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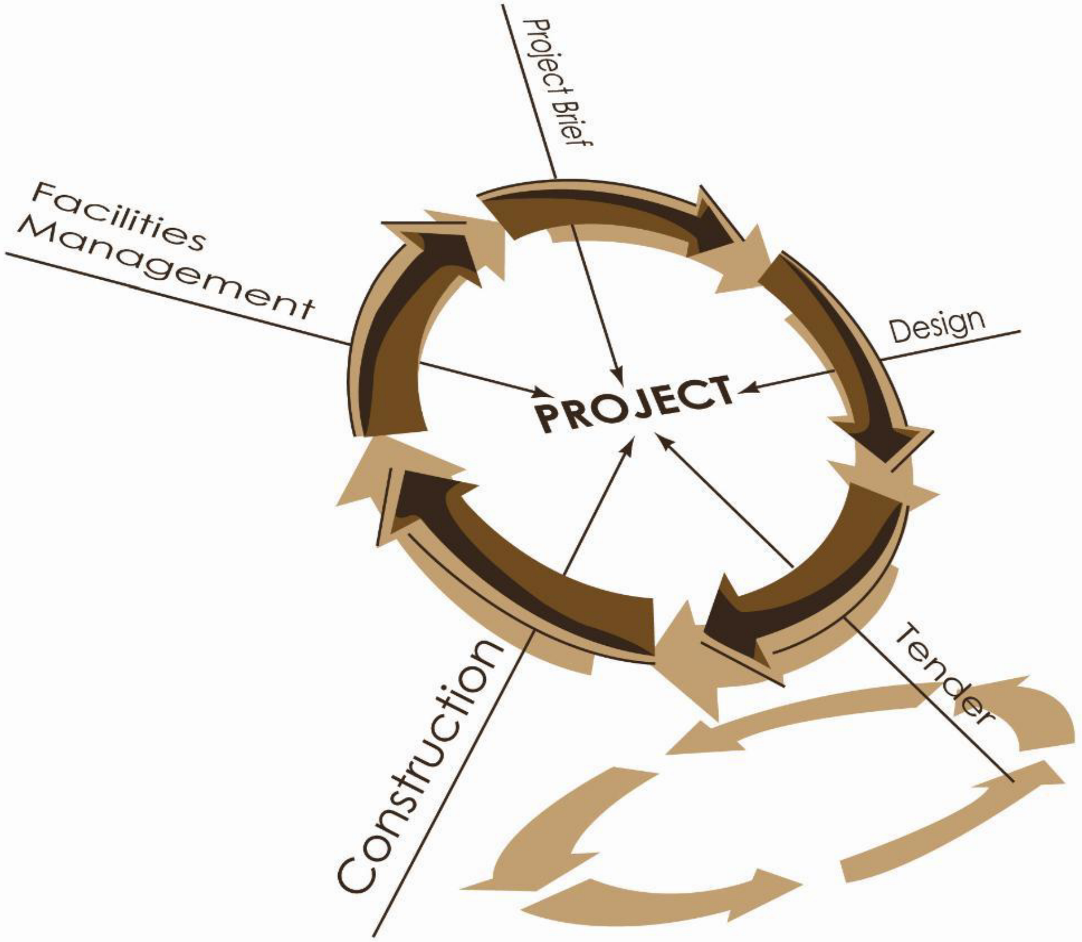

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Contents

Editorial Advisory Board

Editorial

Welcome from the Editors

Welcome to the seventeenth 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 hoped that the readers will find informative articles from this edition of MCRJ. In this issue;

Foo Chee Hung, *et. al.,* conduct a study on Industrialised Building System (IBS) adoption in Malaysia. In 2013, the level of IBS adoption was 15.3%; with the adoption level of 61% and 14% for both government and private projects, respectively. The study points out that most targets set in the IBS Roadmap (2011 – 2015) were achieved, such as (i) to sustain the existing IBS score of 70% through to 2015 for government building projects; and (ii) to assist the private sector to attain an average IBS score of 50% by 2012. However, the number of foreign workers did not reduce as it was expected. The buy-in from the private sector is, hence, of necessary if the country's construction industry is to move towards overall industrialisation.

Ahmad Tarmizi Haron, *et. al.,* conduct a roundtable discussion on the Building Information Modelling (BIM), for the purpose of providing a platform for industry experts to discuss BIM issues, sharing knowledge and information and work collaboratively, and providing recommendations for policy makers for further enhancements of the construction industry. The roundtable discussion concludes that there is still a lack of understanding on BIM among stakeholders in the construction industry, and further suggested the establishment of a BIM task force to facilitate the implementation of BIM. Besides, the development of a case study is suggested so as to comprehend knowledge sharing activities amongst practitioners and academics.

Mohmad Mohd Derus, *et. al.,* examine the desired behavioural competences of project managers in Malaysia's Public Works Department (PWD) through the Modified Delphi Technique. They successfully identified seven specific competences as very important, nine always in use and seven critical. Strikingly, certain competences were eliminated from these three lists even though they have been cited by past competence scholars. It is suggested that the PWD or other Malaysian public procurement agencies to make use the findings in this study in order for behavioural competence training and staff selection. Public procurement agencies of other developing countries can also take the cue from this study when conducting their own internal behavioural competence studies and act accordingly.

Through case study approach, **Azlan Shah Ali, *et. al.,*** examine the cost of four museum refurbishment projects in the state of Malacca, Malaysia. The research findings demonstrate the building services, finishes, and superstructure works as the influential elemental cost of the projects. This reflects the importance of enhancing building functionality and structural stability while preserving architectural heritage values in historical building refurbishment projects. Furthermore, such works must be in compliance with the statutory regulations, specifically the historical buildings.

The chemical compositions of coal bottom ash and fly ash were analysed and compared with previous studies, by **Ali Huddin Ibrahim, *et. al.,***. The coal ash samples were collected from the Sultan Azlan Shah power plants in Manjung, Perak, Malaysia, and were analysed for eight parameters: SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, Na_2O, and K_2O. The SiO_2, SO_3 and K_2O of coal bottom ash were found to be within the range compared to previous study, while the Al_2O_3, Fe_2O_3, CaO, MgO and Na_2O of bottom ash were out of the range shown by previous studies. The findings are able to provide necessary info of properties to be used as supplementary cementitious materials for a partial replacement of cement in typical concrete and mortar.

Lau Pei Ching, *et. al.,* conduct the literature review on lightweight aggregate (LWA) produced from sewage sludge (SS) and sewage sludge ash (SSA). The physical and chemical properties as well as heavy metals leaching characteristics of raw SS and SSA are reviewed. The manufacturing principle of LWA, microstructure, physical, chemical and mechanical properties including heavy metals leaching aspect of SS and SSA LWA are summarized. It is observed that both the LWA manufactured from SS and SSA possess physical and mechanical properties which are comparable to commercially available LWA.

Editorial Committee

STUDY ON INDUSTRIALISED BUILDING SYSTEM (IBS) ADOPTION LEVEL AND CONTRACTORS' READINESS IN MALAYSIA 2013

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Abstract
Industrialised Building System (IBS) – a term representing the prefabrication concept in Malaysia – was introduced in 1966 and has being promoted since then, as a way to stimulate a better performance of the Malaysian construction industry towards industrialisation and open building. This study sets out to assess the level of IBS adoption in Malaysia. The overall IBS adoption in 2013 for the identified potential IBS projects – new building project that worth RM10 million and above – was 15.3%; with the adoption level of 61% and 14% for both government and private projects, respectively. Residential appeared to be the building type that highly adopting IBS. The overall IBS score in government project is higher than the one in private project, where the average IBS scores for residential, non-residential, and social amenities are 70, 80, and 76, respectively; as compared to the one in private project, 65, 63, and 64, respectively. In terms of contractors' readiness on using IBS, 20.4% of the total survey respondents perceived themselves as IBS-ready, with government project respondents reported to have higher readiness (41.3%) than the private project respondents (15.8%). Most targets set in the IBS Roadmap (2011 – 2015) were achieved, such as (i) to sustain the existing IBS score of 70% through to 2015 for government building projects; and (ii) to assist the private sector to attain an average IBS score of 50% by 2012. However, the number of foreign workers did not reduce as it was expected. Although IBS has been proven to be a less labour intensive construction method, its influence was not obviously shown due to the low adoption rate in the Malaysian construction industry, especially within private projects. The buy-in from the private sector is, hence, of necessary if the country's construction industry is to move towards overall industrialisation.

Keywords: *IBS; construction; adoption; readiness; Malaysia.*

INTRODUCTION

Industrialised Building System (IBS) is the term used to represent the prefabrication concept in Malaysia. It is defined as a construction technique where components are manufactured in a controlled environment on-site or off-site, transported, positioned, and assembled into a structure with minimal additional site work (CIDB, 2003). The development of IBS is not new in the Malaysian construction industry as it was introduced in 1966 when the government launched two pilot projects for precast housing, involving the construction of Tunku Abdul Rahman Flats in Kuala Lumpur and the Rifle Range Road Flat in Penang. The use of IBS assures valuable advantages such as reduction of unskilled workers, less wastage, less volume of building materials, increased environmental and construction site cleanliness and better quality control. Besides, it offers benefits to adopters in concerning cost and time certainty, attaining better construction quality and productivity, reducing risk related to occupational safety and health, alleviating issues skilled workers and dependency on manual foreign labour, and achieving the ultimate goal of reducing the overall cost of construction. Towards the end, IBS is believed to be able to stimulate a better performance of the Malaysian construction industry through the development of an Industrialised construction sector and achieving open building. As a statutory body under the Ministry of Works, the Construction Industry Development Board (CIDB) has been actively promoting the use of IBS in the local construction industry. Its commitment can be seen with the development of the IBS Roadmap 2003 – 2010 and IBS Roadmap 2011 – 2015, which aim to provide guidelines towards the establishment of an Industrialised construction sector as stipulated in the Construction Industry Master Plan (CIMP) 2006 – 2015. In order to track on the achievement of IBS in the construction industry, as well as to assess the level of success/effectiveness of IBS implementation in meeting the goals and targets set in the IBS Roadmap, several IBS surveys have been carried out in the last decade (Table 1).

Table 1. IBS surveys (2003 – 2010) and other related studies

Survey/Study	Year	Objective	Core Findings
IBS Survey 2003 (CIDB, 2003b)	2003	To study the awareness and usage of IBS in construction from the point of view of contractor G5, G6, and G7.	– Of the 165 questionnaire respondents, during the period of study (1998 – 2002), IBS usage in building construction was 33.8%. – The construction of bridges (83.2%) and tunnels (90%) greatly utilized IBS. – Companies with zero usage of IBS in construction projects were steadily decreasing from 74% in 1998 to 48% in 2002. – 54% want to use IBS in the future.
IBS Survey 2005 (CIDB, 2005b)	2005	To survey architects' opinion and acceptance on IBS.	– Only 30% of architects are in favour of IBS design. – 70% of architects lack of knowledge on IBS. – 34% want to use IBS in the future.
IBS Roadmap's mid-term review (CIDB, 2007)	2007	Mid-term review of IBS Roadmap 2003 – 2010 to gauge the state of IBS implementation and progress on the roadmap's recommendations.	– Only 10% of the complete projects used IBS in the year 2006 as compared to forecasting IBS usage of 50% in 2006 and 70% in year 2008 as projected in the roadmap.
IBS Survey 2008 (Majid *et. al.*, 2011)	2008	To measure the acceptance of construction industry (class G4 – G7 contractors) towards IBS system and to produce ranking of IBS benefits to contractors.	– Total number of participants = 454 – The ranking of IBS benefits listed from the most beneficial to the least beneficial are: *i. Minimal wastage* *ii. Cleaner environment* *iii. Less site materials* *iv. Reduction of site labour* *v. Controlled quality* *vi. Faster project completion* *vii. Neater and safer construction sites* viii. *Lower total construction costs*
IBS Survey 2010 (Kamar *et. al.*, 2014)	2010	To measure the drivers, barriers, and the critical success factors of G7 contractors in adopting IBS construction.	– Total number of participants = 37 – The acceptance, adoption and deployment of IBS in the Malaysian construction industry is still low and does not help to improve outstanding and persisting problems in productivity, dependency on foreign workers and high level of construction wastage.

The first IBS survey was done in 2003 as to study the awareness and usage of IBS in construction from the viewpoint of contractors. The second IBS survey was conducted in 2005 to study the architects' opinion and acceptance on IBS. The third IBS survey was conducted in 2008, to measure the acceptance of construction industry (G4 to G7 contractors) towards IBS system and the ranking of IBS benefits. The fourth IBS survey in 2010 focused on measuring the drivers, barriers, and the critical success factors of G7 contractors in adopting IBS construction. In 2007, the IBS Roadmap's mid-term review was also conducted to gauge the state of IBS implementation and progress on the roadmap's recommendations. Findings from these studies pointed out that the initial take-up of IBS was not as high as it was anticipated, particularly from the private sector. For example, the IBS Mid-term Review in 2007 indicated that approximately 10% of the completed projects used IBS in the year 2006 (CIDB, 2007) as compared to forecasting IBS usage of 50% in 2006 and 70% in year 2008 as projected in the roadmap (CIDB, 2003).

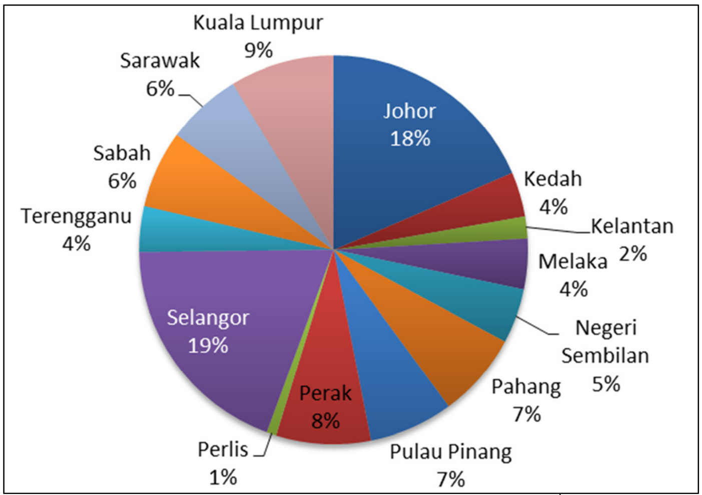
In addition, the surveys also indicate that the limited take-up of IBS is mainly due to cost factor and budget constraint along with availability of cheap foreign labours in Malaysia. This is especially true among small contractors. Since moving towards mechanized and industrialised systems involves high capital investment on heavy equipment and mechanized construction facility, small contractors are unlikely to switch to an unfamiliar system in order to secure their projects which mostly are small scale development. To note, the usage of IBS is reported to result an additional 10% of construction cost as compared to the conventional construction method (CIDB, 2007), whilst the levy exemption given to those who adopt IBS as an incentive is only 0.125% of the project value, which is unable to cover the additional cost incurred. Besides, the negative perception on IBS among industry players also affects IBS adoption in the industry. Since the quality of the overall finished work with IBS construction still left much to be desired (Abd Rahman and Omar, 2006; Kamar *et. al.,* 2007), industry players tended to perceive that IBS may lead to less productive, more costly, and cause the delay of project. As such, the industry has become reluctant in accepting IBS.

While past IBS surveys did provide useful updates on the status of IBS implementation and the industry players' perception on IBS, the findings were basically drawn from a relatively small sample size. For example, the number of survey respondents for IBS Survey 2003, 2008, and 2010 were 165, 454, and 37, respectively. Most importantly, the survey samplings were based on number of registered contractors rather than on the number of building construction project awarded in that particular year. From Table 2, one may observe that 52% (or 34,485) of the registered contractors are G1 and 8% (or 5,332) are G7 in 2013. Among the 7,159 projects awarded to local contractors in 2013, 52% (3,781) are actually under the coverage of contractor G7, while projects awarded to both contractors G1 and G2 covered 1.3% (or 91) only. Since the chances of being awarded projects are higher among G7 contractors as compared to other classes of contractor, drawing sample from the number of registered contractors may be inappropriate. If a more accurate IBS adoption level within the country is to be explored, the target group for sampling should be based on the number of projects awarded in that particular year. Besides, one should be aware that project distribution by state as well as by project status (private or government project) also plays its vital role in influencing the representativeness of the survey sample, which has likely been omitted in the previous IBS surveys. An illustration on project distribution by state and project status is given respectively in Figure 1 and Figure 2, where majority of the projects are observed to be private-initiated in nature and mainly concentrated in Selangor and Johor. To ensure the survey sample being drawn was statistically reflecting the real scenario in the Malaysian construction industry, the sample has to be in compatible with these conditions, both geographically and demographically.

