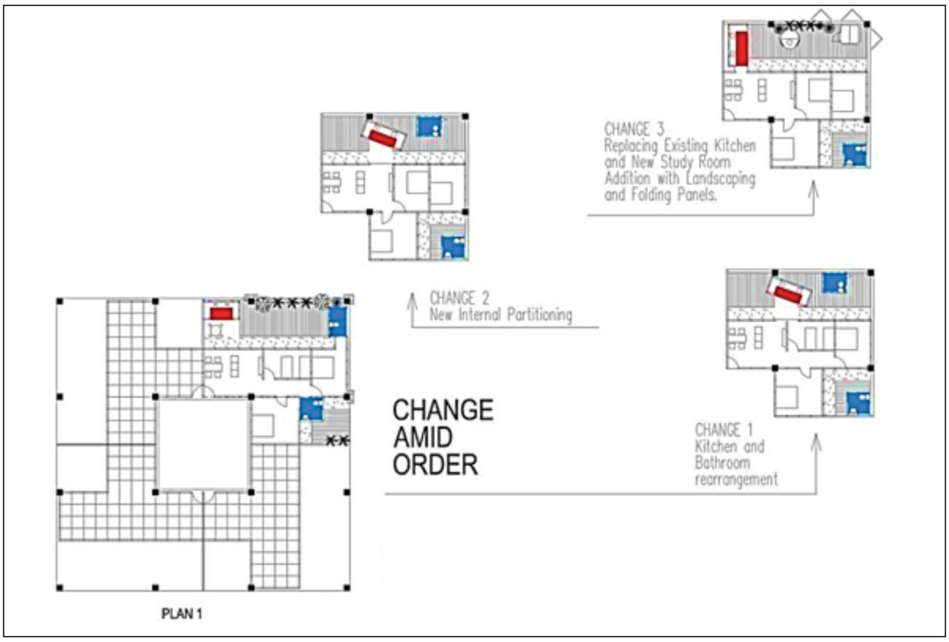
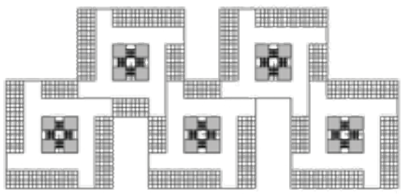
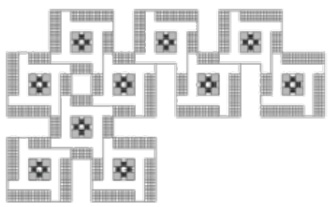


Figure 8. The design unit plan with D3 system

Unit Configurations Design

According to the Construction Industry Master Plan (CIMP, 2006 – 2015), the quality in construction industry encompasses more than contractors alone. Architects and engineers may have to be involved as well since they are the contributing factor to quality failures (material faults, construction faults, and design faults), where 50% of the failures can be attributed to design faults, while the remaining 40% and 10% are due to the construction and material faults, respectively. Since the formulation of the National Urban Policy is to the provision of adequate, affordable and quality housing for all Malaysians, it is essential to include environmental clause in every project development as to strengthen environmental control and preventive measures. A flexible design can respond to events, even when they unfold in unpredictable ways. On a much larger scale, there is current interest in the adaptation of the built environment for climate change. Because the rate and severity of future climate change is unpredictable, design for adaptation is best achieved by providing lifecycle options that will allow future decision makers to respond appropriately to the trajectory of climate change that actually occurs. D3 will sure to put sustainable architecture along the curve followed by science, technology and industrialization, and facilitates a shift towards higher quality housing development that eventually creating sustainable community for everyone in anywhere in the country.

Figure 9 shows some possible formations that can be achieved with D3 system. By combining each and every sustainable individual dwelling, a greater sustainable community or township is formed. No part of it needs ever be obsolete. One does not have to determine in advance the overall makeup of the group of units, for the whole community may just be cultivated or generated in a naturally evolving manner. This programmable dwelling pattern will enable a variety of dwellings to be processed, to constantly renew themselves owing to industrialization and with rational rearrangement of all available habitual spaces and incorporation of machine production resulting in the community that has no slum, and where no redevelopment is necessary. Fundamentally, the evolutionary nature of the D3 – the notion that housing to be designed to evolve not only in configuration and appearance but also in use – responds to an explicit need to accommodate a wide diversity of users and household types.

Types of Formation	Description
	**Linear Formation** Like a straight line that stretches from one point to another, positive and negative COR units are configured to extend in a single path to form a straight row of units.
	**Branching Formation** In each unit there are four possible corners that can have connection. The combination of positive and negative units can stretch in any or all of the four directions.

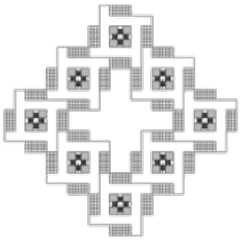
	**Ring Formation** When the arrangement of units stretches to eventually be joined back to the original unit it started from the combination produces an overall “closed” structure.
	**Cellular Formation** Except for the peripheral units in a network combination, each unit is joined on every one of its four corners by other units.

Figure 9. Types of formation in D3 system

Sustainable Strategies Design

In D3 system, flexibility and adaptability are key strategies for sustainable design. The use of concrete construction ensures many of the qualities that aid flexibility in housing design. Concrete is an inert material, with no harmful off-gassing emissions. Coupled with its structural form, concrete is the construction material most commonly associated with building designed with enhanced natural ventilation and daylighting. Concrete construction presents great opportunities to meet the needs of the users by helping to improve the function, value, and whole life performance of the house. With its high thermal mass, concrete construction can reduce energy requirements during the operation of the building by moderating energy demands in cooling and beating buildings, thereby adding to the value in use of a school building. Besides, concrete contributes to the range of other inherent benefits at no extra cost, such as its proven integral fire resistance, high levels of sound insulation, and robust finishes. Through its very nature, concrete provides robust surfaces for walls, partitions, columns, soffits and cladding that are easily sealed and free of ledges or joint details. All these may finally lead to the lower maintenance costs of the building while set in motion an efficient, cost effective and practical method for solving housing needs and overcrowding concerns in urban areas.

The use of a reinforced concrete skeleton structure which allows the design of floor plans that are variable to accommodate different family structures, coupled with the constant improvement in structural design and technology supported by the incorporation of lightweight, durable, smooth edged, space efficient and universally adopted specifications ensure that mass housings remain affordable and sustainable for the long term. The overall result/outcome of the sustainable strategies design can be seen by observing how the dwelling units encourage maximum cross ventilation, minimizing heat island effect, facilitating new technology installation, and promoting green architecture (Figure 10).

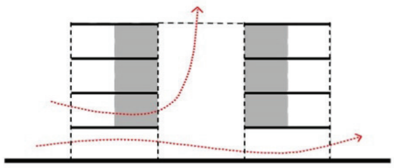
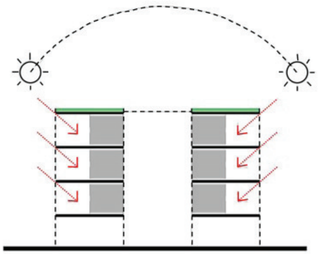
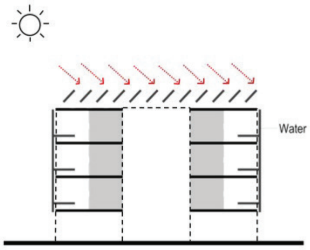
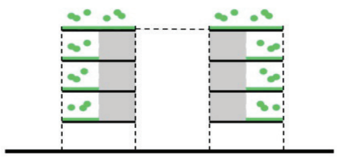
Sustainable Living System	Description
	**Cross Ventilation** Open plan allows easy passage of air and good ventilation.
	**Heat Island Effect** Reduction of 85% heat island effect on wall surfaces
	**Sustainable/Green Technology Installation** Photovoltaic panels and rain harvesting can be incorporated easily.
	**View and Vegetation** Vegetation helps to cool down overall environmental temperature.