Table 2. Chances (%) of being awarded projects, 2013

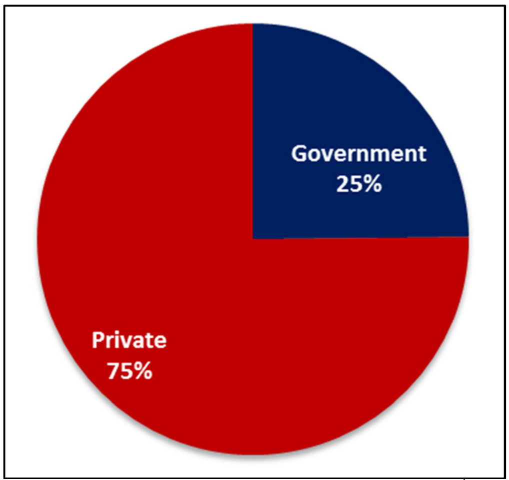
	CIDB Registration Grade						
	G1	G2	G3	G4	G5	G6	G7
Number of projects awarded	30	61	683	846	1,053	705	3,781
Number of contractors awarded with projects	29	56	569	642	773	503	2,434
Total registered contractors	34,485	9,268	8,825	3,038	4,130	1,594	5,332
Chances (%) of being awarded projects	0.1	0.6	5.4	21.1	18.7	31.6	45.6

(Source: CIDB Construction Quarterly Statistical Bulletin, 1st Quarter 2014; Own calculation)



(Source: CIDB Construction Quarterly Statistical Bulletin, 1st Quarter 2014)

Figure 1. Distribution of project awarded in 2013, by state



(Source: CIDB Construction Quarterly Statistical Bulletin, 1st Quarter 2014)

Figure 2. Distribution of project awarded in 2013, by project status

With this respect, the present study was undertaken to provide a better understanding on the status of IBS implementation in Malaysia, for both government and private projects in year 2013. Through questionnaire survey, the study aims to find out (i) the number of building construction projects which adopting IBS in 2013; (ii) the average IBS score for project using IBS construction; (iii) past IBS project experience among contractors; and (iv) contractors' readiness on IBS adoption. Besides, the study also takes initiative to discuss the IBS achievement as stipulated in the IBS Roadmap 2011 – 2015. Towards the end, the study aims to demonstrate a methodology for assessing the level of IBS adoption in Malaysia, which is different from the one stipulated in previous IBS surveys.

METHODOLOGY

Determination of Survey Sample Size

To facilitate data collection through questionnaire survey, target survey population was first identified. The CIDB construction project database was assessed to shortlist potential IBS projects in year 2013. A potential IBS project is a new building construction project that may likely adopt IBS. To note, 7,159 construction projects were awarded in 2013. Among these projects, 24.8% (or 1,778 projects) are government projects and 75.2% (or 5,381 projects) are private projects (Table 3), which can be further categorized into residential, non-residential, social amenities, and infrastructure based on the CIDB construction work categories (Table 4). However, not all these projects are potential IBS project because the total number of construction projects also covers those projects with the construction of roads, bridges, drainage system, landscaping, building renovation, mechanical and electrical appliances etc. As such, projects that fall under the category of infrastructure and sub-categories of civil engineering, electrical, mechanical, upgrading, expansion, maintenance, repair, and renovation are not considered as new building project and are excluded. Consequently, the target survey population of the present study is expected to lie within 2,836 projects (Figure 3), which consist of 411 government projects and 2,425 private projects.

Table 3. Number of project awarded by status of contractors and project category, 2013

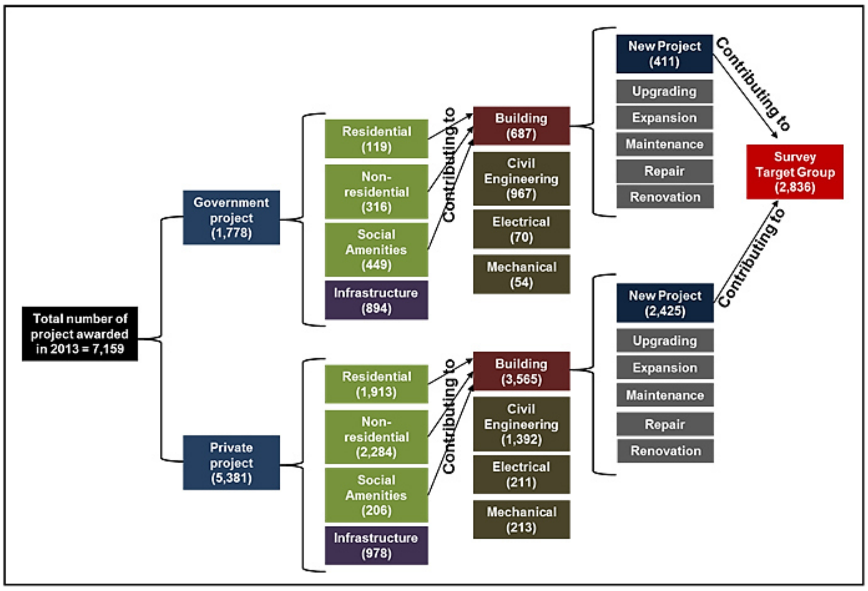
Project category	Government project		Private project	
	Number	%	Number	%
Residential	119	6.7	1,913	35.6
Non-residential	316	17.8	2,284	42.4
Social amenities	449	25.3	206	3.8
Infrastructure	894	50.3	978	18.2
Total	**1,778**	**100**	**5,381**	**100**

(Source: CIDB Construction Quarterly Statistical Bulletin, 1st Quarter 2014)

Table 4. List of construction work category for construction projects in Malaysia

Project Category			
Residential	**Non-residential**	**Social Amenities**	**Infrastructure**
Terrace	Industry	Educational	Utilities
Semi-detached	Business	Public facilities	Transportation
Houses (not specified)	Office	Health	Drainage/Sewage
Flat	Hotel	Sport/recreational	Disaster Prevention
Bungalow	Agriculture	Club & Agency	
Hostel	Landscape	Social Welfare	
Quarters	Safety & Security		
Condominium	Tourism & Entertainment		
Townhouse	Government & statutory body		

(Source: Adapted from CIDB Construction Quarterly Statistical Bulletin, 1st Quarter 2014)



(Source: CIDB Construction Quarterly Statistical Bulletin, 1st Quarter 2014)

Figure 3. Population for survey target group

The size of the target survey population is further narrowed down by taking into consideration the project value range. Only those new building construction projects worth RM10 million and above are considered as potential IBS projects as it is in line with the IBS content set by the IBS Roadmap 2011 – 2015, which specified that exceptions to use IBS are allowed for (i) projects below RM10 million; (ii) projects carried out in far-off places which cannot be easily accessed for IBS purposes; and (iii) renovation and maintenance work of existing buildings and does not involve construction. As such, the target survey population is reduced from 2,836 to 882, comprising 110 government and 772 private projects. Table 5 shows the breakdown of potential IBS projects in 2013 by state.

Table 5. Distribution of potential IBS projects by state and project status, 2013

State	Project Status	
	Government	Private
Johor	12	203
Kedah	2	21
Kelantan	9	5
Melaka	5	29
Negeri Sembilan	5	38
Pahang	16	19
Perak	7	29
Perlis	1	5
Pulau Pinang	6	33
Sabah	6	41
Sarawak	14	35
Selangor	16	237
Terengganu	10	5
Kuala Lumpur	12	72
Total	**110**	**772**

(Source: CIDB Database, IT Department)

Questionnaire Survey

A structured questionnaire was designed to obtain primary data from the target survey group. The questionnaire is divided into four (4) parts: (i) general profile; (ii) level of IBS adoption and IBS score; (iii) readiness towards meeting targeted IBS score; and (iv) perception on IBS uses, in terms of benefits on using IBS, challenges on using IBS, and recommendation on better IBS implementation. For the purpose of this study, focus will be given on findings upon level of IBS adoption and readiness towards meeting targeted IBS score, while the respondents' perception on IBS uses is discussed in another separate study. The response formats include both open- and close-end, where the close-end questions were either in multiple choices or in ranking scale (a 5-point Likert scale).

The potential survey respondents, who were also the person in-charge of the project, were contacted based on the corresponding info recorded in the CIDB database. The respondents were first briefed with the objective of the study and the summary of project awarded to them in 2013. They were then asked whether the particular project is using or not using IBS, the IBS score of the project if IBS was used, and the respondents' past experience on IBS project. The reasons of using or not using IBS for the particular project were also recorded. In terms of readiness assessment, the survey attempts to study the respondents' self-perceive IBS readiness from three perspectives: (i) IBS knowledge & experience, (ii) IBS technical skills & expertise, and (iii) clarity of commercial drivers. Such approach was adapted from the one developed and used by National Federation of Builders (NFB) in the NFB Building Information Modelling (BIM) readiness survey 2012. The readiness assessment presupposes that all three perspectives are necessary elements for a company to move towards Industrialised construction. For example, a company may articulate the business benefits (or 'commercial driver') to be gained from IBS, but if there is a lack of IBS project management skill within the business and a lack of on-site specialized IBS skill, then the gain cannot be realized. Alternatively, a person may have the technical IBS skill, but if the management lacks the knowledge that would enable them to implement IBS throughout the business, then the company will not be able to take advantage of the person's capability. Finally, knowledge and skills can be in place, but without the perception that there are business benefits to be derived from adopting IBS, and the ability to assess the investment and returns within one's own business, there is no commercial rationale for a company to adopt IBS (Figure 4).

Questions were set to tackle the respondents' IBS readiness accordingly. In terms of technical skills & expertise, respondents were asked whether their company has enough project manager/engineer, installation operator, and machine/equipment in conducting IBS project. In terms of knowledge & experience, respondents were asked whether they understand each system used in IBS projects, how it is implemented, and the IBS scoring system. Besides, they were expected to answer whether their staffs have any training or exposure to IBS. To address the clarity of commercial drivers, respondents were asked whether IBS is perceived as a core competency within their company's business, intention to use IBS in the future projects, and is IBS is being considered during the procurement process.

Elements of Assessment	**Present**		**Future**
Technical skills	Existing working practices and experience	→ may inform	Technical capability and skills to use IBS tools
Commercial drivers	Perception of commercial drivers and potential benefits	→ may inform	Management's inclination to adopt IBS
Knowledge and understanding	General knowledge of IBS and specific application to projects	→ may inform	Business' ability to develop IBS competence around behaviour and working practices

Figure 4. Elements for assessing IBS readiness

RESULTS

The present study successfully obtained 602 responses in total: 109 from the government projects, and 493 from the private projects (Table 6). In the case of private project, 493 respondents represented 64% of the population (772 private projects), achieving a precision of 2.65% with 95% confidence level (Equation 1). To note, the number of responses drawn from each state follows the project distribution by state in the population. The respondents were either persons in-charge of the projects (i.e. project manager, site manager, engineer, site engineer), or those who directly involved in the projects (i.e. director, contract manager, quantity surveyor). In terms of project category, 35%, 31%, and 38% of 109 government projects were residential, non-residential, and social amenities, respectively; while for private projects, the distributions were 57%, 40%, and 3%, for residential, non-residential, and social amenities, respectively (Figure 5).

Table 6. Breakdown of population and sample size private and government projects, by state

State	Private Project		Government Project	
	Population	Sample size	Population	Sample size
Johor	203	157	12	12
Kedah	21	18	2	2
Kelantan	5	4	-	-
Melaka	29	24	5	5
Negeri Sembilan	38	12	5	5
Pahang	19	6	16	16
Perak	29	17	7	7
Perlis	5	3	1	1
Pulau Pinang	33	28	6	6
Sabah	41	27	6	6
Sarawak	35	16	15	14
Selangor	237	111	16	16
Terengganu	5	1	10	10
Kuala Lumpur	72	69	9	9
Total	**772**	**493**	**110**	**109**

Equation 1. Determination of survey sample size

$$n = \frac{P[1-P]}{\frac{A^2}{Z^2} + \frac{P[1-P]}{N}}$$

Where:

n	=	Sample size required
N	=	Number of people in the population
P	=	Estimated variance in population, as a decimal: (0.5 for 50-50, 0.3 for 70-30)
A	=	Precision desired, expressed as a decimal (i.e. 0.03, 0.05, 0.1 for 3%, 5%, 10%)
Z	=	Based on confidence level: 1.96 for 95% confidence, 1.6449 for 90% and 2.5758 for 99%
R	=	Estimated Response rate, as a decimal

$$n = \frac{0.5[1-0.5]}{\frac{0.04^2}{1.96^2} + \frac{0.5[1-0.5]}{772}}$$

n	=	493
N	=	772
P	=	0.5
A	=	0.0265
Z	=	1.96

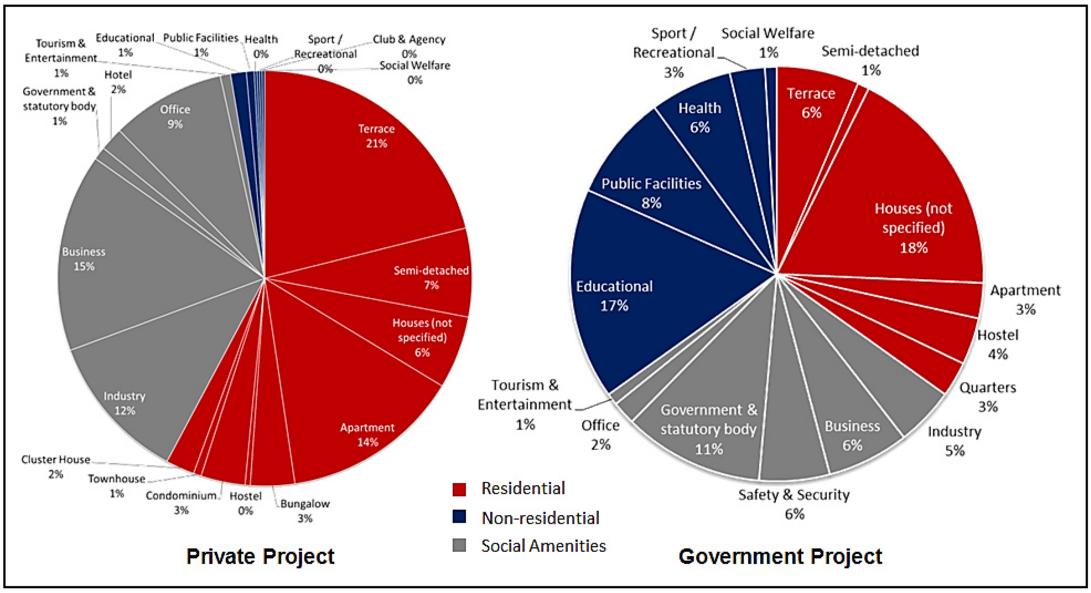


Figure 5. Percentage distribution of respondents' project

IBS Adoption Level

The overall IBS adoption level in 2013 for the identified potential IBS projects – new building project that worth RM10 million and above – was 15.3% (135 out of 602); with the adoption level of 61% and 14% in both government and private projects, respectively (Figure 6). Residential building appeared to be the building type that highly adopting IBS. The distribution of IBS projects by project categories – residential, non-residential, and social amenities – is as shown in Figure 7, where 42%, 24%, and 34% respectively in the government projects, and 57%, 37%, and 6% respectively in the private projects.

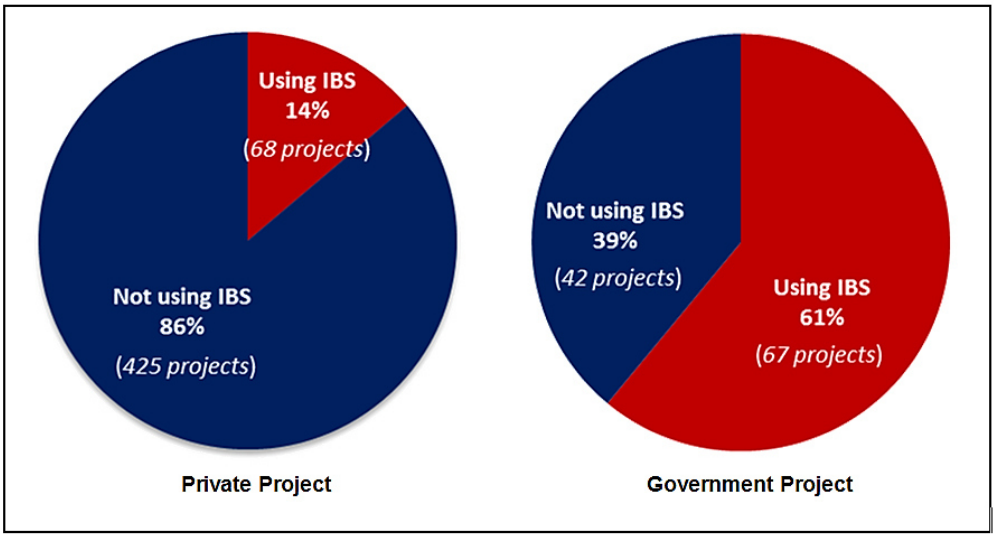


Figure 6. Breakdown of projects with value RM10 million and above, using/not using IBS

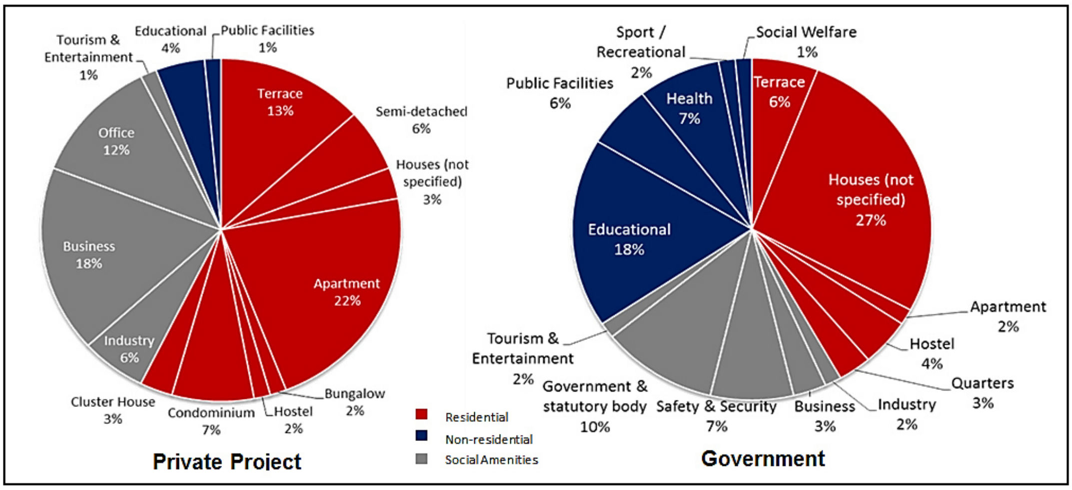


Figure 7. Breakdown of IBS projects by project category

IBS Score

IBS score is a physical measure of the IBS content or usage in a construction by calculated using a predetermined formula covering structural systems, walls, and peripherals of a building, as defined in the CIDB: CIS 18:2101, Manual for IBS Content Scoring System (IBS Score). It has been set as one of the targets to be achieved in the IBS Roadmap 2011 – 2015: (i) to sustain the existing momentum of 70% IBS content for public sector building projects through to 2015; and (ii) to increase the existing IBS content to 50% for private sector building projects by 2015. In the present study, info on IBS score in the present study was obtained through questionnaire survey since the existing CIDB data base does not have record on IBS score. The mean IBS score achieved by each category is shown in Figure 8. For the category of residential, non-residential, and social amenities in the government project, the average IBS scores were 70, 80, and 76, respectively; as compared to the average IBS scores of 65, 63, and 64, respectively in the private project. In this sense, the targets set for both the government and private projects have been achieved.

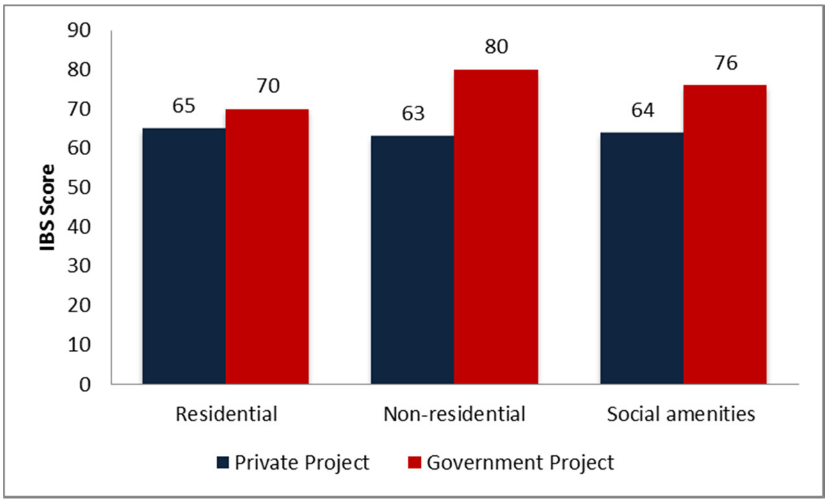


Figure 8. Average IBS Score by project category

Reasons for using/not using IBS

Reasons given by the respondents upon using or not using IBS for the particular awarded project were recorded and content analysis was conducted to categorize these reasons. In general, the reasons of using IBS can boldly be due to: (i) cost effective, (ii) client's requirement, (iii) faster construction, (iv) nature of the project, and (v) management's decision; while the reasons of not using IBS are mainly due to: (i) client' requirement, (ii) nature of the project, (iii) contractor's capability, (iv) high cost, and (v) management's decision. Figure 9 shows the example of reasons given by the respondents upon using or not using IBS for the awarded projects, while Figure 10 and Figure 11 further present the percentage of distribution for each of these reasons.

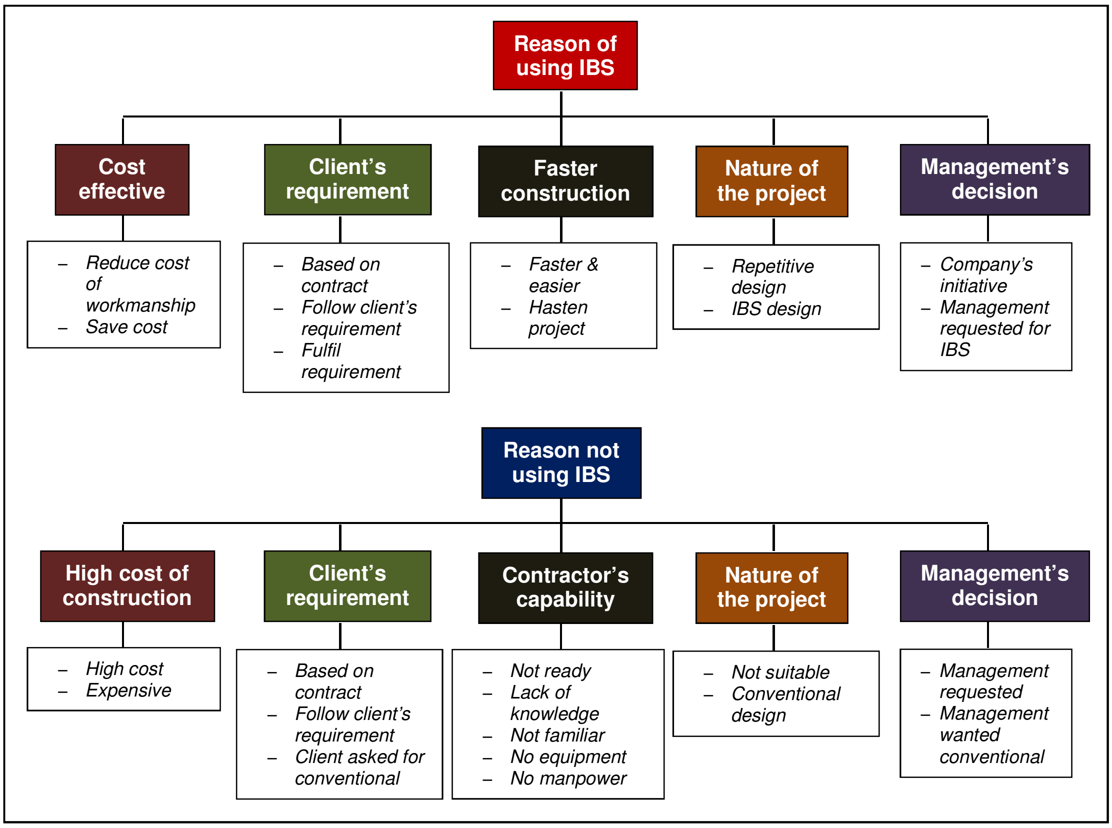


Figure 9. Reasons of using/not using IBS

In government projects, "client's requirement to use IBS" is the dominant reason that drives respondents towards using IBS (79%). Although "client's requirement" (41%) is also the main driving factor in private projects, other factors do play their important role, such as "faster construction time" (35%) and "cost effective" (19%). While contributing to the smallest portion (5%), "management' initiative of adopting IBS" in private project indicates that private sector began to realize and appreciate those benefits brought by IBS construction which cannot be obtained from conventional construction. The three main reasons of not using IBS were due to "high cost of construction", "the nature of project that is not suitable for using IBS", and "client's requirement to use conventional method". In the case of government project, although contractors are subjected to 70% IBS content, exemption of using IBS was given upon consideration. Most of the time IBS was not adopted as it was planned due to "the nature of the project" (32%), which is too custom design and no consistent pattern. In the case of private project, cost and instability of the market (33%), are always the main reasons that discourage the involvement of contractors in using IBS.

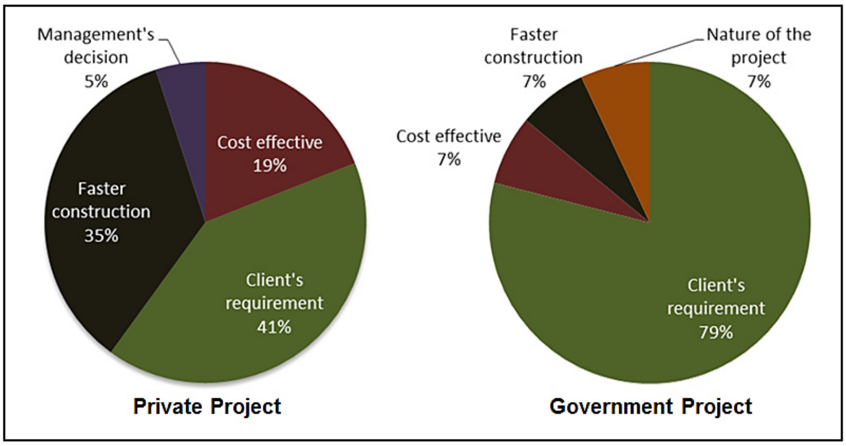


Figure 10. Respondents' reason of using IBS for the surveyed project

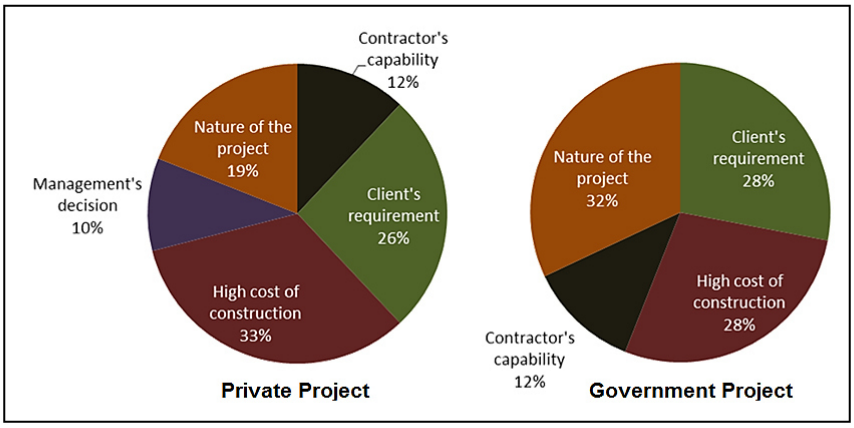


Figure 11. Respondents' reason of not using IBS for the surveyed project

Respondents' Past IBS Project Experience

Overall, 59% of the survey respondents have never involved in any IBS construction (Table 7). The percentage is even higher among private project respondents as 66% of them did not have past IBS project experience, compared to 33% of the government project respondents (Figure 12). Past IBS project experience was found playing an important role in influencing contractors to adopt IBS for their up-coming construction project, because those who have no past IBS project experience tended not to consider using IBS in their next project. A Pearson's chi-square test was run, to examine whether past IBS project experience has driven contractors towards using IBS for the awarded project in 2013. The results show a chi-square of 246.711, with 1 degree of freedom, which is significant at the

0.001 alpha level. As such, one can conclude that there is a significant relationship between the two tested variables, where contractors who have past IBS project experience tend to use IBS for their up-coming construction project.

Table 7. Cross tabulation of respondents' past IBS experience and the adoption of IBS for projects awarded in 2013

No. of past IBS project	Private Project		Government Project	
	Using IBS for the 2013 awarded project	Not using IBS for the 2013 awarded project	Using IBS for the 2013 awarded project	Not using IBS for the 2013 awarded project
None	7	321	3	32
1 to 2	27	96	45	10
3 to 5	20	8	10	0
6 to 9	12	0	4	0
10 and above	2	0	5	0
Total	68	425	67	42

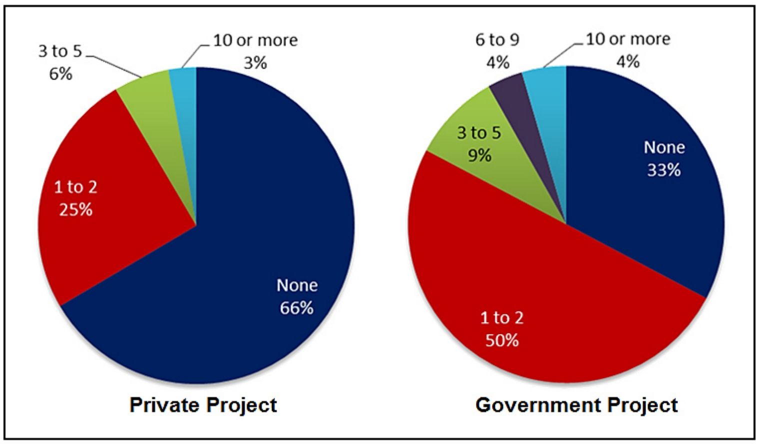


Figure 12. Respondents' involvement in IBS project

Respondents' Perceived IBS Adoption Readiness

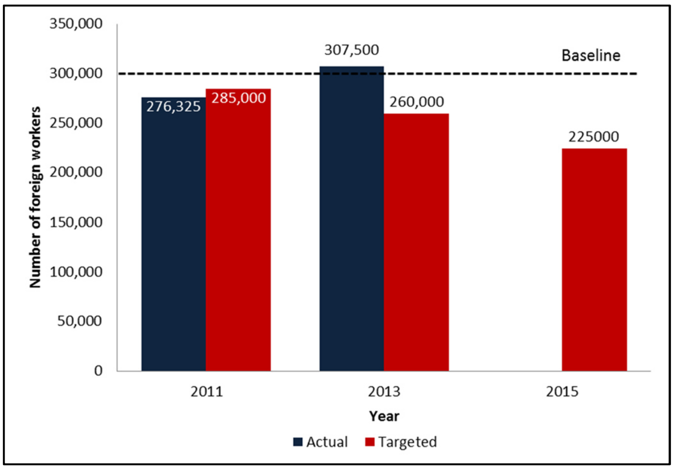
Table 8 shows the respondents' perception on IBS adoption from three perspectives: (i) IBS knowledge & experience, (ii) IBS technical skills & expertise, and (iii) clarity of commercial drivers. Overall, the government project respondents tended to perceive themselves to be more technically-ready and having higher understanding on IBS than the private project respondents, as a result of relatively higher exposure to IBS project in their past experience. Despite having relatively less understanding on IBS as well as technical skills/expertise as compared to government project respondents, a large number of the private project respondents perceived IBS as an important implication for business, where 70% of the respondents perceived IBS as a core competency in their company's business; 66% stated that IBS was being considered during the procurement business; and 65% reported that their companies intend to use IBS more frequently in future projects. This suggested that sentiments in the market are considering IBS as an alternative for future project construction. By assuming only those who reported a "Yes" for all three readiness criteria – IBS expertise, IBS knowledge, and IBS commercial drivers – were IBS-ready, one may find that only 20.4% of the total survey respondents (123 out of 602 respondents) perceived themselves to be IBS-ready. The government project respondents reported to have higher readiness (41.3%), as compared to the private project respondents (15.8%).

Table 8. Respondents' perception on readiness upon IBS adoption

Private Project						Government Project					
IBS expertise						IBS expertise					
Manager		Operator		Machine		Manager		Operator		Machine	
Yes	32%	*Yes*	26%	*Yes*	25%	*Yes*	69%	*Yes*	64%	*Yes*	64%
No	68%	*No*	74%	*No*	75%	*No*	31%	*No*	36%	*No*	36%
IBS knowledge						IBS knowledge					
IBS training		Understanding of IBS system		Understanding of IBS score		IBS training		Understanding of IBS system		Understanding of IBS score	
Yes	47%	*Yes*	42%	*Yes*	31%	*Yes*	82%	*Yes*	70%	*Yes*	53%
No	53%	*No*	58%	*No*	69%	*No*	18%	*No*	30%	*No*	47%
Commercial drivers						Commercial drivers					
Core competency		Procurement process		Use IBS in future		Core competency		Procurement process		Use IBS in future	
Yes	70%	*Yes*	66%	*Yes*	65%	*Yes*	59%	*Yes*	59%	*Yes*	62%
No	30%	*No*	34%	*No*	35%	*No*	41%	*No*	41%	*No*	38%

DISCUSSION

Since the objectives of each IBS surveys are different, direct comparison with previous study cannot be carried out. However, all these IBS surveys, including the present study, have shown a relatively low IBS adoption level in Malaysian construction industry. Low level of IBS adoption (15.3%) as well as the contractors' self-perceived readiness (20.4%), especially among private sector, indicate that government's efforts in promoting IBS as an alternative to the conventional and labour intensive construction method have not made headway. In fact, the reduction of foreign workers is the most desirable outcome for IBS implementation. Targets were set in the IBS Roadmap 2011 – 2015, where the number of foreign workers is to be reduced to 285,000 in 2011, 260,000 in 2013, and further down to 225,000 in 2015 (Figure 13). However, actual figures obtained from the Department of Statistics Malaysia have shown an opposite trend, where total foreign workers in construction sector rose from 272,730 in year 2006 to 307,500 in year 2013. While these figures may seem lesser compared to the one shown in manufacturing and agriculture (Table 9), the induced impact cannot be overlooked because the amount of foreign workers in construction industry could be more when covering those illegal foreign workers. With the current low adoption level, IBS's capability in contributing to the reduction of foreign workers in construction industry cannot be fully shown, unless there is more buy-in from the industry players, especially from the private sector.