Figure 10. Achievable sustainable living system through D3 sustainable strategies

Structure and Construction Design

There is usually a cost with the provision of a structure that allows the most flexibility and adaptability. However, with early consideration of the benefits of using concrete during the design phase, flexibility of the dwelling can be optimized at little or no extra expenses. It is because the use of concrete is compatible with fast housing construction, in part due to its easy mobilisation at the start of a project. In a departure from the conventional mass housing design, D3 system generates a better and cheaper habitat option through the application of existing science, technology and machine production capability. By incorporating IBS and industrialization into the construction process, a compressed construction schedule is not only cost-saving in and of itself, getting the building into productive use sooner and reducing finance periods, but, especially in times of significant inflation, compressed construction schedules save additional significant sums. It is because the use of modern methods of construction, including sophisticated formwork systems, posttensioning, prefabricated roll out reinforcement and precast elements can all save time.

In D3 system, modular construction concept is widely adopted, where pre-fabricated elements or existing structures are used as the basic structure while additional natural materials are used to add insulation or to adjust the aesthetics. This allows for the construction of various building types, be it the low-rise low-density configuration, vertical tower configuration, low-rise high density pyramid configuration, or the high-rise high density configuration (Figure 11). Short term flexibility can be achieved by movable partitions. Since common walls between the dwelling units are non-load-bearing walls, the dwelling unit floor areas can be arranged independent from boundaries, thereby providing an entirely flexible arrangement of living room and wet room locations in the plan layouts. Partition walls in D3 system that enabling flexible planning will encompass the following features: (i) easily applicable; (ii) produced in standardized dimensions and not require base coat; (iii) easy to remove any traces left by demounted partition elements on the adjoining elements, such as floors, ceiling, face walls, and fixed partition walls; and (iv) possible to coat them with different materials and to change colour and texture of their surfaces in accordance with the requirements of the space and the individual taste of the users.

In the longer term, adaptability is needed over the life of the dwelling unit to allow internal walls to be moved, to change the size or use of spaces or suites of spaces. As such, flexibility is achieved through both the arrangement of columns and load-bearing walls and the possible clear span. Steel or pre-stressed reinforced concrete floor systems and components are used to obtain maximum clear space in the plan layout. The ceiling surfaces are clear, and beams are hidden in the exterior wall axes or fixed infill wall axes. All structural elements are located at the exterior of the layout to allow for unlimited unobstructed clear spaces that can be freely arranged over the life of the dwelling unit.

There is also the bonus of a gain in flexibility in the process of designing the primary-use spaces. Architects and planners have more time to work with clients, medical consultants, and others to plan these spaces more effectively. Additional costs may be saved by increasing the number of contractors who can bid on a single job that can now be divided into several jobs. Smaller, more competitive firms, whose bond limitations might have precluded their undertaking a project as costly as an entire hospital, can bid on individual aspects of the project – say, the M/E core alone.

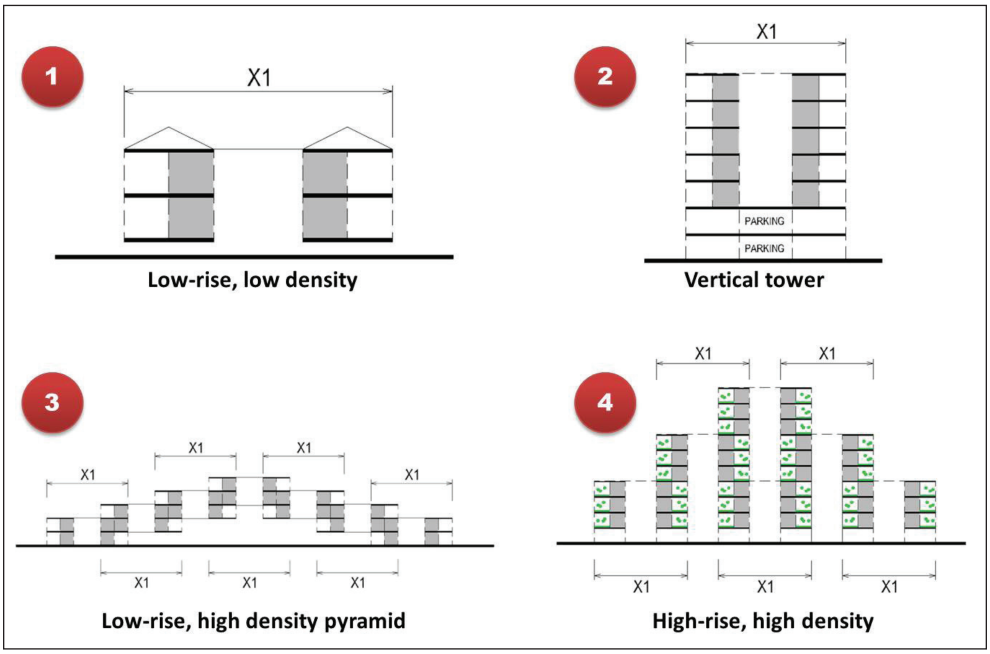


Figure 11. Possible building types with D3 system

CONCLUSION

Affordable housing in the past has never been designed to last. It was aimed to provide a short-term solution – maximum number of houses in the shortest possible time – to meet the urgent housing demand as if poverty and lack of affordable housing is a short-term problem. Although it is a government effort in providing adequate and affordable housing for the general population, the new contemporary household with its diversity of interior design needs in their consideration of future housing prototypes can no longer be ignored. Moreover, in the realm of the current architecture and urban planning, affordable housing development is acquired to last into the future without becoming obsolete, as sustainability is increasingly embedded into building regulations and is no longer perceived as a novel idea pertinent to only certain locations, populations, or building typologies. Realizing that past trends of energy and resource consumption for constructing and operating the built environment are no longer feasible to continue environmentally or economically, how architects design affordable housing that is intrinsically sustainable becomes the most essential. Many people think that sustainability is about planting more trees. Yet even more people believe that sustainability is about producing green energy with more solar panels. But very few realize that sustainability is all about ensuring dynamic balance of environment through the regulatory mechanism of divergent design process.

This paper suggests that the incorporation of flexibility in architecture is essential for the design of affordable housing that is environmentally, economically, and socially sustainable. D3 – a new design approach to the sustainable living system that derived from the tropical vernacular architecture – has lots to offer towards sustainable construction solutions in the development of affordable housing, as it is not only able to reduce both the initial build cost and running expenses of housing construction, but also balance affordability, durability, and adaptability in designing sustainable solutions that are resistant to obsolescence. Due to its consideration in addressing the shortcomings in the current housing development, as well as taking into account the beginning of the design process for the dwelling unit, the construction process, and the flexibility in future development, D3 is capable to redefine tropical housing as adaptable and resilient, and shows promise for the creation of more environmentally and economically sustainable architecture and infrastructure.