(Data source: Department of Statistics Malaysia; IBS Roadmap 2011 – 2015)

Figure 13. Observed and targeted number of foreign workers in construction industry

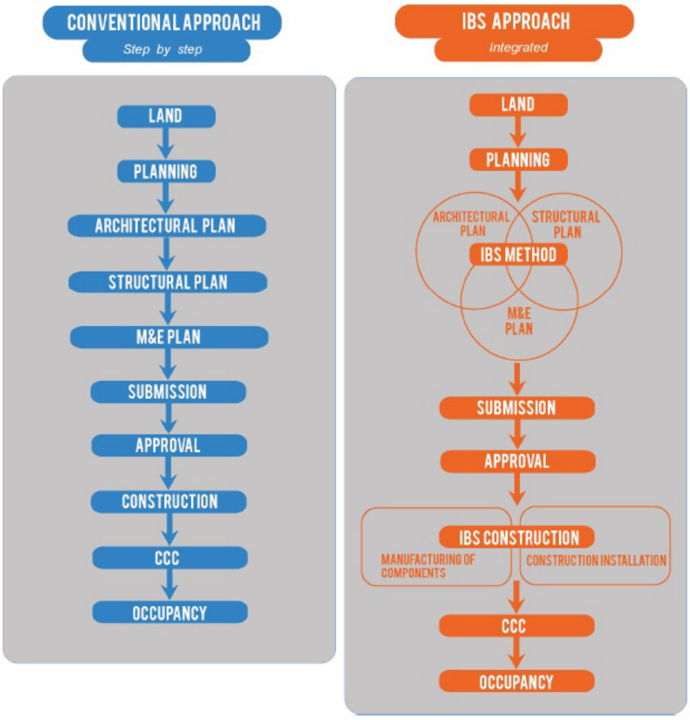
Table 9. Distribution of foreign labours in manufacturing, construction, and agriculture

Sector	2006	2007	2008	2009	2010	2011	2012	2013
Manufacturing	628,576	766,451	737,523	355,710	539,579	422,117	389,203	408,600
Construction	272,730	298,422	285,845	204,237	187,743	276,325	265,673	307,500
Agriculture	162,338	162,338	220,528	116,324	150,823	371,259	355,359	373,300

(Data source: Department of Statistics Malaysia)

The increasing number of foreign workforce in construction sector carries two messages: first, the country is lacking of manpower and heavy relies is placed on foreign manpower; second, the conventional construction is still being practiced widely rather than emphasizing on mechanization and industrialisation. Developers, among the wide range of industry players, hold a very important position to ensure the success of IBS adoption, especially among private sector, because the adoption of IBS is hugely dependent on readiness and maturity of developers to move from existing contracting role into IBS system integrator. As shown in the present questionnaire survey, "client's requirement to use IBS" has been the main driving factor for IBS adoption in both private and government sectors. If more of the developers from private sector can be convinced to adopt IBS, an overall higher level of Industrialised construction industry can be achieved. Through the present questionnaire survey, private developers were found to be aware of the importance of IBS as an implication for business in future construction project. However, conventional construction is still preferable over IBS due mainly to the sheer cost of investment and the inadequacy of market size. As shown in the present survey study, 33% of the private project respondents were not using IBS due mainly to the high cost of construction resulted from IBS construction. IBS is still not viewed as cost-effective because of the existing closed system in IBS supply chain that may cause an increase in the price of components and tender pricing. Apart from that, there is an abundance of cheap foreign workers in Malaysia, resulting the shift of building system from conventional to IBS not motivated by cost factors.

In addition, IBS and conventional construction are totally different in various aspects, be it the idealism, processes, management, or even the skill sets. Figure 14 compares the housing construction process flow between conventional and IBS approaches. While the two processes are almost similar, IBS approach requires high level of collaboration among project parties to account for major constraints in the design with respect to transportation of components, installation logistics, permits and inspection schedules. In short, it requires fundamental structural change to the industry, both in the design and construction stage. During the design stage, IBS approach requires the integration of the architectural plan, civil and structural (C&S), mechanical and electrical (M&E), and workshop drawing, to ensure the effectiveness of design coordination; while during the construction stage, IBS components are manufactured in a factory and then delivered on-site for assembly and erection. Overall, IBS requires a different strategy on supply chain, planning, scheduling, handling, as well as purchasing of materials, which lent the adopter to serious rethinking about how construction projects are planned and executed. With this regard, a new business approach, investment, and financial planning including the effective combination of cost control and selection of projects that give enough volume to justify the investment is a must in IBS construction.



(Source: Adapted from CIDB, 2014)

Figure 14. Process flow using conventional and IBS approach for housing construction by developer

The limited take up of IBS in private projects is also affected by the different payment system required when using IBS. From the developer's point of view, the costs of material, labour, and machinery in the IBS system are not deemed as a good business investment compared with the conventional system. In current practice, before a construction begins, the client pays between 10% and 25% of the total amount of the contract value as an initial payment. However, in an IBS project, initial spending has to be made to the manufacturers before any progress in the payment is made. IBS manufacturers are normally required to advance approximately 75% of the capital to manufacture the IBS components before delivering these components to construction sites. Without sufficient financial backup, the developers are hardly convinced to use IBS in their projects. Moreover, the adoption of IBS mainly depends on the readiness and maturity of the developers/constructors in terms of know-how and expertise. In several cases, the use of IBS by the developers/contractors has not led to total satisfaction, and actually has been less productive, lacking in quality, and is more costly than the conventional method. Sometimes certain building projects were awarded and constructed using IBS system but suffered project delays and bad qualities. This condition has left the industry with noticeable difficulties when using IBS. Consequently, the industry has become reluctant in accepting IBS, except when it is required by the clients.

Most projects in Malaysia were designed in a conventional way. If IBS is to be adopted in these projects, they had to be first converted into IBS. As such, the developers may face many difficulties, to accommodate the changes in the design phase as well as getting approval from the authorities thereafter, since the conventional design did not consider the modularity and manufacturality of components. In order to ease the process during the tendering stage and also to reduce cost amount, conventional system that can guarantee a rather smooth path is highly preferable. The issues of expertise and technology cannot be avoided in ensuring the successful IBS implementation. IBS labour competency and skills are still a critical area to be developed. Currently, the country remains lacking in professional skilled workers to lead the implementation of IBS on site, production, moulding, and fabrication, as well as lacking of land surveyor for guideline panel. Poor human capital development on IBS will affect not only the contractors but also the entire supply chain. The skill level of IBS workers is more demanding compared with the skills demanded of workers under conventional construction methods. The system demands more machine-oriented skills, thus requiring the reorientation in terms of the training and education of human resources in a given organization. Finally, technology transfer is also one of the barriers in implementing IBS system. Currently, local developers depend on foreign expertise and technology. Since most of the machines and materials used in the design of IBS components are imported from developed countries, the cost of producing IBS components and their installation is not competitive. Given that profit is the main motivation, most of the developers will put a second thought in attempting to apply IBS system in their construction projects.

CONCLUSION

The present study sets out to assess IBS adoption level in Malaysia, for both the government and private projects in 2013. The survey sampling method adopted here is different from the past IBS surveys, where the survey target group was based on number of projects awarded (instead of number of contractors), and the survey sample being drawn was statistically reflecting project distribution by state as well as by project status (private or government project), which are most likely be omitted in the past IBS surveys. As such, the results presented in this study can provide a clearer picture on the country's IBS adoption level as well as the readiness of its construction industry towards IBS implementation.

The introduction of IBS – embedded within the CIMP, championed by the CIDB, and promoted by the government – is paving the way for a radical change in the Malaysian construction industry towards the globalization era where an increase in productivity, quality and safety is a must. Throughout this study, one may find that conventional construction, which is excessively reliance on unskilled foreign workers, is still representing a significant portion in the country's construction projects, even though its levels of quality, productivity, and safety are no longer in line with the future development of the country. Nevertheless, the future development of IBS in Malaysia is encouraging. Considering that labour cost has dramatically increased due to the rising of living standard and the levy imposed by the government on foreign workers, it is important for the builders to explore other building system that requires the least labour input, like IBS, as shorter construction time may eventually imply lower site staff overhead and cost saving on equipment rental. Besides, following the commencement of various mega projects within the Klang Valley region as well as the increasing demand for affordable housing around the country, greater adoption of IBS is expected to meet the time and cost-effective requirements.

ACKNOWLEDGEMENT

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AN INDUSTRIAL REPORT ON THE MALAYSIAN BUILDING INFORMATION MODELLING (BIM) TASKFORCE: ISSUES AND RECOMMENDATIONS

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Abstract
The government of Malaysia has a vision to become a fully developed country by the year 2020, and the construction industry has a significant role to play in assisting the government to achieve this vision. In order to become an advanced country, the construction players in Malaysia need to be globally competitive, and encouraging innovation in the industry is a key aspect of this is and provides the rationale for the roundtable discussion workshop this paper describes. The main objectives of this roundtable discussion were to establish the Building Information Modelling (BIM) task force, provide a platform for industry experts to discuss BIM issues, share knowledge and information and work collaboratively, and to provide recommendations for policy makers for further enhancements of the construction industry. The exploratory roundtable discussion was used as the research method. This roundtable discussion demonstrated the lack of understanding of BIM by the construction industry in Malaysia and the importance of establishing a BIM task force to promote BIM and National BIM Guidelines in Malaysia. This paper also presents the draft organisational chart for the BIM Taskforce, concludes that Industrial Building System (IBS) should provide one of the directions for this task force to implement BIM and that the next step is to develop a case study to increase knowledge sharing activities amongst practitioners and academics.

Keywords: *Malaysian construction industry, Building Information Modelling (BIM), BIM Taskforce and National BIM Guidelines.*

INTRODUCTION

In a typical construction project, a lot of information has to be gathered and in many forms including drawings, contracts, reports, charts and worksheets. The project involves numerous parties (owner, architects, engineers, contractors), decisions and data, and a long set of processes starting with the initial idea and followed by a feasibility study, design, construction and operation and maintenance works (Waleed *et. al.,* 2003). Communication between members of the construction supply chain thus becoming crucial and can be difficult to be delivered due to the differences of background, references and goals. The challenges in communication requires extra effort to be put in and time consuming to deal with clarification of information, changing plans and sometimes re-working components that were installed according to misinterpretation of the documents. (Rashid, 2009; Nawi *et. al.,* 2009). Due to this, Waleed *et. al.,* (2003), consider construction to be a fragmented industry because of the lack of information sharing through its life cycle.

To overcome these challenges, many construction companies in Malaysia have invested in Information and Communication Technologies (ICTs) to handle all the information between parties in a construction project because they believed ICTs can process data and information with minimum delay and errors. Fischer and Kunz (2004) and Stewart *et. al.,* (2002) have argued that to have a real-time connection between work stakeholders and suppliers, ICTs could be an effective tool that improves the processing of data and communication and could improve the coordination and collaboration among parties in a construction project. As a result, Building Information Modelling (BIM) could provide a platform for sharing digital information among parties in a construction project in order to minimise the fragmentation issues (Rashid, 2009; Haron 2013; Hervas *et. al.,* 2007; Waleed *et. al.,* 2003). Haron (2013) defined BIM as *"an approach to building design and construction through modelling technology, with an associated set of processes and people to produce, communicate and analyse building information models*." In this regards BIM will act like a repository system of digital information for sharing within a construction project. Use of a single and integrated repository system of project information has been shown to reduce errors associated with inconsistent and uncoordinated project documents (Khanzode and Fisher, 2000). The other benefit associated with BIM is enhanced collaboration between project stakeholders which itself results in better design and drawing coordination, constructability conflict resolution, automated cost estimating and simulation of project planning (Atkin, 1999; Staub-French and Khanzode, 2007).

Realising the importance and the benefits gained through the utilisation of ICT in the construction industry, in 2008 the Construction Industry Board (CIDB) set up a team to promote ICT in construction industry in line with the Malaysian government's policy (CIDB, 2008). However, implementing and adopting ICTs can be complex and numerous issues need to be taken into account especially during the early stages. Yoke *et. al.,* (2002) found that the majority of Malaysian construction companies failed to utilise the full potential of the Internet due to an ICT adoption process that followed that of the successful companies without considering the contextual problems, strategies and needs. Yusuf and Othman (2008) added that a lack of training and limited availability of expert ICT users in the construction industry worsen the current situation. Hence, to avoid these pitfalls a thorough study need to be conducted to identify the right strategy for adopting ICT in the Malaysian construction industry. This paper discusses the benefits and the challenges of implementing BIM in construction projects. Additional, the importance of establishing a BIM Taskforce in Malaysia is also discussed and it concludes with some recommendations to the BIM Taskforce to progress further in the industry.

BUILDING INFORMATION MODELLING (BIM): THE BENEFIT, THE CHALLENGES AND THE TASK FORCE

In August 2009, in the very first seminar of Building Information Modelling in Malaysia, the Director of Public Work Department Malaysia (PWD), Datuk Seri Prof Judin Abdul Karim, in the keynote speech, urged construction companies to adopt ICT and stressed on the importance of having an integrated software system and standardisation for obtaining effective workflow for the project development and implementation (Sani, 2009). Targeting first at improving efficiency, a BIM pilot project has also been delivered by PWD in 2010 on National Cancer Institute building in Putrajaya, Malaysia. The results of the pilot project will be used to determine if BIM can be applied in the 10th Malaysia Plan development projects (New Strait Times, 2010). The keynote speech and the advertisement have opened up an early indicator of the government's commitment to implement BIM.

According to Eastman *et. al.,* (2011), BIM is defined as *"a modelling technology and associated set of processes to produce, communicate, and analyse building models".* Meanwhile Smith (2009) defines BIM as *"a systems approach to the design, construction, ownership, management, operation, maintenance, use, and demolition or reuse of buildings"* and The BIM SmartMarket Report by McGraw-Hill (2008) defines BIM as *"the process of creating and using digital models for design, construction and/or operations of projects"*. Onuma (2008) believes that the most important part of BIM is not the software functionality, but collaboration in the design and planning process which speeds the process and clarifies design. The National Institute of Building Sciences (NIBS, 2007) states that *"BIM stands for new concepts and practices that are so greatly improved by innovative information technologies and business structures that they will dramatically reduce the multiple forms of waste and inefficiency in the building industry"*. Meanwhile, specifically to the Malaysian construction industry, Haron (2013) defined BIM as *"an approach to building design and construction through modelling technology, with an associated set of processes and people to produce, communicate and analyse building information models.* Based on several definitions, BIM can be conceptualised as a combination of three main components namely; process, technology and policy (Figure 1).

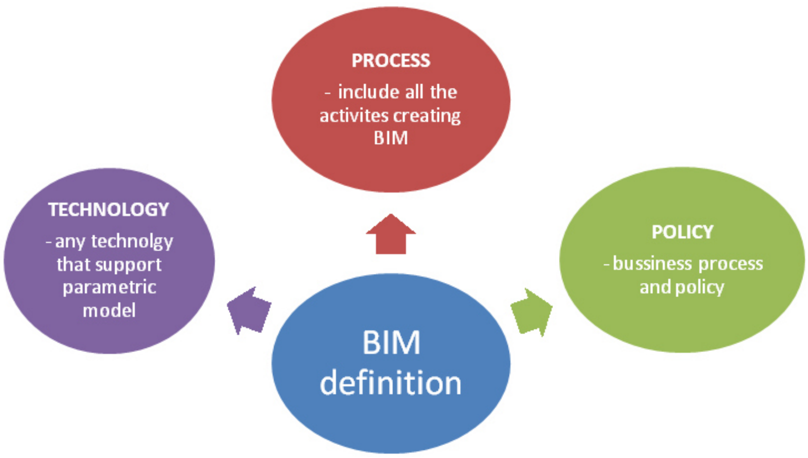

Figure 1. BIM definition components

The Benefits of BIM

Numerous construction projects have already demonstrated significant benefits from employing Building Information Modelling (BIM) technologies and processes. CRC Construction Innovation (2007) mentioned that one of the key benefits when implementing BIM is having information about the parts of a building in an integrated data environment. Having an integrated data environment acts as a central database of the construction project for all parties to refer to and that can avoid unnecessary data re-entry as the project develops. This environment promotes information collaboration activities resulting in;

- Increasing productivity: Kaner *et. al.,* (2008); Khanzode *et. al.*. (2008) and Staub-French and Fischer (2001) reported that utilisation of BIM can result in error free design documentation, shortened lead times and a reduction in Requests For Information (RFI) which lead to significant increases in construction project productivity;

- Smoothing of the coordination process: Visualization and simulation in BIM is a major advantage when utilizing BIM. Heesom and Mahdjoubi (2004) argued that 4D simulations can improve project planning due its capabilities to predict the potential problems at the construction stage. This capability allows considerable savings to be made on construction projects by identifying problems prior to construction and avoiding re-work during the project. Visualization and simulation in BIM can be utilized as a clash-detection tool to avoid re-work (Khanzode *et. al.,* 2000).

According to findings from Stanford University Centre for Integrated Facilities Engineering (CIFE) based on 32 major projects, using BIM allows the following benefits to be realised (Azhar *et. al.,* 2008):

- compared to traditional methods project time can be reduced by 7%;
- a good visualization tool can be used to detect clashes enabling the owner to save up to 10% of the contract value via clash detection activities;
- compared to traditional methods used to generate a cost estimate, utilisation of BIM can save up to 80% in time to generate a cost estimate.

In conclusion, the benefits from optimization of BIM includes cost reduction, risk reduction through automated clash detection, and increasing the quality of construction due to better management processes, the quality of the building itself or the construction period having access to complete information.

The Challenges

Despite the numerous benefits that have been gained from the utilisation of BIM, the uptake within Malaysia seems to be stagnant. Some organizations believe that productivity will suffer when implementing BIM because the technology is difficult to learn and the established workflow will be disturbed; designers believe that the owner and contractors will gain the most benefits when implementing BIM but that BIM will increase the risk (Haron, 2013). Legal issues also contribute to this scenario: the most prominent questions that need to be answered are; who owns the design; for data entry of the model, who will be responsible for the activities that ensure the data is accurate; and if there any inaccuracies in the model, who will be taking responsibility for them (Azhar *et. al.,* 2008).

Many organizations believe that implementing BIM will affect their established business processes according to Taylor and Levitt (2007). They argue that implementing Information Technology (IT) will reshape their business processes and during this process productivity will suffer (Olatunji, 2010). Ustinovicuius *et. al.,* (2007) added that reshaping the construction processes and business from being fragmented to collaborative in nature will put the project outcomes and clients' expectations at risk. Fisher (2008) identified that the main hurdle that the Architect-Engineering-Construction (AEC) industry needs to overcome is the integration of BIM across the different phases and the different participants of a construction project.

In conclusion, there are three challenges when implementing BIM: legal issues (i.e. ownership, contracts, project delivery, etc.); technology (i.e. the level of user friendliness, inter-operability between software, cost, etc.); and issues related to the organization and its business structure and culture (i.e. productivity, level of acceptance intra and inter organization, knowledge sharing, etc.).

To ensure smooth implementation of BIM in Malaysia, the authority must address these issues accordingly.

The Needs of the Task Force

Many researchers, for example Eastman *et. al.,* (2011); Gilian and Kunz (2007); Tse, Wong, and Wong (2005), have discussed the potential of BIM at length and they believe that BIM has a capability as a collaborative tool in streamlining design and construction processes by providing a central repository of project data for all parties that can avoid unnecessary data re-entry as the project develops. However, in order to gain the benefits from implementing BIM, Succar (2010) emphasises the need to align both internal and external organisation processes, and without such alignment an organization or a project team will only benefit from a small subset of what BIM has to offer. Smith and Tardif (2009) and Eastman *et. al.,* (2011) identified that the implementation of BIM requires a strategic implementation approach to be successful as it is more of a business decision than a technical one. These arguments reveal the importance of implementing BIM with a proper strategy in order for the benefits to the construction industry in terms of managing risk, time, quality and cost to be successfully achieved.

The pace of BIM adoption and implementation is still slow because of concerns about the legal aspects, technology capability and user friendliness, and business structure. Thus, it is believed that establishing the task force will provide a good platform for industrial players to discuss BIM issues, share knowledge and information, work collaboratively, and provide recommendations to policy makers for further enhancement of the construction industry. Although the direction and scope of the task force are yet to be decided, a kickoff event is needed to identify and bring the industrial experts to come together.

MALAYSIAN CONSTRUCTION INDUSTRY: BACKGROUND

In Malaysia, the construction industry makes a significant contribution to the country. Over the past decade, this sector annually accounted for about 3-5% of the Gross Domestic Product (GDP) and provided employment for about 10% of the total labour force (CIDB, 2009). This shows the importance of projects in Malaysia's construction industry to its economy, and provides both great challenges and opportunities for various companies in the construction industry. In year 2009, to maintain the growth of the national economy, despite of economic crisis the government took firm measures and introduced government driven stimulus packages for the construction. For example, a second economic package for the year 2009 with an additional budget amounting to RM60 billion (about 13 billion Euros) were allocated to keep the construction activities active (Market Watch Malaysia, 2010).This shows that the demand for construction is highly sensitive to developments in other sectors of the economy.

However, the government of Malaysia realized that the current construction industry needs to reform in order to be internationally competitive. In 2005 about 17.3% of government contract projects in Malaysia were considered sick due to delays of more than three months or complete project abandonment for a variety of reasons (Murali and Soon, 2007). This figure can tarnish the image of the construction industry in Malaysia; therefore, the government of Malaysia launched the Construction Industry Master Plan (CIMP) 2006-2015 to overcome the weaknesses of the current construction industry. The vision and the mission of CIMP are: *"The Malaysian construction industry shall be a world class, innovative and knowledgeable global solution provider;"* and *"To be a dynamic, productive and resilient enabling sector, supporting sustainable wealth creation and value creation, driven by technologically-pervasive, creative and cohesive construction community"* (CIMP, 2006).

In CIMP, there are seven strategic thrusts which are identified as follows:

1. Integrate the construction industry value chain to enhance productivity and efficiency;
2. Strengthen the construction industry's image;
3. Strive for the highest standard quality, occupational safety and health, and environmental practices;
4. Develop human resource capabilities and capacities in the construction industry;
5. Innovate through research and development and adopt new construction methods;
6. Leverage on information and communication technology in the construction industry;
7. Benefit from globalization including the export of construction products and services.

(CIMP, 2006)

Strategic thrust number six shows that the government of Malaysia realises that Information Communication Technology (ICT) can be used as a tool for changing the traditional approach and at the same time it can strengthen the construction industry's image. However, Gerald (2006) believed that ICT in Malaysia is not fully utilised to benefit the construction industry; even digital submission for approval by local authorities is still in an experimental stage meaning that there is a lot work to be done to promote the benefits from utilising ICT. Although a survey completed by Gaith *et. al.,* (2009) on ICT use in Malaysia revealed that the majority of Construction companies believed IT capable of integrating and sharing information among parties involved in a project, the pace of using IT as a tool for collaboration was still low. From a contractor's point of view, the use of IT is only to improve communication and to reduce the loss of information, a finding from a survey completed by Mui *et. al.,* (2002) on internet use in the Malaysian construction industry. This survey also found that most of the companies used the Internet and considered it an important tool, although the researchers believed that they did not fully utilise the power of the Internet because they were only using the basic functions like e-mail.

Compared to other industries, Stewart and Mohamed (2003) revealed that the construction industry is still slow in terms of IT implementation due to the service or product characteristics offered by the industry. Steward and Mohamed (2003) added that fragmentation is one of the characteristics of the construction industry and it forms a barrier that prevents the strategic use of IT. Froese *et. al.,* (1997) believed that the main factor contributing to industry fragmentation is the volume of information that has been produced by many sources and at many levels, and the consequences of this scenario include problems like low productivity, cost and time overruns, and conflicts and disputes resulting in claims and time-consuming litigation. The major issue affecting the performance of the UK construction industry is the lack of integration across parties involved in the construction project according to Latham (1994). Various researchers, such as Mohamed (2003) and Alshawi and Faraj (2002) believed that in order to reduce delays, rework and communication breakdowns, collaboration and teamwork are crucial for enabling up to date information to be shared between parties in the construction project. Hence, BIM is recommended for promoting collaboration between parties in the construction industry, as mentioned by Rashid (2009); Haron. (2013); Waleed *et. al.,* (2003) and Hervas *et. al.,* (2007) is BIM.

THE METHODOLOGY

The Construction Research Institute of Malaysia (CREAM) in collaboration with Faculty of Civil Engineering and Earth Resources, University of Malaysia Pahang (UMP) organised an event entitled "IBS BIM: Mechanisation of Industrialised Building System (IBS) Through Building Information Modelling (BIM)" which was held on 17th November 2011 at Cyberview Resort and Spa, Cyberjaya, Selangor. At the event, the first author was involved as the chief coordinator, responsible for managing all activities for the one day event. The event consisted of three BIM case study presentations by the industrial practitioner, a BIM organisational readiness validation workshop and a roundtable discussion. The roundtable discussion was the main aim of the event, targeted at discussing the need for the BIM taskforce, and issues and recommendation associated with BIM implementation in Malaysia. This roundtable discussion was organised to bring together all experts with an interest and experience in implementing BIM and it was attended by 25 participants representing various organisations including private developers, government agencies, universities, contractors and consultants. Table 1 shows the background of the workshop participants:

Table 1: Background of the workshop participants.

No	Designation	Background	Experience (Years)
1	Head of Structural Department	Civil Engineering	>20
2	Senior Manager	Quantity Surveyor	11-15
3	Principal	Engineering	>20
4	Senior Architect	Architect	6-10
5	Principal	Planner & Scheduler	>20
6	Head of Architect	Architect	>20

7	Director	Civil Engineering	>20
8	Senior Manager	Architect	11-15
9	Assistant Director	Civil Engineering	11-15
10	Principal	Quantity Surveyor	>20
11	Senior Manager	Mechanical Engineering	11-15
12	Senior Manager	Architect	11-15
13	Principal	Architect	>20
14	Assistant Director	Engineering	>20
15	Principal	Civil Engineering	>20
16	Professor	Civil Engineering	>20
17	Lecturer	Civil Engineering	11-15
18	Senior Lecturer	Quantity Surveyor	11-15
19	Senior Lecturer	Buildings	11-15
20	Manager	Civil Engineering	11-15
21	Director Asset & FM	Quantity Surveyor	>20
22	Head of Development	Civil Engineer	>20
23	Assistant Vice President	Architect	16-20
24	Head of R&D Innovation	Architect	>20
25	Director	Computer Science	>20

The exploratory roundtable discussion was used as the research method. The advantages of this method are that participants are more objective and constructive in their arguments and instead of reporting the subjective impression of an individual interviewee, roundtable discussions identify the potential consensus about a subject as well as the range of opinions that led to that conclusion. In the process, data in a form of qualitative audio were captured by using Dictaphone during the roundtable discussion. After that, all audio were transcribed into written transcription before content analysis technique was used to determine the pattern of answer. As a result, four patterns has emerged and becoming the main discussion of the paper. They are all related to the BIM taskforce concerning the way forward, the strategy, the knowledge sharing and willingness of participants to share as can be referred to the next subchapter.

The ultimate objective in this discussion was to develop the BIM Taskforce in Malaysia in order to promote the implementation and utilisation of BIM in the Malaysian Construction Industry. However, before the BIM Taskforce was drafted, it was necessary to answer the following research questions:

- Research Question 1: What is BIM's status in Malaysia and what is the direction of the Task Force?
- Research Question 2: What is our strategy to make this happen?
- Research Question 3: What is the main issue in implementing BIM and what are the driving factors that can expedite the adoption of BIM?

DISCUSSION

The roundtable discussion was chaired by the fifth author who is the Director of The Construction Research Institute of Malaysia (CREAM). To start the discussion, the director presented two important issues for the discussion; a proposal for a Building Information Modelling (BIM) taskforce for promoting BIM in Malaysia's Construction Industry and its direction and elements for a successful and sustainable working group.

BIM Taskforce: The Way Forward

The first topic for discussion was "What is the direction of this taskforce to promote BIM in Malaysia?" and "What does it look like?"

Lots of questions and comments arose amongst the participants towards this topic, some of which include;

- *"...in order to set up the taskforce committee, there is the need to set up the clear direction".*
- *"... not clear and specified".*
- *"...which area we focusing? Industrial Building System (IBS) or traditional construction method?"*
- *"...who will involve in this taskforce?"*
- *"...who will lead this taskforce and what is the function of this taskforce?"*

From the responses given by the participants on the direction and area of focus for the BIM task force, the chairperson suggested IBS as a platform to promote the implementation of BIM in Malaysia. This is because the ultimate target of IBS in Malaysia is achieving mechanization and currently IBS in Malaysia is in the reproduction stage. It is hoped that by implementing BIM, the transition stage from the reproduction stage into the mechanization stage will speed up. Along the way, the improvement of construction needs such as quality, time and cost will also be considered. The majority of the respondents agreed that IBS will be used as a platform to promote BIM in Malaysia because the majority of the government's construction projects in Malaysia are shifting from traditional construction methods to IBS. Therefore, the BIM task force can take this opportunity to promote BIM. Although the majority of participants agreed to use IBS as a direction for promoting BIM, there are some issues that should be taken into account: *"...how to embed the use of BIM in current situation," "...how about current condition of contract," "...lacking of literatures that relate BIM with mechanisation of the IBS construction system has also been pointed out as a critical problem to set the direction"* and *"...limiting BIM on mechanisation are also meant limiting the benefits that BIM technology could offer. Such benefits are BIM standardisation of information, management of knowledge and information, standardisation in terms of planning assessment, application assessment, and, etc."*

Although some of the participants agreed with the issues raised, they suggested that to tackle them there is a need to establish a proper BIM task force organisational structure, to identify the key people to be involved in the BIM task force and to agree its agenda, which must tackle the issues arising from the roundtable discussion. One of the participants suggested that participants who attended this discussion event should be elected as 'Protem' steering committee members for the BIM task force, and CREAM as part of the government body will become the secretariat for BIM task force. The drafted BIM taskforce organisation chart is shown in Figure 2.

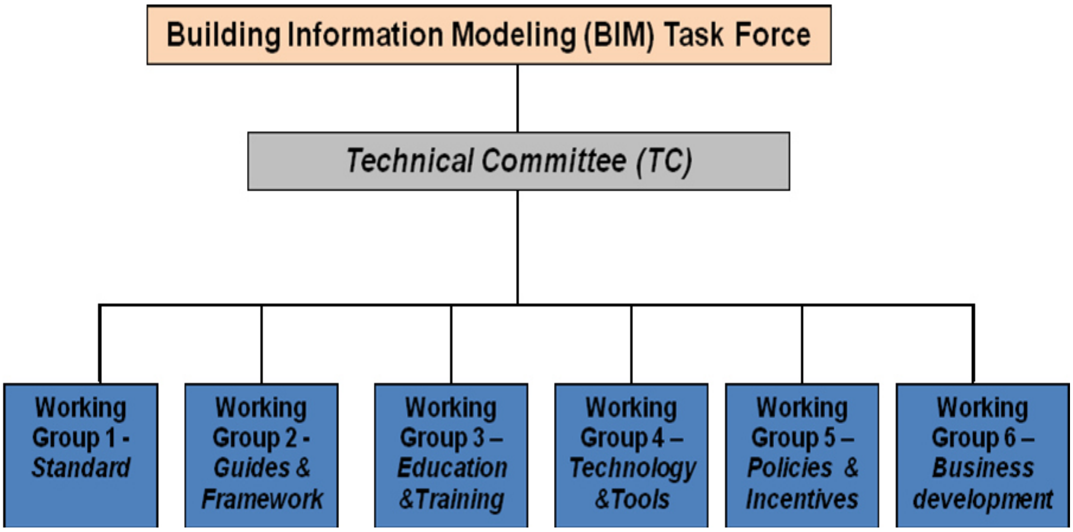

Figure 2. 'Protem' BIM Taskforce organisation chart

The Working Group will focus on its own niche area. It will present its findings to the other group to establish collective solutions for any issues arising, for example standards and guidelines, long life learning, technology, policies and business development.

BIM Taskforce: Strategy

One of the issues raised by the participants was the policy. There were lots of arguments about this, such, *"...how to change government policy?" "...how about private sector? Are they ready to change their business process?"* It was found that the participants had two different views, first to amend policy for the public sector and second to amend policy for private sector. The majority of participants believed that in Malaysia to change any policy, especially for the public or government sector, it is very difficult and time consuming compared to the private sector. The reason is because it involves procurement issues, circular, warranty issues, awards system design, and audit and these are believed to be very difficult tasks to tackle and resolve. However, respondents from the private sector argued that they believed that the use of BIM is viewed to be easy to fit in to every type of contract that could suit the business case.

The second most prominent issue raised was the Condition of Contract for those who implement BIM in their project. The majority of the participants agreed that the current Condition of Contract needed to be revised because it does not include BIM as a part of the contract. Without modification of this consultants, architects and contractors claimed that implementing BIM will create a new role which develops the model, and they will demand new fees based on their new role. Participants raised the issue of ownership of a BIM design model, especially when the contract is terminated. In the current Condition of Contract there is no clause related to these issues. These arguments or concerns are aligned with similar issues that Azhar *et. al.,* (2008) raise which most of the industry players who intend to implement BIM are expected to raise, i.e.; who has the ownership of the design? For data entry of the model who will be responsible for the activities that ensure the data is accurate? If the deliverables of 3D models are inaccurate, who will be taking responsibility for those issues?

To address these issues the steering committees of the BIM Taskforce have to develop a proper strategy plan or road map. One of the presenters suggested that the steering committees of the BIM Taskforce should convey to the related ministry how other countries have implemented BIM. They could use the United Kingdom, Australia and Singapore as examples how they pushed BIM into their construction industries. The UK for instance, is mandating BIM; Australia is supporting BIM and Singapore is assisting BIM. However, a comment was also made that BIM is still at an early stage within Malaysia's market and it is too early to adopt any particular approach.

For the moment, the participants suggested that working groups 2, 3 and 5 have a very critical role to study BIM in Malaysia's context to establish the right strategy or approach. They believed that BIM should be evaluated and the potential success rate must be determined as any organisation does not want to waste money and resources without any solid evidence.

BIM Taskforce: Knowledge Sharing and Willingness of Participants to Share: Are We Ready?

One of the elements of a successful and sustainable working group is knowledge sharing. It is known that some organisations are reluctant to share their thoughts through open discussion, but to ensure that this taskforce becomes successful and sustainable the key is willingness of its participants to share but it needs to be clear whether the taskforce is ready for this or not. The information should not only be limited to good experiences alone, but it should also identify bad experiences so that comprehensive lessons can be learnt thus expediting a thorough understanding of BIM. CREAM through the taskforce can be used as a point of dissemination of information related to BIM.