Malaysian demographics are changing rapidly, with average households becoming smaller as an increasing number of people live independently in their later years. Prefabrication and modular construction are believed to be the solution for constructing houses that meet the vast number of demands in urban areas. Yet, as a housing strategy it is still considered unresponsive to local climates and conditions with low acceptance rate. One of the problems that Malaysian prefab housing industry does not perform as well as other countries (i.e. US, Japan) may likely be due to the lack of variability and an individual identified design. At this juncture, how prefab housing design can be evolved from mass repetitive production level to mass customization level that account for flexibility and variability is the primary issue to be explored. D3 system discussed in this paper is deemed to bring improvement to the country's prefab housing industry with respect to time, cost, and quality, through the design of adaptability of individual residential units, the buildings that contain those units, and the surrounding site. On a much larger scale, there is current interest in the adaptation of the built environment for climate change. Because the rate and severity of future climate change is unpredictable, design for adaptation is best achieved by providing lifecycle options that will allow future decision makers to respond appropriately to the trajectory of climate change that actually occurs. D3 will sure to put sustainable architecture along the curve followed by science, technology and industrialization, and facilitates a shift towards higher quality housing development that eventually creating sustainable dwellings for everyone in anywhere in the country.

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REVIEW OF CARBON EMISSION AND LCA APPLICATION TOWARDS SUSTAINABLE BUILDING

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Abstract
Building sector contributes to a significant amount of carbon emissions and consumes enormous environmental materials and energy. The assessment on all phase of building life cycle can be applied as a robust approach in reducing impact from building industries. Embodied energy and carbon emission are the most targeted parameters in order to implement sustainable building. Thus life cycle assessment (LCA) tool application in building sector becomes an important approach in evaluating building performance. This review attempts to investigate the application of LCA in building construction process in order to promote low environmental impact and sustainable building. Wide application of LCA in many types of buildings and countries suggest the efficiency of this tool in evaluating building performance in terms of life cycle approach. Thus, implementation and application of this approach in building sector is well recommended towards energy saving and emission reduction as well as natural resource conservation.

Keywords: *Sustainable building, life cycle assessment, embodied energy, CO_2 emission, construction, Malaysia*

INTRODUCTION

Global warming and climate change are significant effects of greenhouse gases (GHG) due to pervasive use of fossil fuels. Many researches reveal that global climate is changing rapidly and will continue with time (Cabeza et al, 2014). This is because high concentration of GHG traps heat from earth surface which in turns increase the earth surface temperature. CO_2 emission which is one of GHGs is the most important gases because of its features of high grow rate, largest atmospheric concentration and longer atmospheric life time (Kumar and Imam, 2013). Other than environmental impact, CO_2 concentration also can cause carbonation to the concrete structure that can reduce the strength of the structure such as buildings and bridges (Kumar and Imam, 2013). Moreover, major source of CO_2 emission in Malaysia particularly relates with energy industries due to fuel used for producing electricity, petroleum refining and natural gas transformation followed by transportation and manufacturing industries including construction (NRE, 2010). There is also severe environmental degradation affecting our world that can endanger the current and future generation. Thus, it is important to mitigate the environmental problems that associated to anthropogenic activities in order to conserve our world (Sharma et al, 2011; Cabeza et al, 2014).

As industry, transportation and building construction are the world primary economic sectors (Al-homoud, 2001), Malaysia has the tremendous growth of economic wealth that is supported by effective Malaysia economic plan. Being a developing country, building industry in Malaysia is one of the rapid development sectors. On average, the construction activity in Malaysia is concentrated at the central region containing the states of Selangor, Kuala Lumpur and Putrajaya (DOS, 2011). The development of construction industry is based on the economic activities that crucially require building that serve a variety of functions such as office, housing and factories. High energy consumption and natural resources that always relates to buildings are responsible to produce high emission of CO_2 (Dimoudi and Tompa, 2008; Gustavsson et al, 2010; Monahan and Powell, 2011; Sharma et al, 2011).

Building sector consumes high amount of energy throughout its life cycle from manufacturing processes of building materials until its demolition (Ibn-Mohammed et al, 2013; Cabeza et al, 2014). Because of great energy consumed, building industries are responsible to almost 30-40 % of global CO_2 emission (IPCC, 2007; Chau et al, 2012; Jeong et al, 2012; Ibn-Mohammed et al, 2013). According to Harris (2012) and Syed Fadzil and Byrd (2012), energy demands of a building is based on the building designs, environment and operation processes such as heating, cooling and lighting. Moreover, building operational energy is always the main priority as operational energy of housing accounts about 85-95 % of total energy use (Thormark, 2006; Dimoudi and Tompa, 2008; Jeong et al, 2012). Basbagill et al (2013) also reported that energy use in building (includes all energy required to construct a building and also building embodied energy) is the main concern in order to mitigate the impact of building sector to the environment. Embodied energy is defined as the energy that is required in processing the building materials (directly and indirectly) as well as the transportation method to deliver the materials to the construction site and assembly processes (Treloar et al, 2001; Fay et al, 2000; Chang et al, 2012; Ibn-Mohammed et al, 2013).

Crisis on energy relates to the ability to support the needs for growing population and the impact of fossil fuel consumption, which has always been debated. The rising awareness on natural environment creates sustainability indicator that includes social, economic and environment which in turn draws an attention to the construction industry in both developed and developing countries (Ortiz et al, 2009a; Cabeza et al, 2014). Then, the sustainable building principles arose with an objective to conserve the natural resources; water and energy; and represent health built environment (Berardi, 2013). Thus, several sustainable buildings are introduced such as the construction of buildings with low energy intensity and green building to minimize the environmental impacts and to evaluate the performance of the building. Moreover, with aims to reduce energy consumption of a building, passive building and zero energy building have been proposed while providing so called criteria in improving building performance. There are several measurement tools available in assessing environmental impact from building and to overcome the world problems of resource depletion and environmental degradation, one of it is life cycle assessment (Cole, 1998; Treloar et al, 2004; Thorn et al, 2011; Peuportier et al, 2013).

Life cycle assessment (LCA) was design purposely to have clear understanding on how environmental impacts are generated of a product and services during their whole life cycle (Blengini and Di Carlo, 2010; Peuportier et al, 2013). Moreover, this assessment is the best measurement tool due to its completeness in emphasizing the product's life cycle starting from raw material extraction until the end of life of the product or system by using cradle to grave approach. The application of LCA for environmental assessment evaluation of a product development process is very wide but in the building sector, it was just in the last 10 years (Singh et al, 2011; Buyle et al, 2013; Cabeza et al, 2014). The application of LCA in terms of building sector is a practical management approach to achieve optimum cost and solution through process of design, building material extraction, material processing, construction, building operation and disposal management (Chang et al, 2010). Therefore LCA can be an important tool in construction management in Malaysia in providing adequate information on building construction impact to the environment. This paper aims to provide an overview of construction activities in Malaysia and reviewing the importance of application of LCA in building construction. Thus, the embodied energy was quantified to provide some information on building materials and comparison to other studies.

CONSTRUCTION INDUSTRY IN MALAYSIA

Industrial sector in Malaysia is dominated by services sector, followed by manufacturing, agriculture, construction and mining respectively (MOF, 2012). According to Abd Hamid (2012), construction industry in Malaysia is crucial for generating wealth to the country so the function of this industry cannot be underestimated. As one of the main contribution to Malaysia's economy, construction industry plays important role in providing excellent services to meet the needs of the people. In year 2010, non-residential sub-sector led the Malaysia's construction industry because of rapid construction of industrial building, office building and retail building especially in Klang Valley (DOS, 2011). Other sub-sectors which are civil engineering, residential and special trades also reported outstanding performance especially with high encouragement from the government. Figure 1 shows the performance of sub-sector in construction sector in year 2010.