One participant from an established developer company responded to the willingness of sharing by commenting that the company is always open to sharing knowledge and information regarding BIM implementation. However, there are some sensitive issues that cannot be shared and must be respected by others. The participant has also offered to share as much information as possible regarding the use of BIM within current practice and the Idea House project was provided as an example of this. The project was developed by using both traditional 2D CAD and 3D BIM and engaging prefabricated construction.

The Department of Development and Property from one local university added that in the era of globalisation we cannot live in our silo alone if we are to eliminate the so called construction industry as a fragmented industry; knowledge sharing is one of the options or strategies to overcome the fragmentation problem.

Suggestions was made to conduct case studies on projects that have been completed using BIM and to explore the potential, identify the needs and the critical success factors in implementing BIM and that these case studies can be used as a platform to promote knowledge sharing among practitioners and academics. Three projects were identified:

a) Idea House by Sime Darby;
b) Dewan Usahasama University Tun Hussein Onn Malaysia (UTHM);
c) National Cancer Institute by Malaysia Public Work Department (JKR).

CONCLUSIONS AND RECOMMENDATIONS

During the discussion the majority of the respondents agreed that Building Information Modelling (BIM) could be a good platform for collaboration among parties in construction projects. The respondents were aware that BIM not only promotes 3D modelling but that the most important part is the information that is shared. However, construction players in Malaysia regarded BIM as a new technology and the participants believed that to implement BIM without a proper plan and clear road map the construction industry will portray BIM as nothing other than another 3D software in the market. Therefore, to avoid this situation the BIM Taskforce will have to work to overturn this perception. The BIM Taskforce can study how other countries are implementing BIM in their construction industry, such as Singapore, Australia, Finland, the United Kingdom and the United States. Singapore, for example, has been promoting BIM since 1997 and has slowly enforced the requirements of BIM when submitting building plan approvals and fire safety certifications. And the BIM Guideline called "Integrated plan checking" has been completed. Hong Kong and Korea are very active in promoting BIM in their construction industries. Although Malaysia has a well planned road map and strategy, support from the government is vital and without this push the implementation of BIM in the Malaysian construction industry will be slow or stagnant. We can learn how the Governments of Singapore, the United States, Norway, Denmark and Finland enforced the use of BIM through government procurement and facility management processes, but in the end to ensure successful implementation of BIM in the Malaysian construction industry the BIM Taskforce needs strong collaboration and support from the government and key industry players. The BIM Taskforce must have a good coordination approach among the public and private sectors to ensure BIM development spreads across the country.

To gain strong support from the government and industry players the participants suggested some recommendations to enhance the effectiveness of the BIM Taskforce. One of the recommendations is related to the direction of BIM in Malaysia. Although the majority of the participants agreed that IBS will be used as a platform to promote BIM, it is agreed that the task force direction should not be limited to IBS alone but take a broader perspective. The participants understand why IBS needs to move up to the mechanisation stage, but a lack of knowledge and experience in that area can impede the speed in implementing BIM. Therefore, the participants suggested that Working Group 4 (Technology and Tools) will play their role to study and investigate the application of BIM towards mechanisation of IBS.

However, having the direction alone is insufficient to promote BIM. Therefore, there needs to be a clear rationale for the use of BIM and its impacts to improve current practice need to be identified; it is therefore recommended that case studies are conducted. The participation of lecturers and research students are also highlighted in assisting with the development of the case studies. The findings from the case studies will be used to formulate the direction of the BIM Taskforce, and the direction needs to be documented and agreed upon by the entire task force membership.

Before drafting the strategic plan, a thorough study needs to be carried out especially on the critical success factors and current status of BIM in Malaysia. From that study the BIM Taskforce can establish how it can draft a strategic plan before presenting it to the government, because the government, as a client, needs to be convinced and it was suggested that all the experiences that the participants had with BIM should be captured and presented to the client.

The BIM Taskforce was encouraged to develop the BIM guidelines and standards in Malaysia's context because the lack of these was identified as a weakness for BIM implementation. The Working group under area 2 (Guidelines and Framework) should investigate and study International guidelines and standards, potentially using the United Kingdom, United States of America, Australia and Singapore's guidelines as references. It will be important to establish whether any of these standards can be adapted to suit the needs of local usage or whether the standards will need to be tailor-made to suit local culture.

The participants responded to say that in order for this strategic plan to have an impact on the nation the involvement of the government is a necessity because without this the BIM agenda will stall. Therefore, four additional members were identified and proposed to be invited to join the BIM Taskforce and represent the following organisations:

a) Ministry of Housing and Local Government;
b) Economy Planning Unit (EPU);
c) 1Malaysia House Program (PR1MA);
d) Ministry of Works.

These additional members can strengthen the image of the BIM Taskforce and they can directly convey to the government the importance of implementing BIM in Malaysia's construction industry.

Finally, to promote knowledge sharing among the practitioners and the academics, it was suggested that the BIM Taskforce should develop a database to gather all research findings related to BIM and IBS. The Construction Research Institute of Malaysia (CREAM) has a close connection with local university and can collect all related research. All the findings of various researchers can be shared within the BIM Taskforce and the industry. In conclusion this roundtable discussion was successfully conducted and a lot of information and many suggestions and ideas have been collected and stored. The participants agreed that the next roundtable discussion will be hosted by Sime Darby which would combine an industrial visit to the Idea House project and CREAM has agreed to carry out secretariat roles.

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CRITICAL BEHAVIOURAL COMPETENCES OF PUBLIC SECTOR PROJECT MANAGERS - A MODIFIED DELPHI TECHNIQUE APPROACH

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Abstract
Unlike technical competences, behavioural competencies have received less scholastic attention even though its importance during project implementation has been recognised. Within the context of public sector organisations in developing countries, competence studies are noticeably scarce. A study was conducted to examine desired behavioural competences of project managers in Malaysia's Public Works Department (PWD). Specifically, the objectives were to determine their degree of importance, degree of frequency of use and finally level of criticality. Instead of collecting data from practising project managers, senior project managers who appraised them were solicited for input, on the basis that what is perceived to be desired by the former may not cohere with what is actually desired by the organisation. The Modified Delphi Technique was adopted, an approach infrequently used by project management competence scholars. The study identified seven specific competences as very important, nine always in use and seven critical. Strikingly, certain competences were eliminated from these three lists even though they have been cited by past competence scholars. PWD and other Malaysian public procurement agencies should use the findings for behavioural competence training and staff selection. Public procurement agencies of other developing countries can also take the cue from this study to conduct their own internal behavioural competence studies and act accordingly.

Keywords: *Behavioural competences; public procurement bodies, staff selection, training interventions*

INTRODUCTION

It is accepted wisdom that project managers have a strong influence on project success. Competences of project managers make popular research topic for construction management researchers. Unlike hard technical competences that are regularly examined, soft behavioural competences have drawn less academic interest (Miranda and Ghimire, 2007), even though it is increasingly acknowledged that behavioural competences are more crucial than technical competences for project success (El-Saaba, 2001; Aitken and Crawford, 2008; Stevenson and Starkweather, 2010; Gomes *et. al.,* 2012). Of late, researches on behavourial competences of project managers have been dominated by the IT sector (Stevenson and Starkweather, 2010), but not construction.

Moreover, the few completed studies on behavioural competences of construction project managers either suffer from the limited range of items that were tested (e.g. Dainty, 2005; Brière, *et. al.,* 2014) or their examination jointly with other categories of competences such as technical (Edum-Forte and McCaffer 2000; El-Saaba 2001; Hyvari, 2006), therefore diluting their impact on anyone keen to know more about the subject. Many also neglected to rank those competences which prevents organisations from prioritising them (Garavan and McGuire, 2001).

On another note, with the exception of a few publications, there is a preponderance of literature on construction project management competences pertaining to the private sector over public administration (Edum-Fortwe and McCaffer 2000; Fisher 2011; Virtanen, 2000); Gomes *et. al.,* 2012; and Brière, *et. al.,* 2014). Even less researched are public sector organisations in developing countries (Rwelamila, 2007). The culture, politics, institutional arrangements and legislation of such organisations are bound to be different from business organisations in developed economies (AIPM 2008, PMI 2013). The relevance for competence studies of public sector organisations in developing countries are heightened in light of their poor infrastructure development delivery (Rwelamila, 2007).

Based on the combination of limited investigations on project managers' behavioural competences in public sector organisations in developing countries, a study was initiated to examine the desired behavioural competencies of public sector project managers in Malaysia. Without fail, every time the Auditor-General's report is released, distressed construction projects either commissioned by the federal government or local authorities make staple mention (Hui *et. al.,* 2011; Nur Berahim *et. al.,* 2015). Behavioural incompetences may be one of many causation factors behind Malaysia's project failures. Specific objectives of the research were:

1. To evaluate the desired behavioural competences for public sector project managers in terms of degree of importance.
2. To evaluate the desired behavioural competences for public sector project managers in terms of frequency of use.
3. To isolate the critical desired behavioural competences critical for public sector project managers.

Behavioural competences refer to a person's behaviour that influences his work performance (Mansfield, 1999). They include team leadership, communication skill and achievement orientation. Unlike personality and intelligence, behavioural competences can be acquired through training and development (McClelland, 1998).

Data were collected from senior supervising project managers attached with Malaysia's Public Works Department (PWD). Established in 1872 by the British to provide physical infrastructure for its colony which was then called Malaya, PWD continues to play its role as the main government agency responsible for planning, designing, constructing and maintaining of the nation's physical infrastructure such as highways, airports and public buildings. With more than 3,000 construction management and professional personnel (PWD, 2012), it is the largest public (possibly outmatching even the private) construction multi-project organisation in Malaysia.

The study adopted the Delphi technique as a research method. Despite being around for over half a century and its ubiquity in certain research disciplines (Rowe and Wright, 2011) such as health (Reetoo *et. al.,* 2005; Irvine, 2005) and education (Williams, 2003, Brill *et. al.,* 2006), the Delphi Technique has not been popular among construction management researchers. As for competence studies of project managers, Brill's *et. al.,* (2006) research pertaining to instructional design education is the few which used the technique.

BACKGROUND

The study on competences can be traced to Frederick Winslow Taylor (1911), the father of Scientific Management, who articulated his ideas in "The Principles of Scientific Management" published just over a century ago (Blake and Moseley, 2011). In 1954, Flanagan produced the Critical Incident Technique which collects qualitative data to differentiate effective and ineffective work behaviours for the United States Army Air Force. White (1959) has been accredited for being the first to introduce the word 'competence' in his paper on performance motivation. It became common use following McClelland's (1973) publication which proposes that competences rather than intelligence are essential for work performance. Boyatzis (1982) however is acknowledged for popularising the competence concept through his publications and management consultancies.

Competences can be divided into two categories: technical and behavioural. The body of literature on behavioural competences can be divided into three; prescriptive, opinion and empirical. Some professional project management bodies have developed their respective global competency standards that apparently are suited for all disciplines and situations. They include Project Management Institute (2013) with its Project Management Body of Knowledge Guide, International Project Management Association (2006) with its Competence Baseline, Association for Project Managers (2012) with its Association for Project Management Body of Knowledge, and Australian Institute of Project Management (2008) with its Professional Competency Standards for Project Managers. The Alberta Public Services (2012) is among the few public sector organisations to come up with a prescriptive list of behavioural competences that separate "the best from the rest". A number of scholars have criticised the generic behavioural competencies approach, among them Ruth (2006) for trading generalisability and transferability at the expense of the particular, Garavan and McGuire (2001) for ignoring the international organisational context, and Crawford (2004) for assuming a positive relationship between standards and effective workplace performance. Later, Crawford (2005) empirically found no statistical significant relationship between performance and the widely used standards in their entirety, and senior management perceptions of effectiveness of workplace performance.

There is also a body of literature on competences of project managers that is based entirely on opinion, among them Posner (1987). This body emerged when there was little empirical study on the subject matter, and is now in decline. Finally, there is a collection of competence literature that are empirically-derived and premised within certain contexts or disciplines, among them on instructional design professionals (Brill *et. al.,* 2006), project managers involved in mass housing building projects in Ghana (Ahadzie *et. al.,* 2008) project managers in international non-governmenal organisations (NGOs) (*Brière et. al.,* 2014). Ahsan *et. al.,* (2013) found from job advertisements for project managers in the ICT, construction, engineering, government and healthcare sectors in the Australasian region that the emphases on 'soft skills' were dissimilar from the literature. Other empirical studies that are contextually defined include Fisher (2011). Ahsan *et. al.,* (2013) found that even though certain project management competences are regularly cited in literature, there are subtle emphases in their application across industries.

RESEARCH METHOD

The Delphi approach is a facilitation technique involving iterative multi-stage canvassing of opinion from a panel of experts through questionnaires until group consensus is achieved (Linstone and Turoff, 1975; Hasson *et. al.,* 2000). Among the strengths of this technique are the widening of knowledge through multiple rounds (Powell, 2003) and minimisation of group conflict (Gupta and Clarke, 1996). Rowe and Wright (1999) argue that the Delphi approach can outperform alternative statistical techniques when properly conducted. The technique is without limitations. With multiple iterative rounds, there is risk of some panel members gradually losing interest and dropping out (Williams and Webb, 1994).

The Delphi Technique has evolved over the years into numerous variants (Rowe and Wright, 2011), one of which is the Modified Delphi Technique (Custer *et. al.,* 1999) which was adopted for this research. In the First Round, rather than soliciting possible items from the respondents through an open-ended questionnaire for testing in subsequent rounds, the experts were provided with a prepared list of items derived from a review of literature for them to respond (see Table 1). Instead of producing a 'laundry list' of behavioural competences, Spencer and Spencer (1993) advice that it is more effective to come up with a shorter, more focused list of the most essential. The modified approach is appropriate when basic information concerning the target issue is available and usable (Kerlinger, 1973). Recent studies that have used this approach include Chen *et. al.,* (2013), Karen *et. al.,* (2013), and Wihlborg and Johansson (2013). The draft questionnaire for the First Round was scrutinised by four senior PWD officers for relevancy, and then pilot-tested by 10 industry-experienced academicians. The questionnaire has two parts: the first to determine the degree of importance of the desired behavioural competences and the second to determine the degree of frequency of use of these competences.

Table 1. Sources of literature on the various aspects of behavioural competences

Behavioural competence	Description	Reference
Achievement orientation	Desire to work beyond excellent standards.	Birkhead *et. al.,* (2000), Morris (2001), Toney (2001), Dainty *et. al.,* (2005), Alberta Public Services(2012), Ahsan *et. al.,* (2013).
Concern for order and quality	Act to reduce mistakes and maintain high quality.	Blackburn (2000), AIPM (2008).
Initiative	Propensity to take appropriate action.	Skulmoski *et. al.,* (2000), AIPM (2008), Toney (2001), Udo and Koppensteiner (2004), Dainty *et. al.,* (2005).
Information seeking	Inquisitive, wanting to know more.	Dainty *et. al.,* (2005), Alberta Public Services (2012).
Interpersonal understanding	Willingness to understand other people.	Udo and Koppensteiner, (2004), Brill *et. al.,* (2006), Forgues-Savage and Wong (2010), Fisher (2011), Brière, *et. al.,* (2014).
Customer service orientation	Provide service to customer organisation	Dainty *et. al.,* (2005), Alberta Public Services (2012).
Strategic influence	Influence and win over others to rally support.	Udo and Koppensteiner (2004), Dainty *et. al.,* (2005), AIPM (2008), Alberta Public Servicesn (2012).
Organisational awareness	Learn to appreciate power relationships inside and outside the organisation.	Blackburn (2000), Virtanen (2000), Udo and Koppensteiner (2004), Forgues-Savage and Wong (2010), Alberta Public Services (2012).
Relationship building	Forge and preserve cordial relationship with others.	Blackburn (2000), Toney (2001), Udo and Koppensteiner (2004), Brill *et. al.,* (2006), Fisher, (2011), Alberta Public Services (2012).
Communication skill	Skilful in oral and written communication.	Brill *et. al.,* (2006), Hyvari (2006), APM (2012), Alberta Public Services (2012), Pivac *et. al.,* (2011), Ahsan *et. al.,* (2013), Brière, *et. al.,* (2014).
Directiveness	Use positional power appropriately.	El-Saaba (2001), Udo and Koppensteiner (2004), Dainty *et. al.,* (2005), AIPM (2008), APM (2012).
Developing others	Teach and strengthen the knowledge of others.	Birkhead *et. al.,* (2000), PMI (2004), Hyvari (2006), Alberta Public Services(2012), Brière, *et. al.,* (2014).
Teamwork and cooperation	Ability to work with others.	El-Saaba (2001), Morris (2001), Dainty *et. al.,* (2005), Fisher (2011), APM (2012), Alberta Public Services(2012), Ahsan *et. al.,* (2013), Brière *et. al.,* (2014).
Team leadership	Play the role of a leader of a particular group.	Edum-Fortwe and McCaffer (2000), Udo and Koppensteiner (2004), Dainty *et. al.,* (2005), Brill *et. al.,* (2006), AIPM (2008), APM (2012), Alberta Public Services (2012), Ahsan *et. al.,* (2013), Brière, *et. al.,* (2014).
Delegation	Ability to delegate part of the work to others.	Skulmoski *et. al.,* (2000), Birkhead *et. al.,* (2000), Gomes *et. al.,* (2010), Fisher (2011), APM (2012), Ahsan *et. al.,* (2013).
Technical motivation	Motivated to expand and use technical knowledge.	Virtanen (2000), Brill *et. al.,* (2006), Ahadzie *et. al.,* (2008), Gomes *et. al.,* (2010), Alberta Public Services (2012).
Analytical thinking	Understanding situations by disecting big issues into smaller parts.	Skulmoski *et. al.,* (2000), Birkhead *et. al.,* (2000), Dainty *et. al.,* (2005), Brill *et. al.,* (2006), Alberta Public Services (2012); Ahsan *et. al.,* (2013).
Conceptual thinking	Understand a situation and visualise it at the macro level.	Toney (2001), Udo an Koppensteiner (2004), Dainty *et. al.,* (2005), Brill *et. al.,* (2006), Ahadzie *et. al.,* (2008), Pivac *et. al.,* (2011), Alberta Public Services (2012), Ahsan *et. al.,* (2013).
Self-control	Ability to control own emotion.	Dainty *et. al.,* (2005), Forgues-Savage and Wong (2010), Fisher (2011), Alberta Public Services (2012); Ahsan *et. al.,* (2013).
Self-confidence	Self-belief in being able to undertake assigned tasks.	El-Saaba (2001), Udo and Koppensteiner (2004), Hyvari (2006), Forgues-Savage and Wong (2010).

Flexibility	Self-adjust to all kinds of situations and individuals effectively.	El-Saaba (2001), AIPM (2008), Alberta Public Services (2012), Udo and Koppensteiner (2004), Dainty *et. al.,* (2005), Ahsan *et. al.,* (2013), Brière, *et. al.,* (2014).
Commitment to organisation	Harmonise behaviour with organisational objectives and priorities.	Toney (2001), Udo and Koppensteiner (2004), Forgues-Savage and Wong (2010), Gomes *et. al.,* (2010).
Self-awareness	Understand oneself and ability to impact others.	Toney (2001).

(Source: Adapted from Gehring (2007) and Ahsan *et. al.,* (2013)

As the Delphi Technique legitimises human judgement, assembling experts is key for its success (Linstone and Turoff, 1975). With the consent of PWD's Director General, 156 of its senior project managers at the state and district levels throughout the country were invited to become Delphi panel members. These people were approached, not only for their experiences which is what some previous researchers looked for (Brill *et. al.,* 2006), but more importantly, for their regular role in appraising the work performance of subordinate project managers. They were in the best position to indicate the actual desirability of the various behavioural competences rather than what are perceived to be desirable by their subordinates. As cautioned by Crawford (2005), the perceptions and expectations of project management competences of project managers is dissimilar from that of their supervisors.

Of the 156 senior PWD project managers that were approached, 60 volunteered to become panel members in the First Round, but that number dropped to 21 in the Second and Third Rounds. The Delphi panelists remain anonymous throughout the survey, therefore avoiding the results being 'contaminated' by domineering individuals (Ellis and Whittington, 1993). Each was able to express his judgements privately and free from social pressures to conform to other people's opinions. This is an important point in organisational cultures steep with seniority deference such as the PWD. Additionally, for subsequent iterations, the panel members had the liberty to change their judgements without losing face to other panelists.

RESULTS

Degree of importance of desired behavioural competences

In the First Round, panel members were asked to indicate in the questionnaire the degree of importance of all 23 listed competences in terms of desirability (see Table 1) using the 6-point Likert Scale (1= not relevant, 2= unimportant, 3= quite unimportant, 4= quite important, 5=important, 6=very important). Each item was provided with a short description to avoid ambiguity as to its meaning. Since the panel size was 60 members (i.e. $\geq$ 35), consensus was deemed achieved when standard deviation < 1.00 (Siebert, 2004). All items that were tested achieved standard deviation of < 1.00 (the lowest being 0.51, the highest being 0.98) (see Table 2). However the item with the highest standard deviation (i.e. strategic influence) was dropped from the next round as it had a mean of 4.45, which was below the 4.50 cut off.

Table 2. Results of Rounds One and Two for importance of competences

First Round				Second Round						
No.	Behavioural competence	Min	S.D.	No.	Behavioural competence	Min	S.D.	% panel consensus for the scale		
								1-3	4	5-6
	Consensus criterion fulfilled				*Consensus criterion fulfilled*					
1	Technical motivation	5.73	0.51	1	Integrity	5.71	0.46	-	-	100
2	Concern for order and quality	5.60	0.52	2	Teamwork and cooperation	5.66	0.48	-	-	100
3	Commitment to organisation	5.60	0.58	3	Self-confidence	5.66	0.57	-	4.8	95.2
4	Teamwork and cooperation	5.56	0.56	4	Communication skill	5.61	0.49	-	-	100
5	Self-confidence	5.56	0.59	5	Commitment to organisation	5.61	0.58	-	4.8	95.2
6	Communication skill	5.51	0.59	6	Concern for order and quality	5.57	0.50	-	-	100
7	Achievement orientation	5.46	0.65	7	Technical motivation	5.52	0.67	-	9.5	90.5
8	Initiative	5.45	0.64	8	Directiveness	5.42	0.74	-	14.3	85.7
9	Directiveness	5.41	0.69	9	Initiative	5.42	0.59	-	4.8	95.2
10	Team leadership	5.33	0.68	10	Self-control	5.33	0.73	-	14.3	85.7
11	Information seeking	5.28	0.71	11	Delegation	5.33	0.73	4.8	-	95.2
12	Self-control	5.28	0.76	12	Team leadership	5.28	0.56	-	4.8	95.2
13	Customer service orientation	5.25	0.72	13	Achievement orientation	5.28	0.56	-	4.8	95.2
14	Delegation	5.23	0.69	14	Customer service orientation	5.23	0.76	-	19.0	81.0
15	Analytical thinking	5.16	0.74	15	Interpersonal understanding	5.04	0.58	-	14.3	85.7
16	Relationship building	5.16	0.76	16	Relationship building	5.04	0.86	9.5	4.8	85.7
17	Flexibility	5.15	0.70		*Consensus criterion unfulfilled*					
18	Self-awareness	5.06	0.79	17	Information seeking	5.09	0.76	-	23.8	76.2
19	Conceptual thinking	5.01	0.79	18	Analytical thinking	5.00	0.77	-	28.6	71.4
20	Organisational awareness	5.00	0.82	19	Conceptual thinking	4.95	0.80	4.8	19.0	76.2
21	Interpersonal understanding	4.98	0.79	20	Organisational awareness	4.95	0.66	-	23.8	76.2
22	Developing others	4.95	0.90	21	Flexibility	4.95	0.66	-	23.8	76.2
	Mean below cut-off			22	Developing others	4.85	0.72	-	33.3	66.7
23	Strategic influence	4.46	0.98	23	Self-awareness	4.76	0.76	4.8	28.5	66.7
				24	Political sensitivity	4.28	1.10	19.1	28.5	52.4

Note: Mean score interpretation: 1.00-1.49=not relevant, 1.50-2.49=unimportant, 2.50-3.49=quite unimportant, 3.50-4.49= quite important, 4.50-5.49=important, 5.50-6.00=very important.

Still on the First Round, the panel members were allowed to modify the provided descriptions for the various items, which resulted in two modifications (See Table 3).

Table 3. Suggested descriptions to the terms used in the questionnaire

Competence	Original description	Suggested description
Developing others	Teach and strengthen the knowledge of others.	Guide and strengthen the knowledge of those in need.
Directiveness	Use positional power appropriately.	Use positional power appropriately based on rules and ethics.

At the same time, the panel members were asked to suggest additional desired competences they felt were missing from the pre-designed questionnaire, for which 10 were offered. After scrutiny, only two were found to be entirely different from the prepared list (see Table 4).

Table 4. Suggested additional competence

Proposed competence	Description
Integrity	Work with honesty, trustworthiness and responsibly, fulfilling promises, transparency and commitment.
Political sensitivity	Understand the political ramifications of the project to the surrounding community, and ability to address the public and politicians' whims.

In the Second Round, the respondents were given the opportunity to re-evaluate the 22 competences generated from the First Round ('strategic influence' was dropped), this time in light of the aggregated scores as well as their own scores. They were also asked to give fresh evaluation for the additional two competences proposed in the First Round. Since the panel size reduced to < 35 (i.e. 21) in the Second Round, consensus was deemed achieved when ≥ 80% of the expert responses were located at the top two highest scores on the Likert Scale (Pulcini *et. al.,* 2006), i.e. 5 and 6. Of the 24 tested competences, 16 met the consensus criterion; eight did not (see Table 2).

In the Third Round, the panel members of 21 were only asked to re-evaluate the eight failed competences from the previous round using the same 6-Likert scale. Four managed to secure more ≥ 80% in the 5 and 6 score ranges whereas the remaining four did not (see Table 5).

Table 5. Re-evaluation of the eight failed competences from the Second Round

No.	Behavioural competence	Min	S.D.	% panel consensus for the scale		
				1-3	4	5-6
	Consensus criterion fulfilled					
1	Information seeking	5.19	0.67	-	14.3	85.7
2	Organisational awareness	5.19	0.67	-	14.3	85.7
3	Flexibility	5.14	0.72	-	19	81.0
4	Conceptual thinking	5.04	0.66	-	19	81.0
	Consensus criterion unfulfilled					
5	Analytical thinking	5.14	0.79	-	23.8	76.2
6	Developing others	4.90	0.70	-	28.6	71.4
7	Self-awareness	4.90	0.70	-	28.6	71.4
8	Political sensitivity	4.28	1.10	19.0	28.6	52.4

Note: Mean score interpretation: 1.00-1.49=not relevant, 1.50-2.49=unimportant, 2.50-3.49=quite unimportant, 3.50-4.49= quite important, 4.50-5.49=important, 5.50-6.00=very important.

Instead of ending the survey when a pre-determined consensus is reached, Dajani *et. al.,* (1979) suggest that group stability should be the cessation criterion. Stability occurs when the responses obtained in two successive rounds are statistically not significantly different from each other. Pearson correlation coefficient test shows that there was strong correlation between Second and Third Rounds responses for the four items, hence there was no significant shift in the opinions of the panel members between the two rounds (see Table 6). The four competences that failed to meet the consensus criterion were therefore dropped from the final list. And with that, the survey came to an end. The final list of desired behavioural competences in terms of importance is shown in Table 7.

Table 6. Test for stability for competences that failed to reach consensus in previous round

Behavioural competence	Second Round		Third Round		Correlation coefficient Pearson *r*
	Min	S.D.	Min	S.D.	
Analytical thinking	5.00	0.77	5.14	0.79	.896**
Developing others	4.85	0.72	4.90	0.70	.758**
Self-awareness	4.76	0.76	4.90	0.70	.699**
Political sensitivity	4.28	1.10	4.28	1.10	.959**

Note: Mean score interpretation: 1.00-1.49=not relevant, 1.50-2.49=unimportant, 2.50-3.49=quite unimportant, 3.50-4.49= quite important, 4.50-5.49=important, 5.50-6.00=very important.
** Correlation is significant at 0.01 level (2-tailed)

Degree of frequency of use of desired behavioural competences

In the first Round, panel members were relieved from indicating the degree of frequency of use for the listed competences. In the Second Round, panel members were asked to indicate in the questionnaire the degree of frequency of use for all 24 competences using the 5-point Likert scale (1=not sure, 2=not required, =seldom, 4=often, and 5=always). Only 20 panelists completed this part of the questionnaire – one less than for the first part of the questionnaire on the degree of importance for the same behavioural competences list. As the panel size was still < 35, consensus was deemed achieved when ≥ 80% of the expert responses were located at the top two highest scores on the Likert Scale (Pulcini *et. al.,* 2006), i.e. 4 and 5. All 24 tested competences fulfilled the consensus criterion, except two (see Table 7). These two were taken to the next round for re-evaluation.

Table 7. Results of Round Two for frequency of use of competences

No.	Behavioural competence	Min	S.D.	% panel consensus		
				1-2	3	4-5
	Consensus criterion fulfilled					
1	Integrity	4.85	0.36	-	-	100
2	Technical motivation	4.75	0.55	-	5.0	95
3	Teamwork and cooperation	4.75	0.44	-	-	100
4	Self-confidence	4.65	0.48	-	-	100
5	Communication skill	4.65	0.48	-	-	100
6	Commitment to organisation	4.65	0.58	-	5.0	95.0
7	Concern for order and quality	4.57	0.59	-	4.8	95.2
8	Team leadership	4.55	0.60	-	5.0	95.0
9	Directiveness	4.52	0.60	-	4.8	95.2
10	Achievement orientation	4.47	0.67	-	9.5	90.5
11	Initiative	4.47	0.60	-	4.8	95.2
12	Delegation	4.45	0.60	-	5.0	95.0
13	Customer service orientation	4.42	0.74	-	14.3	85.7
14	Relationship building	4.42	0.59	-	4.8	95.2
15	Self-control	4.35	0.58	-	5.0	95.0
16	Conceptual thinking	4.30	0.65	-	10.0	90.0

17	Self-awareness	4.25	0.63	-	10.0	90.0
18	Organisational awareness	4.23	0.70	-	14.3	85.7
19	Information seeking	4.15	0.58	-	10.0	90.0
20	Interpersonal understanding	4.14	0.65	-	14.3	85.7
21	Analytical thinking	4.10	0.71	-	20.0	80.0
22	Flexibility	4.00	0.64	-	20.0	80.0
	Consensus criterion unfulfilled					
23	Developing others	3.95	0.66	-	23.8	76.2
24	Political sensitivity	3.60	0.99	5.0	45.0	50.0

Note: Mean score interpretation: 1=not sure, 2=not required, =seldom, 4=often, and 5=always.

In the Third Round, the 21 panel members were asked to evaluate the two competences that did not succeed in the previous round. 'Developing others' fulfilled the consensus criterion but 'political sensitivity' still did not.

Table 8. Re-evaluation of the two failed competences from the Second Round

No	Behavioural competence	Min	S.D.	% panel consensus		
				1-2	3	4-5
	Consensus criterion fulfilled					
1	Developing others	4.04	0.66	-	19.0	81.0
	Consensus criterion unfulfilled					
2	Political sensitivity	3.57	0.97	4.8	47.6	47.6

Note: Mean score interpretation: 1=not sure, 2=not required, =seldom, 4=often, and 5=always.

As previously, the stability test was applied (Dajani *et. al.,* 1979). Table 9 shows there was strong correlation between responses during the two rounds for the item, indicating that there was no significant shift in the opinions of the panel members. The item was therefore dropped from the final list. The stability test brought an end to the survey. The final results of competences according to frequency of use are shown in Table 8.

Table 9. Test for stability for competences that failed to reach consensus in previous round

Behavioural competence	Second Round		Third Round		Correlation coefficient Pearson *r*
	Min	S.D.	Min	S.D.	
Political sensitivity	3.60	0.99	3.57	0.97	.947***

Note: Note: Mean score interpretation: 1=not sure, 2=not required, =seldom, 4=often, and 5=always.
** correlation is significant at 0.01 level (2-tailed)

Critical desired behavioural competences

To isolate critical desired competences, the importance and frequency of use mean scores for each item were mutiplied to obtain the combined value (Wadongo *et. al.,* 2011). To ascertain the critical cut-off point, the lower limit of the highest mean scores for importance (5.55-6.0=very important) and frequency of use (4.50-5.00=always) were referred to. Hence for degree of importance, the lower limit of the highest mean score was 5.5 while for degree of frequency of use, it was 4.5. The competences were considered critical if the product of their scores were ≥ 24.75. The final result is shown in Table 9.

DISCUSSION

Table 7 shows the final list of desired behavioural competences in order of importance. Items that were dropped because they did not meet the cut-off mean value of 4.50 were strategic influence and political sensitivity. The latter, together with three other items (i.e. analytical thinking, developing others and self-awareness) were also dropped because it failed to meet the consensus criterion.

Table 7. Final results for desired behavioural competences in order of importance

Behavioural competence	Delphi Round	Rank+	Mean	S. D.	%freq., 5– 6#	Annotation
			Consensus criterion fulfilled			
Integrity	Second	1	5.71	0.46	100	Very important
Teamwork and cooperation	Second	2	5.66	0.48	100	Very important
Self-confidence	Second	3	5.66	0.57	95.2	Very important
Communication skill	Second	4	5.61	0.49	100	Very important
Commitment to organisation	Second	5	5.61	0.58	95.2	Very important
Concern for order and quality	Second	6	5.57	0.50	100	Very important
Technical motivation	Second	7	5.52	0.67	90.5	Very important
Directiveness	Second	8	5.42	0.74	85.7	Important
Initiative	Second	9	5.42	0.59	95.2	Important
Self-control	Second	10	5.33	0.73	85.7	Important
Delegation	Second	11	5.33	0.73	95.2	Important
Team leadership	Second	12	5.28	0.56	95.2	Important
Achievement orientation	Second	13	5.28	0.56	95.2	Important
Customer service orientation	Second	14	5.23	0.76	81.0	Important
Information seeking	Third	15	5.19	0.67	85.7	Important
Organisational awareness	Third	16	5.19	0.67	85.7	Important
Flexibility	Third	17	5.14	0.72	81.0	Important
Interpersonal understanding	Second	18	5.04	0.58	85.7	Important
Relationship building	Second	19	5.04	0.86	85.7	Important
Conceptual thinking	Third	20	5.04	0.66	81.0	Important
*Strategic influence	First	21	4.46	0.98	n.a	Quite important
			Consensus criterion unfulfilled			
* Analytical thinking	Third	22	5.14	0.79	76.2	Important
* Developing others	Third	23	4.90	0.70	71.4	Important
* Self-awareness	Third	24	4.90	0.70	71.4	Important
* Political sensitivity	Third	25	4.28	1.10	52.4	Quite important

Note: + Rank according to highest achieved mean, * competences that were dropped, # frequency percentage for 5 and 6 scale. Mean score interpretation: 1.00-1.49=not relevant, 1.50-2.49=unimportant, 2.50-3.49=quite unimportant, 3.50-4.49= quite important, 4.50-5.49=important, 5.50-6.00=very important.