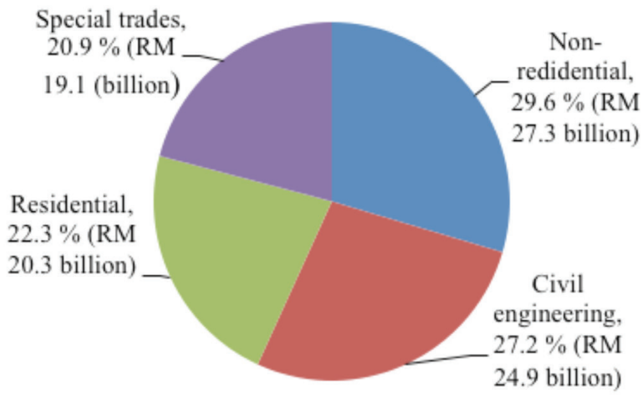


Figure 1. Share of sub-sector in Malaysia construction industry in year 2010

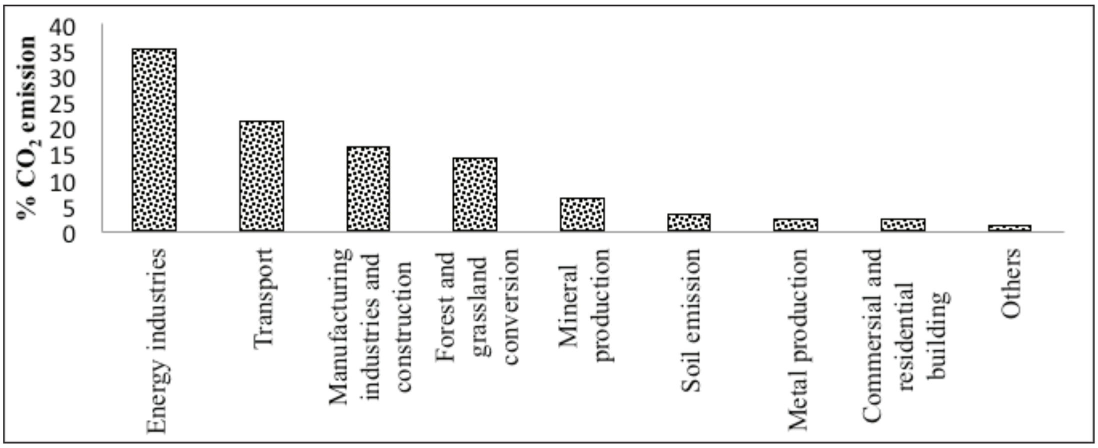
The green building certification schemes has been specified by a few of the policy makers and professional representative since year 1990's (Peuportier et al, 2013). While in Malaysia, this term is still new and was launched in year 2009. Malaysia government also played a big role in supporting and encouraging private sector in developing green building as the rating tools had being introduced in assessing the performance of green building. For example, the green building in Malaysia includes Ministry of Energy, Green Technology and Water building called Low Energy Office; Malaysia Green Technology Corporation, Green Energy Office; Energy Commission Diamond Building and several more. As reported by Chang et al. (2010), the implementation of green building approach needs to be supported by economic incentives such as tax rate reduction and low-interest loan in order to trigger the supply and demands for widespread development of environmental friendly buildings. Same action had been taken by Malaysia government in encouraging development of green building by tax exemption for the owner of the building and introduction of Green Technology Financial Scheme in year 2010 to accelerate the development of green building and green technology. In other hand, the development of green building is very expensive so it is usually dominated by high income company and high expertise is required, normally acquired from outside the country. The obstacle of green building especially in Asia cities is that building designers do not seriously take into account on the coordination of rating standards and there is also lack of consistency (Chan et al, 2009; Zuo et al, 2012).

Building sector scenario in Malaysia currently tends to only focus on improving the performance of building by reducing the construction's duration and workload. In year 2003, the cabinet agreed with the implementation of national blue print of Road Map Industrialised Building System 2003-2010 for the introduction of Industrialised Building System (IBS). IBS is the construction processes which involves prefabricated components and on site-installation with objective to improve construction quality and productivity, uniform design, accelerate construction time and reducing the dependency to foreign worker (CIDB, 2003; MOF, 2008). The application of IBS in Malaysia started in early 1960 and was adopted from European countries after representatives from Ministry of Housing and Local Government visited several building with IBS system (Abd Hamid, 2012). Until December 2010, there are 357 projects with valued RM7.82 billion built using IBS technique (MOW, 2010). There are also other terminologies to describe the use of IBS techniques, for example certain countries are more comfortable using prefabricated and modern method construction (MMC). Even though there are several terms and words available in describing IBS, the application of IBS promotes sustainable construction and persistent quality. For instance, as reported by Cabeza et al (2013), prefabricated building elements replaces energy intensive clinker in Portland cements, reducing the cement production energy. Furthermore, the use of prefabricated building helps in reducing construction waste up to 52% through efficiency of off-cuts and somewhat enhance the energy, time and cost saving (Osmani et al, 2006; Jaillon et al, 2009; Aye et al, 2012).

CO_2 EMISSION FROM CONSTRUCTION INDUSTRY

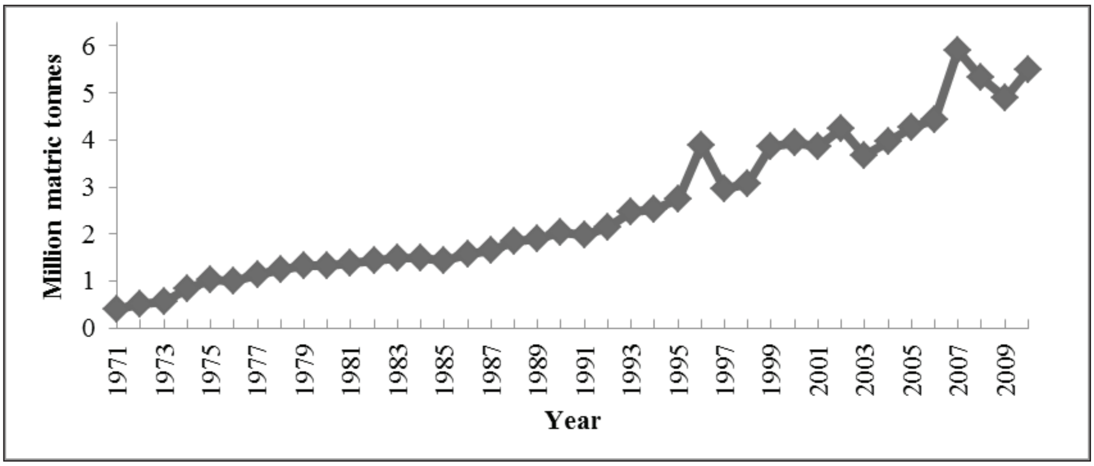
Building construction is one of the world largest CO_2 emitter that produces near 40 % of world CO_2 emission (Jeong et al, 2012; Li et al, 2013; Zhang et al, 2013). As reported by González and Navarro (2006), large amounts of CO_2 emission produced in all the phases of building life cycle includes the production of materials and products, construction of the building, site setting and exploitation, renovation and until demolition. Building sector is responsible for high amount of CO_2 emission because of high consumption of energy and natural resources with significant alteration to the environment. It is estimated that building industries consumes $^1/_6$ of the fresh water, ¼ of harvest wood and $^2/_5$ of materials and energy flows (Gottfried, 1994; Rodman and Lenssen, 1996; Chan et al, 2009). The building sector around the world are dominated by residential building, therefore the energy consumption and CO_2 emission from residential are very significant (Li et al, 2013). In year 2000, construction sector and manufacturing industries in Malaysia recorded having the third highest CO_2

emission with 16 % while commercial and residential sector contributed about 2 % of CO_2 emission (Figure 2) whilst the emission of CO_2 by commercial and residential sector was rapidly increased year by year (Figure 3). Moreover, the construction industry in Malaysia contributed to 9 % of total carbon footprint in year 2001 and it is expected to increase as the national population increases (Hertwich and Peters, 2009).



(Source: NRE, 2010)

Figure 2. Percentage of CO_2 emission by sectors in Malaysia in year 2000



(Source: IEA, 2014)

Figure 3. CO_2 emission trend from year 1971-2010 contributed by commercial and residential sector in Malaysia

Because of the energy crisis that hit the world, promotion of energy regulation that limits the energy consumption of buildings become more emphasized (Berardi, 2013). In fact, most of the buildings in many countries proposed energy consumption reduction especially during operational phase. Buildings has a life time about 50 years with operational phase as the longest period that makes operational phase as the highest energy consumption period of a building (Chang et al, 2012; Mequignon et al, 2013). Reducing heating demands, increased efficiency in energy supply chain and application of renewable resources for materials and fuel are the alternative in reducing primary energy demands and CO_2 emission by building sector (Gustavsson et al, 2010). The increasing emission of CO_2 and global warming effect creates sustainability awareness and commitments by many countries to reduce the use of energy. Reducing energy consumption in buildings clearly can contribute in achieving less CO_2 emissions and good management of energy used in buildings is recognized as an important aspect of sustainable development (Harris, 2012). Moreover, a research by González and Navarro (2006) shows that almost 30 % of CO_2 emission can be reduced in construction phase by wise selection of low environmental impact materials. This means material selection during design stage of buildings significantly contributes in CO_2 emission and energy reduction. The embodied energy and carbon can be used in determining the most sustainable and environmental friendly materials. Thus, it is important to measure carbon stored in building materials and emission of carbon during the manufacturing processes to observe the effect of building towards global carbon emission (Buchanan and Levine, 1999).

EMBODIED ENERGY IN BUILDING

Energy estimation for a building includes operational energy and embodied energy where operational energy stands for energy to fulfill building function especially to provide comfortable indoor environment while embodied energy is energy used for building execution (Dakwale and Ralegaonkar, 2012; Chang et al, 2012). Even though, operational energy hold the largest share in building life cycle, the mitigation process of energy demands of a building shifted to include embodied energy in building materials (Dixit et al, 2010; Dixit et al, 2012). Generally, embodied energy can be describe as total energy needed (directly or indirectly) during all stages of building material's life that includes materials manufacturing, transportation to the site and on site construction (Treloar et al, 2001; Calkins, 2009; Dixit et al, 2010; Chang et al, 2012; Yung et al, 2013). The analysis of embodied energy significantly helps in improving building energy consumption and also provides detailed energy analysis in producing construction materials. Thus, comparison between construction materials with the lowest energy and emission can assist the designer in developing the most sustainable building and promotes energy conservation. In fact, waste minimization and high efficiency of materials usage is also achieved due to the application of embodied energy analysis (Aye et al, 2012). Many countries and organizations started to have their own database on embodied energy for construction materials based on in-depth studies on total energy requirement for building materials production. Moreover, embodied energy analysis is not only crucial in building materials but also used in determining energy requirement for goods and services in an economy (Lenzen and Dey, 2000).

According Lenzen and Dey (2000), Treloar et al (2001), Suh et al (2004), Aye et al (2012) and Dixit et al (2012), embodied energy can be determined by using process analysis, input-output analysis and hybrid analysis. All these analysis are part of LCA which usually used in assessing environmental impact of product or system. Moreover, embodied energy calculation is one of the many components in LCA in assessing a material and product (Dixit et al, 2012). Studies by Dias and Pooliyadda (2004), Utama and Gheewala (2008), Utama and Gheewala (2009) and Utama et al (2012) had successfully determined embodied energy for building materials using process analysis even though it requires lot of data and is time consuming. Meanwhile input-output analysis which is the most applied and widely used technique was used to determine embodied energy for various types of materials and building by Lenzen and

Dey (2000), Norman et al (2006), Nassen et al (2007), Kofoworola and Gheewala (2009), Aye et al (2012) and Jeong et al (2012). The derivative of process analysis and input-output analysis was then developed and called hybrid analysis in order to provide more accurate data which had been performed by Treloar (1997), Treloar et al (2001) and Chang et al (2012).

Embodied energy analysis research and application in Malaysia currently is scarcely done and has never been published. Moreover, the analysis of energy in building sector is only limited to operational energy and further limited to residential and commercial types of buildings. Many researchers tend to investigate and invent a new environmental friendly product rather than evaluate its impact to the environment. Moreover, limited study on embodied energy and emission is due to obstacles in data collection that relates to unavailable data, lack of cooperation from manufacturer and restriction in local energy consumption data. Even though there is an input-output analysis technique that can be applied using Malaysia Input-Output Table, this analysis requires lots of data and the specific data on building material are restricted to few materials only. So it is very hard to evaluate the whole impact of buildings to the environment in terms of Malaysia current situation. Generally embodied energy and CO_2 emission were not considered during the design, specification and construction process of a building, thus the management of a building urgently needs to be improved in order to have good management of building towards energy waste mitigation. As reported by Calkins (2009), embodied energy of a product or system depends on regional and national condition, manufacturing processes, recycle content, energy source and other parameter. Studies by Kua and Wong (2012) using process with hybrid analysis and Utama et al (2012) using process analysis in Singapore and Indonesia respectively prove that research on embodied energy is an important aspect in many countries such as Southeast Asia.

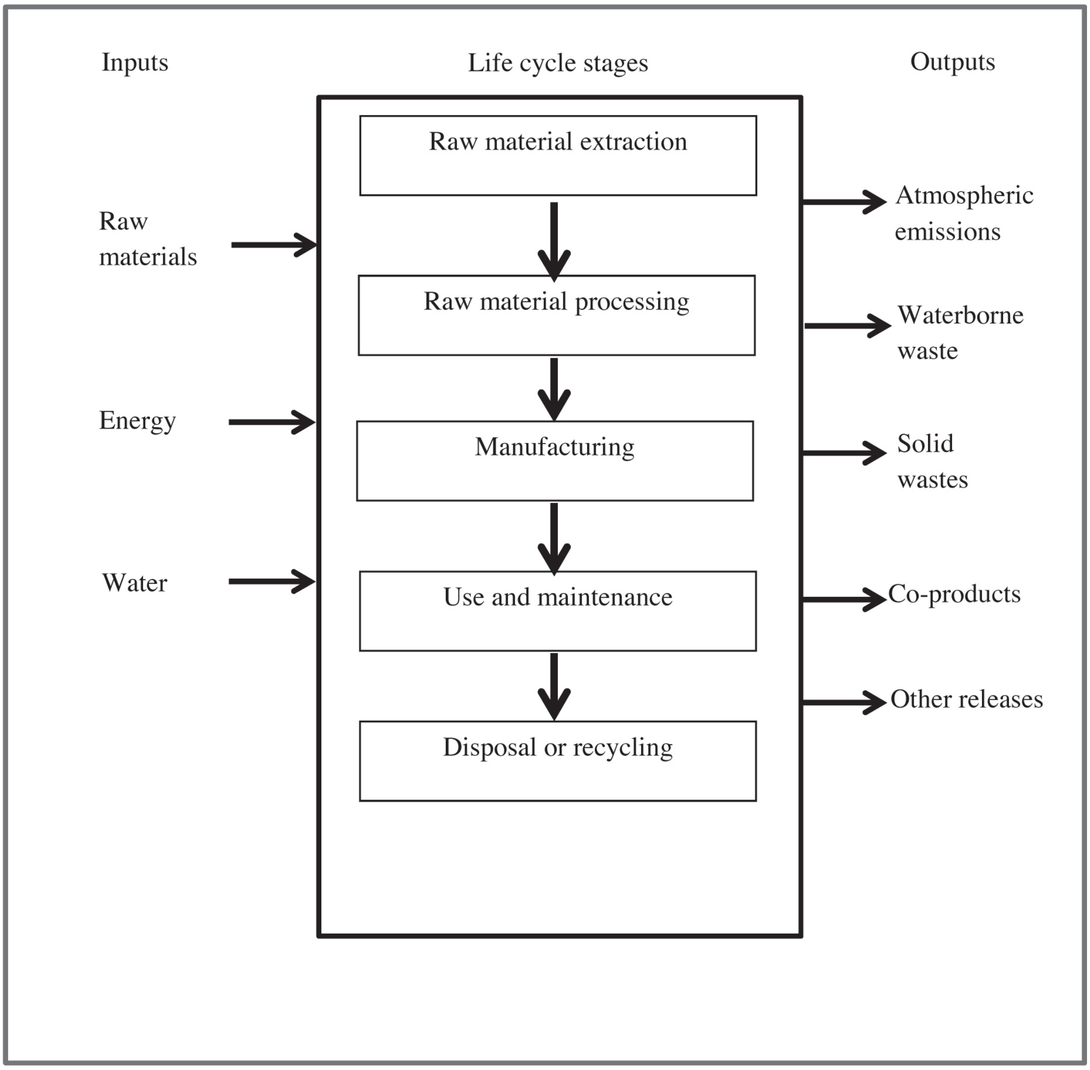
LCA APPLICATION IN BUILDING

Development and protecting natural resources are usually contradicting actions. These issues are widely discussed and each party has their own reason to support the side they are on. In order to have rapid construction development at the same time protecting the environment, our industry must be prepared with good alternative options such as using reuse, reduce and recycle approach. The assessment of environmental performance attracted the interest of many countries and disciplines especially in manufacturing and construction industries (Zhang et al, 2013). There are also several tools developed to assess sustainability and environmental performance from different points of view for example environmental impact assessment (EIA), System of Economic and Environmental Accounting (SEEA), Environmental Auditing and Material Flow Analysis (MFA) (Buyle et al, 2013), Environmental Indicator System, Environmental Management Accounting, Eco-labelling and Life Cycle Assessment (LCA), being the most complete tool (Asdrubali et al, 2013).

LCA is defined as a technique in evaluating a product's environmental aspect and potential impacts by compiling an inventory of input and output of a product system, evaluating the potential environmental impact and interpreting the result based on target objective of the study (ISO, 1996; Nebel and White, 2006; Ortiz et al, 2009b; Zhang et al, 2013). The scope of LCA usually involves cradle to gate (manufacturer's gate) or cradle to grave (disposal of the product) with the quantification includes all input (energy, water, materials resource) and output (emission, effluence, waste) (Calkins, 2009; Chang et al, 2010). Figure 4 shows the input and output parameters in life cycle stages of a product. Moreover, LCA is also an essential practice that can be applied at every phase of product and system life cycle as the life cycle approach is the main interest of LCA. Life cycle concept has been developed since year 70s and 80s which then focuses on the quantification of energy and materials used and waste produced throughout the life cycle (Sharma et al, 2011; Cabeza et al, 2014). Based on four stages of analysis comprised of goal and scope definition, inventory analysis, impact assessment and interpretation, LCA aims to provide a holistic assessment that catches interests of researchers and also industrial parties (Kibert, 2008; Calkins, 2009; Ortiz et al, 2009b; Sharma et al, 2011; Zhang et al, 2013). As LCA analysis is recognized and acknowledged by International Organization for Standardization (ISO), the details on this method can be widely assessed. Furthermore, there are three types of analysis categorized by LCA that are Process LCA, Input-Output LCA and Hybrid LCA (Sharma et al, 2011) where this three types of method could also used in embodied energy analysis as described in sub-heading 4.0. Even though scientific base method is related to LCA, this tool had been used extensively in several sectors especially building industries (Blengini and Di Carlo, 2010).

The application of LCA in building and infrastructure is practical in reducing cost and gain benefit with the implementation of process design, extraction of building materials, materials processing, construction, building operation and disposal management (Chang et al, 2010). Furthermore, research is aimed to identify possible sources of the most significant environmental impact from materials and product selection (Cabeza et al, 2014). In order to assess the emission of carbon from buildings, whole life phases of building need to be investigated which are building materials manufacturing and transportation to the site, construction, operational and maintenance, demolition and waste disposal (Chen et al, 2011; Zuo et al, 2012) which makes LCA as a crucial tool in assessing building environmental performance. As reported by Roh et al (2014), assessment during planning and design phase of construction helps in estimating the impact of the building construction hence building with low energy consumption and emission can be built. Thus, LCA can helps in decision making towards sustainable and environmental friendly building. A comparison of selected studies on LCA application in building sector listed in Table 1.

Nassen et al (2007) compared the magnitude of primary energy use and CO_2 emission from Swedish building sector between top down input-output analysis with previous bottom up process analysis studies. This study aimed to achieve better understanding of energy use in building production and provides much information on suitable analysis that can be applied in building assessment. The authors revealed that input-output analysis indicated two-fold higher energy used of a building compared to process analysis. The major difference was reported in several sectors such as transport, construction activities, production of machines and service sector where high amount of energy were recorded by input-output analysis. Moreover, the authors also found that the production of buildings contributes to high CO_2 intensity due to high energy consumption.



(Source: Crawford, 2011)

Figure 4. Input and output for a product's life cycle

Table 1. Comparison on LCA application in building sector

	Building type	Parameter	Type of analysis	Location
Nassen et al, 2007	No building	Primary energy use and CO_2 emission	Input-output LCA	Sweden
Utama and Gheewala, 2008	Single house	Embodied energy	Process LCA	Indonesia
Kofoworola and Gheewala, 2009	Office	Energy assessment	Economic input-output and process LCA	Thailand
Blengini and Di Carlo, 2010	Low energy house	Energy saving	Inventory based LCA	Italy
Monahan and Powell, 2011	House	Embodied carbon in three types of building materials	Process LCA	United Kingdom
Ramesh et al, 2012	Residential	Energy performance	Inventory based LCA	India

Thiers and Peuportier, 2012	High energy performance house	Energy assessment	LCA and available database	France
Zhang et al, 2013	Commercial building	CO_2, CH_4, N_2O, SO_2, CO, NOx, NMVOC, PM emission	Inventory based LCA	Hong Kong

Utama and Gheewala (2008) estimated the embodied energy content in building enclosure materials that are clay bricks and concrete blocks using process based LCA in Semarang, Indonesia. This study is limited to several phases of building life cycle which are transportation of building materials to the construction site (cradle to gate) and operational phase. The result from this study show that clay-based bricks had higher embodied energy compared to concrete blocks because of low efficiency of burning method (as it runs by traditional family operation) and small size of bricks that enhances the surface area, hence the long time needed for burning process. Moreover, low fossil fuel energy was consumed to produce concrete block. However, in terms of life cycle energy estimation that includes energy for raw materials extraction, material production, transportation and operational phase, clay brick building materials recorded better performance than concrete bricks due to differences in electricity consumption and occupational behavior of the building's occupant. The author also suggests applying lightweight enclosure materials for reducing the life cycle energy of a house.

Kofoworola and Gheewala (2009) carried out a life cycle energy analysis of office buildings located at Bangkok, Thailand. The objective of this study is to determine the embodied energy coefficient of building materials applied in Thailand, to assess the energy consumption throughout building life cycle and to identify the contribution of different life cycle phases of the building. The result attributed from the study shows that embodied energy coefficient had been produced and only has slight variation from previous literature. Operational phase contributed as highest energy consumption period especially in applying lighting and HVAC system (heating, ventilation, and air conditioning) while manufacturing of concrete and steel were the most significant element in building life cycle. Moreover, some of the alternative to reduce the consumption of energy during operational phase are by setting up the temperature of indoor environment to 26 ^{o}C, practicing load shedding, using appropriate window size and applying glazing. Initial embodied energy of the building also can be reduce using recycle building materials up to 9 %, thus natural resource can be conserve and enhancing energy performance of the building.

Blengini and Di Carlo (2010) had used LCA in determining energy consumption of a low energy single family house in Northern Italy. The research finding shows that materials impacts has emerged and extend over 70 years while maintenance operation also plays a major role. Moreover, the author suggested performing field measurement in order to compare the result with simulated data after a few years. Every life cycle phase of a building is very important in determining the impact of the building even though operational energy is always the main concern. The low energy building showed outstanding energy saving and high environmental performance fulfilling the objective in showing energy saving can be achieved.

Monahan and Powell (2011) conducted a process based LCA to compare the embodied carbon in a low energy affordable house constructed using offsite panellised modular (Modern Method of Construction, MMC) timber frame system with timber frame brick cladding and conventional masonry cavity wall in Norfork, United Kingdom. This cradle to site of the construction focused on MMC construction element where it was claimed that resource input and waste output can be reduced compared with on-site construction. The result shows that a house built by traditional conventional masonry cavity wall recorded 51 % higher embodied carbon compared to a MMC timber frame system as building materials. Moreover, concrete is also among the most significant materials which is responsible for 36 % of materials related to embodied carbon. The authors also suggested in utilizing offsite manufacturing component, consideration of materials selection of sustainable materials to reduce environmental impact and the importance of on-site waste minimization strategies.

Ramesh et al (2012) presented an analysis of energy of different types of residential house in India. The residential houses consists of one storey, two storey, duplex and multiple storey with several energy features which are thermal insulation on wall and roof, and double pane glass for window. Several inventories of data taken from literature and simulation tools from several softwares were used in assessing energy performance of the target buildings. The main results conclude that single storey house has higher energy demands compared to two storey and apartment type of residential house resulting from higher external surface area per usable floor area that contribute to higher embodied energy and energy consumption for cooling and heating. The energy demand of a building can also be reduced about 5-30 % with the installation of insulation of wall and roof along with double pane glass for windows. The authors comment that the results from this study can helps in designing energy efficiency buildings and suggested an application of energy efficient cooling and heating equipment to reduced life cycle energy consumption.

Thiers and Peuportier (2012) studied the contribution of heating devices in two high energy performance building in North France by using LCA. The high energy performance buildings in this study consist of two attached passive house and renovated collective social housing building. The findings found that energy needs for both type of houses appeared to be low with application of solar panel module in energy generation and operational phase is influenced by thermal envelope and equipment. The attached passive house has better performance compared to renovated collective social house because of high efficiency of solar panel in generating energy. As collective social housing is a renovated building, it is hard to reach a very high efficiency compared to new building and the installation of solar panel is not very optimal because of bad solar exposure and bad orientation of the house.

Zhang et al (2013) quantified the selected air emission such as CO_2, methane (CH_4), nitrous oxide (N_2O), sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen oxide (NOx), non-methane volatile organic compound (NMVOC) and particulate matter (PM) form high commercial buildings in Hong Kong by using LCA. According to the author of this study, air emission during the raw materials manufacturing stages resulted from calcination, evaporation and surface coating volatilization while other building life cycle stages that are transportation of building materials, construction, operation and building demolition are generally due to fossil fuel combustion and electricity used. Overall, operational and maintenance phase of building life cycle are responsible for most emission in building construction while CO_2, N_2O, SO_2 NOx and NMVOC occupy only a small proportion at the other phases of building life cycle. The application of this approach can help in identifying the optimal solution in choosing building materials, construction method and ways of using the building in order to minimizing the quantity of air emission as recommended by the authors.

From the previous literature, there are extensive studies on building with application of LCA that related to many types of building for example office (Cole and Kernan, 1996; Suzuki and Oka, 1998; Xing et al, 2008; Chau et al, 2012), residential house (Fay et al, 2000; Treloar et al, 2001; Ortiz et al, 2009a; Utama and Gheewala, 2009; You et al, 2011; Aye et al, 2012; Cuéllar-Franca and Azapagic, 2012; Lee et al, 2013; Peuportier et al, 2013), university (Scheuer et al, 2003), educational building (Arena and de Rosa, 2003; Chang et al, 2012) and commercial (Kua and Wong, 2012; Han et al, 2013) from all over the world. Every study has their own objectives and parameter to be investigated which indicate the significant application of LCA in building industries. However, LCA utilization in the early stages of building project especially during design stages is still limited. According to Basbagill et al (2013), the complexity in in performing LCA in early stages of building project is that LCA utilization is time consuming and needs high effort to implement, unavailable data on building component and high process of decision making. Yet there are several LCA tools that evaluate construction materials and building which makes the analysis works much easier such as ATHENA and BEES, there are also LCA based program designed as developed by (Roh et al, 2014). The details on ANTHENA and BEES tools showed in Table 2. Moreover, there are also software available in order to perform LCA but not only restricted to building assessment for example GaBI and SimaPro.

Table 2. Notes on LCA based tools in building industry

Name of tools	Description	Country
ANTHENA Impact Estimator	• Assessing industrial, institutional, office and residential type building • The analysis includes all phase of building life cycle • Wide range of impact categories such as global warming, acidification, human health • Comprehensive databases regionally for each materials • Provide comparison to alternative design	Canada
BEES Building for Environmental and Economic Sustainability	• Provide a rational, systematic technique for selecting environmental and cost effective building product • Analyse all the phases in product life cycle • Measure the economic performance of building product using American Society for Testing and Materials (ASTM) • Integration of LCA with computer-aided design (CAD) tools • Complete analysis can be produced through inbuilt database of environmental impact from the target product	United States

Source: Calkins, 2009; Crawford, 2011

CASE STUDY OF EMBODIED ENERGY COEFFICIENT

Input-output LCA method was used in determining embodied energy coefficient for main construction materials in Malaysia. Basically, the Malaysia Input-Output Table containing 122 sectors and the data on building materials was limited. Plywood, glass, cement, concrete and steel are the available data that can be extracted from Malaysia Input-Output Table year 2010. The calculation of embodied energy of selected building materials followed the method as described by Treloar et al (2001) and Kofoworola and Gheewala (2009). Energy consumed to produce the product were obtained from the extraction of data in input-output table and combined with energy intensity factor by fuel types. In order to generate energy consumed in the production of the product, the energy intensity was multiplied with national energy tariff. The embodied energy coefficient was then calculated with the multiplication of materials price. The data for building materials price was obtained from Construction Industry Development Board Malaysia (CIDB) and energy tariff was provided by Tenaga National Berhad (TNB).

The embodied energy coefficient result was shown in Figure 5 while comparison with previous studies listed in Table 3. Overall, steel showed high embodied energy content with value of 8.78 MJ/Kg. Other building material recorded embodied energy value between 0.35 MJ/Kg to 5.10 MJ/Kg. The embodied energy coefficient obtained by previous studies shows quite less variation compared to this case study. Highest embodied energy coefficient in steel compared to other studied materials consistent with findings by Alcorn and Wood (1998), Hammond and Jones (2008), Calkins (2009) and Aye et al (2012). Moreover, study by Baird et al (1997) showed lower embodied energy coefficient of steel compared to plywood and glass due to steel material in New Zealand produced from recycled steel that reduced the energy consumption. Aye et al (2012) performed an embodied energy analysis to prefabricated steel and concrete with the result recorded high value of embodied energy for both materials compared to other studies. The author also comment that even though prefabricated material has higher embodied energy but the environmental benefits of the materials is significant as it have potential to be reuse and long material life.

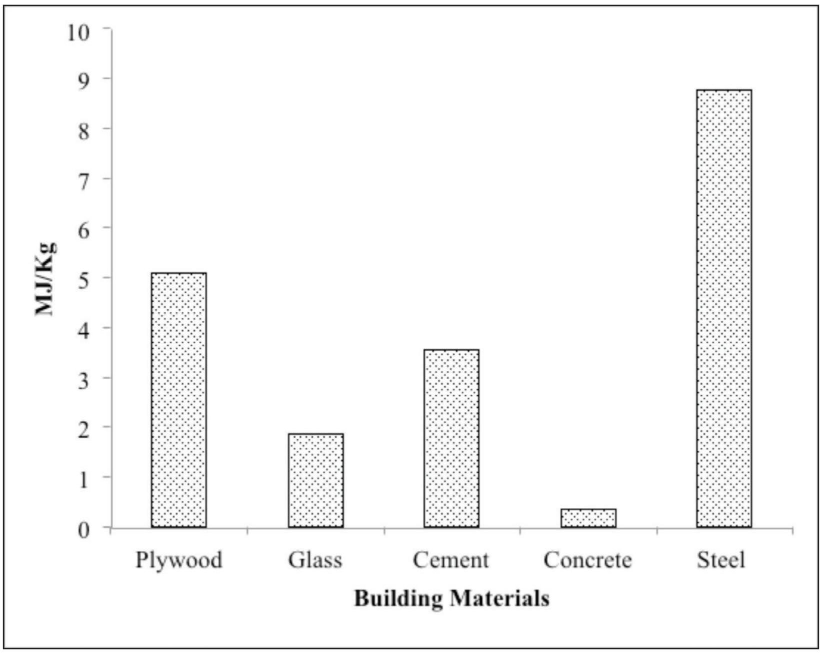


Figure 5. Embodied energy of selected building materials

Table 3. Summary of selected embodied energy coefficient in materials compared with this study

References	Embodied energy (MJ/Kg)	Plywood	Glass	Cement	Concrete	Steel
Baird et al, 1997	Embodied energy	10.4	15.9	7.8	0.94	10.1
Alcorn and Wood, 1998	Embodied energy	nd	nd	9.0	1.4	35.9
Hammond and Jones, 2008	Embodied energy	15	15	4.6	0.95	35.3
Calkins, 2009	Embodied energy	16.5	nd	5.7	1.1	21.7
Kofoworola and Gheewala, 2009	Embodied energy	8.5	17.1	0.2	1.3	11.1
Aye et al, 2012	Embodied energy	-	-	-	7.44 (wall)	54.6 (wall)
This study	Embodied energy	5.10	1.85	3.56	0.35	8.78

nd: no data

CONCLUSION

Building sector significantly contributed to enormous carbon emissions due to high energy consumption. Cut down of energy consumption and CO_2 emission from building clearly important and in line of government sustainable development policy. In order to overcome this issue, proper planning and execution needs to be taken. LCA approach that advocated with detail analysis throughout the whole life cycle of buildings can be used in determining the best solution of sustainable building. Moreover, the use of LCA in the beginning of building life especially during design stage can provide various information on material's embodied energy thus material selection for the most environmental friendly and low energy materials can be suggest. Moreover, energy analysis that emphasized on embodied energy is required in order to perform detailed LCA analysis. The application of MMC which also refers to prefabricated and IBS (terms of Malaysia situation) method also proved carbon emission reduction and plays significant role towards sustainable construction. Thus, for a country with high awareness of energy consumption and environmental performance like Malaysia, more research is needed for optimal implementation in order to investigate and evaluate the real condition of our building performance towards sustainable green environment. As other countries race towards producing sustainable building, our countries decision maker need` to provide more incentive and encouragement in order to gain more interest from the developer and all parties involved. Moreover, reducing energy and emission and impact to the environment will also give advantages not only to the mother's nature but also economy growth.

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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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Jamalodin Noorzaei[1], Mohd. Saleh Jaafar, Abdul Waleed Thanoon, Wong Jern Nee

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Abstract: Arial Bold, 9pt. Left and right indent 0.64 cm.

Abstract: it should be single paragraph of about 100 – 250 words.

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Keywords: *Cooling tower; Finite element code; Folded plate; Semiloof shell; Semiloof beam*

Body Text: Times New Roman, 11 pt. All paragraph must be differentiate by 0.64 cm tab.

Heading 1: Arial Bold + Upper Case, 11pt.
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Units: All units and abbreviations of dimensions should conform to SI standards.

Figures: Figures should be in box with line width 0.5pt. All illustrations and photographs must be numbered consecutively as it appears in the text and accompanied with appropriate captions below them.

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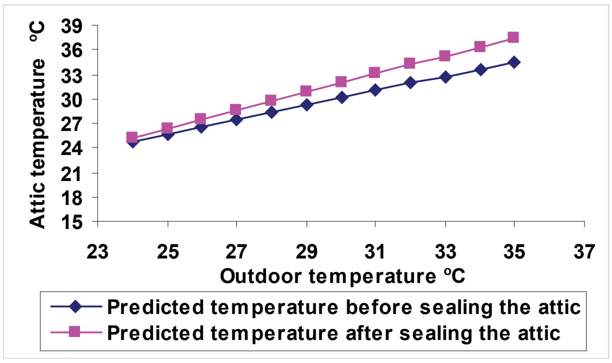

Figure 8. Computed attic temperature with sealed and ventilated attic

Tables: Arial, 8pt. Table should be incorporated in the text.

Table caption: Arial Bold + Arial, 9pt. Caption should be written above the table.

Table Line: 0.5pt.

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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