The final results for desired behavioural competences in terms of frequency of use are shown in Table 8. Political sensitivity was dropped as it failed to meet the consensus criterion.

Table 8. Final results for behavioural competences in order of frequency of use

Behavioural competence	Delphi Round	Rank+	Mean	S. D.	%freq., 4– 5#	Annotation
			Consensus criterion fulfilled			
Integrity	Second	1	4.85	0.36	100	Always
Technical motivation	Second	2	4.75	0.44	100	Always
Teamwork and cooperation	Second	3	4.75	0.55	95	Always
Self-confidence	Second	4	4.65	0.48	100	Always
Communication skill	Second	5	4.65	0.48	100	Always
Komitmen Kepada Organisasi	Second	6	4.65	0.58	95	Always
Concern for order and quality	Second	7	4.57	0.59	95.2	Always
Team leadership	Second	8	4.55	0.60	95	Always
Directiveness	Second	9	4.52	0.60	95.2	Always
Achievement orientation	Second	10	4.47	0.60	95.2	Often

Initiative	Second	11	4.47	0.67	90.5	Often
Delegation	Second	12	4.45	0.60	95	Often
Customer service orientation	Second	13	4.42	0.59	95.2	Often
Relationship building	Second	14	4.42	0.74	85.7	Often
Self-control	Second	15	4.35	0.58	95	Often
Conceptual thinking	Second	16	4.30	0.65	90	Often
Self-awareness	Second	17	4.25	0.63	90	Often
Organisational awareness	Second	18	4.23	0.70	85.7	Often
Information seeking	Second	19	4.15	0.58	90	Often
Interpersonal understanding	Second	20	4.14	0.65	85.7	Often
Analytical thinking	Second	21	4.10	0.71	80	Often
Developing others	Third	22	4.04	0.66	81	Often
Flexibility	Second	23	4.00	0.64	80	Often
	Consensus criterion unfulfilled					
* Political sensitivity	Third	24	3.57	0.97	47.6	Often

Note: + Rank according to highest achieved mean, * Competences that were dropped,
Frequency percentage for 5 and 6 scale
Mean score interpretation: 1=not sure, 2=not required, =seldom, 4=often, and 5=always.

Clarke (1999) argues that in the management of large and complex projects, it is impossible to give equal attention to the many differing and even competing factors. She proposes that priority should be given to the few from the trivial many. Using the computation described earlier, critical desired behavioural competences were separated from the rest. They are integrity, teamwork and cooperation, self-confidence, communication skills, commitment to organisation, concern for order and quality and technical motivation. Five on the other hand are considered redundant. They are analytical thinking, developing others, self-awareness, political sensitivity and strategic influence. Both the critical competences as well as those that were dropped from the list are discussed below.

Table 9. The level of criticality of behavioural competences

Rank	Behavioural competence	Combined score	Annotation
1	Integrity	27.69	Critical
2	Teamwork and cooperation	26.89	Critical
3	Self-confidence	26.32	Critical
4	Communication skill	26.22	Critical
5	Commitment to organisation	26.09	Critical
6	Concern for order and quality	26.09	Critical
7	Technical motivation	25.45	Critical
8	Directiveness	24.50	Essential
9	Initiative	24.23	Essential
10	Self-control	24.02	Essential
11	Delegation	23.72	Essential
12	Team leadership	23.60	Essential
13	Achievement orientation	23.19	Essential
14	Customer service orientation	23.12	Essential
15	Information seeking	22.28	Essential
16	Organisational awareness	21.95	Essential
17	Flexibility	21.67	Essential
18	Interpersonal understanding	21.54	Essential
19	Relationship building	21.07	Essential
20	Conceptual thinking	20.87	Essential
21	Analytical thinking	20.83	*Dropped in Round Three*
22	Developing others	20.56	*Dropped in Round Three*
23	Self-awareness	19.80	*Dropped in Round Three*
24	Political sensitivity	15.28	*Dropped in Round Three*
25	Strategic influence	n.a	*Dropped in Round One*

Integrity is the highest scored critical behavioural competence. According to Virtanen (2000), ethical competence is one of two competences (the other being political competence) that make the important difference between public and private entities. As public servants, it is crucial that PWD project managers do not betray the public's trust. There have been several high-profile project failures recent years which shook public confidence in PWD, such as beam cracks on the Kepong Flyover in Kuala Lumpur that persisted between 2004 until 2008, roof collapse of the newly-constructed Sultan Mizan Zainal Abidin Stadium in Kuala Terengganu, Terengganu, in 2009, and ceiling collapses at different parts of the eight-year old Serdang Hospital in Kuala Lumpur since 2011. Beginning 2009, all government agencies are required to implement the Integrity Pact by inserting an anti-corruption clause in all government procurement documents relating to the offer for tender, price quotation or e-bidding.

Teamwork and cooperation is the next highest critical desired behavioural competence, which coheres with El-Saaba (2001), Morris (2001), Ahsan *et. al.,* (2013) among others. This finding also echoes that of Fisher (2011) who narrowed down behavioural competences for effective project managers to six, one of which is teamwork and cooperation. Self-confidence is the third highest critical desired behavioural competence, with matches with El-Saaba (2001), Udo and Koppensteiner (2004), Hyvari (2006), Forgues-Savage and Wong (2010), among others. Communication skills is the next highest critical desired behavioural competence. Previous studies that have also highlighted this particular competence include Brill *et. al.,* (2006), Hyvari (2006), Brière, *et. al.,* (2014) among others. Miranda and Ghimire (2007) found from their study that communication is the most sought after competence by employers.

Commitment to organisation is the fifth critical desired behavioural competence required of PWD project managers, with supports Gomes *et. al.,* (2010). According to Perry and Wise (1990), commitment to organisation extends to overall public service motivation including public ethics and a desire to serve the public interest and loyalty to the government as a whole (Perry and Wise, 1990). Concern for order and quality is the next critical desired behavioural competence, which matches with Blackburn (2000) and AIPM (2008). Technical motivation is the last critical desired behavioural competences that PWD project managers should possess. Construction work gets done by other people. So the project manager is not expected to possess task proficiency, but rather to appreciate the project's technical requirements (Virtanen, 2000; Ahadzie *et. al.,* 2008; Gomes *et. al.,* 2012).

What is especially interesting from the study is that PWD project managers are not required to possess certain competences (i.e. analytical thinking, developing others, self-awareness, political sensitivity and strategic influence) even though the literature suggests otherwise, perhaps because of their encroaching nature into general management territory (Crawford, 2005). A case in point is developing others which, whilst regarded by some as important (Birkhead *et. al.,* 2000; Alberta Public Services, 2012), may be superfluous in organisations such as PWD that regularly provides to its project managers all sorts of training programmes be it at the federal or state levels. Brill *et. al.,* (2006) and Ahsan *et. al.,* (2013) posit that project managers must have analytical skills, yet the respondents opine it is not even essential. Styhre (2006) articulates the notion that in some situations or organisations, project management practices are more about routine tasks and less about creative and innovative activities, in which case analytical skills are redundant. In similitude, Paton *et. al.,* (2010) observe that project management can be just a new form of bureaucracy with its emphasis on plans, processes and formalised procedures. PWD has certainly come up with standard operating procedures for project management such as 'Q-Plan', a quality management system encompassing the design (Project Design Plan or D-Plan) and construction (Construction Quality Plan or C-Plan) stages. McGurk found that improvement of self-awareness among mid-level managers of public organisations is incongruous with work norms and constraints in certain public sector organisations. PWD may well be one such organisation in which no link can be made between self-awareness and improvement in organisational activities. El-Saaba (2001) found political sensitivity to be important for project managers in the information system, electricity and agricultural projects in Egypt. Virtanen (2000) argues that being able to contribute to political outcomes, regardless of how good the output is technically is what makes the distinction between public and private managers. Yet the study found that this particular competence is not desired at all for PWD project managers. In Malaysia's current political landscape where both the ruling and opposition parties incessantly try to make mileage from anything conceivable, it is better perhaps that PWD project managers remain neutral. For many people, success that is based on strategic influence violates the sense of a just world, as they do not believe that good outcomes should be solely derived from this trait (Pfeffer, 2009).

CONCLUSION

The centrality of project managers in project success is well recognised. This study is perhaps the first to comprehensively distill behavioural competences which PWD project managers should possess. Seven behavioural competences were singled out as being critical, most of which cohere with past studies – teamwork and cooperation, self-confidence, communication skill, commitment to organisation, concern for order and quality and technical motivation. One critical behavioural competence stands out as being generated by the respondents, and that is integrity. Interestingly, some other competences (i.e. analytical thinking, developing others, self-awareness, political sensitivity and strategic influence) raised by certain past scholars were not even deemed as essential, let alone critical, by the experts. The divergence between the present and past studies reaffirms the importance of organisational culture, structure, industry and religious milieu in determining what competences are crucial (Boyatzis, 2008).

PWD is the largest public sector procurement agency in Malaysia. Funded by tax-payers' money, the entire nation expects it to deliver quality buildings and infrastructure on time and cost. With close to 150 years of experience, PWD of the 21st century should be more efficient than ever before. Sadly, there is an opinion that Malaysia's public sector competence is in a state of decline (Siddique, 2010). It is imperative that public sector organisations including PWD restore the nations' faith in them. One way is to ensure that their project managers are truly competent for the job, through, among others, continuous training. Behavioural competences are more complex than technical competences as they are intrinsic or hidden. Not surprisingly, training in public sector organisations tend to overly focused on professional standards of competence at the neglect of softer skills (McGurk, 20009). Training interventions designed to develop behavioural competences should leverage on the research findings. Creative techniques beyond the traditional classroom lectures should be deployed by taking into account past studies on training. For example, from investigating how professionals learn, Cheetham and Chivers (2001) found that on-the-job training, working alongside more experienced colleagues and teamwork have major influence, mentoring and role models less so. The findings can also be used for recruitment. Applicants who have a predisposition to be ethical and keen to serve the greater good of the nation would make good candidates. Those that have an inclination to use strategic influence to get their way do not.

One source estimates that between 2010-2020, developing countries need to invest an average of 7% of their GDP to meet basic needs and build the infrastructure required for rapid growth (World Bank, 2011). Hence, their public sector procurement agencies hold a tremendous responsibility in ensuring that the projects are carried out as efficiently as possible. This means having professional manpower that are not only competent technically but also behaviourally. This research outcome can serve as inspiration to these countries in their quest to improve the performance of their own public sector projects.

As with any research, there is scope for advancing the present work. A qualitative one-to-one interview approach can be conducted to capture the context and meaning behind the responses provided. This applies for items that fall under all three categories of critical, essential, and especially, dropped. Why political sensitivity is redundant in an organisation that is heavily influenced by political masters requires further probing, for example. And why is analytical thinking superfluous contrary to some research findings? Though supporting literature was provided to support their exclusion from the critical list, actual field evidence would reinforce further the validity of the study.

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INFLUENTIAL ELEMENTAL COSTS OF MUSEUM REFURBISHMENT PROJECTS: A CASE STUDY OF MALACCA, MALAYSIA

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Abstract
The purpose of building refurbishment is to enhance the function of the buildings, to extend their useful life, and to improve their overall value. In the past few years, many historical buildings had been refurbished to enhance the building functionality as well as preserve and conserve the architectural and heritage values. Some of the historical buildings in Malacca, Malaysia are converted as museum with preservation of the building facade. In the projects, large amount of refurbishment cost is allocated. Whereby, lack of cost information and understanding causes difficulties in preparation of budgeting for refurbishment projects. This paper aims to study on the cost of the museum refurbishment projects through case study approach. The elemental cost analysis is applied to study the cost data of the projects and subsequently, to identify the most influential elemental cost in those projects. The case study includes four museums in Malacca, Malaysia, which have undergone the refurbishment works. The research findings demonstrate the building services, finishes, and superstructure works as the influential elemental cost of the projects. This reflects the importance of enhancing building functionality and structural stability while preserving architectural heritage values in historical building refurbishment projects. Furthermore, such works must be in compliance with the statutory regulations, specifically the historical buildings.

Keywords: *Refurbishment; Elemental Cost; Cost Estimation; Conservation; Historical Building*

INTRODUCTION

Refurbishment is defined as the improvement, adaptation, upgrading, renovation, rehabilitation, modernisation, conversion, retrofit, and repair works carried out on existing buildings (Egbu, 1999). Preserving the architectural heritage is a primary benefit of refurbishment (Balaras *et. al.,* 2004). It is also meant to decrease energy consumption; improve the whole condition of the building such as its exploitation, noise insulation conditions, exterior, and comfort; prolong building life cycle; increase value of the building; reduce negative impact to environment; as well as guarantee healthy living and working space (Mickaityte *et. al.,* 2008). According to Rahmat and Ali (2010b), refurbishment is making use of whatever usable in the ageing building stock, the skilful adaptation of building shells to a new or an updated version of its existing use.

Recently, the stock of existing buildings is more than the number of new buildings (Balaras, 2002). The operating costs of buildings increase over the time due to the inevitable decay and deterioration. Thus, the practice of maintenance, refurbishment and upgrading is introduced in construction industry lately. Whereby, some buildings might not fit for its purpose after a few decades due to obsolescence. The refurbishment work is then proposed to enhance the function of the buildings, to extend their useful life, and to improve their overall value. In addition, the refurbishment cost is lesser than the cost of demolition and reconstruction (Caccavelli & Gugerli, 2002).

By comparing to demolition and reconstruction, the benefits of building refurbishment includes reduced landfill disposal, transportation costs, greater reuse of materials, retention of community infrastructure and additional benefits of local economic development and neighbourhood renewal and management (Gohardani & Bjork, 2012). However, it is argued that the refurbishment project is more difficult to manage than new construction project (Egbu, 1997). Whereby, the issue of management of refurbishment project often relates to the unclear information and quality standards. The project requirements and scale are therefore hardly to be predicted (Bryde & Schulmeister, 2012). It is also deemed as the most challenging task in construction industry as the works are restricted by the exiting condition of the building (Ali & Au-Yong, 2013). Typically, the risk of refurbishment projects can be classified into five clusters as shown in Table 1 (Reyers & Mansfield, 2001).

Table 1. Risk cluster and description of risks

Risk cluster	**Risk Description**
Capital and cost risks	• Reliability of cost data, cost and quality procedures investigated by client, cash flow decisions, changes to finding structure, invalid estimate • Risks in capital investment, influenced by physical deterioration of the building • Risks from various accounting regimes, influencing the extent and timing of work
Design information risks	• Difficulties in providing detailed, concise and inclusive definitions of the processes which may lead to a decline in value • Inadequate completion time, incomplete site survey information, clarity of specification of workmanship clauses, efficiency of contractual
Client briefing risks	• Risks of inaccurately identifying boundaries between the processes in the physical cycle of refurbishment, example replacement, repair, and renewal • Vague brief, inflexibility requirement, over or under involvement in projects, limited awareness of constraints and inflexible to contractors and suppliers • Risks of loss of architectural or historical significance of the original fabric resulting from negligence • Risks of misunderstanding of liability such as under-insurance and failure to undertake risk management procedure
External risks	• Bureaucratic and slow approval procedures, statutory constraints and procedures, infrastructure charges, planning condition, interest rate
Other internal parties risks	• Continued occupancy during work, involvement of other consultants, reliable consultants, suitability of experience labour • Risks from the impact of liability of the designers and contractors such as bankruptcy due to award of damages • Risks in the team itself such as client-imposed specialists and those outside the establish team

In conservation refurbishment project, it is perceived by design professionals to be inherently more risky than new-build projects (Reyers & Mansfield, 2001). Difficulty in identifying and defining a problem (recognition during survey) and the appropriate remedial technique (where repair is recommended) may bring out additional risk for those advising on projects to conserve cultural heritage (Reyers, 2003). Such risks in conservation are further compounded involving mandatory compliance with statutory requirements, the reliance on availability of specialist craftsmen and the use of authentic materials and components (Mansfield, 2009).

Besides, Reyers and Mansfield (2001) believed that conservation work often cannot be accurately predetermined in terms of specification, extent of duration and cost because conservation projects are all unique and non-duplicate projects. The projects have difference requirements to each other. Commonly, they do not have precedent case to refer to.

However, there are several purposes and benefits when doing the conservation refurbishment project, such as (Zolkafli *et. al.,* 2012):

- Save cost in term of financing scheme due to shorter development period
- Shorter contract period and reduce inflation on building cost
- Lower total costs compared to new-build
- The building retain the original ancient tradition
- Preserve the architectural character and integrity of building
- Retain the past historical value and aesthetic of building
- Promote the heritage building to attract tourists

Therefore, governments have increasingly assumed the duty of ensuring the protection and preservation of cultural heritage as a critical aspect of maintaining community identity. The effort also embraces the active management of the heritage place so that it is not only conserved, but also enjoyed by the community without further deterioration in its condition (Smith, 2005).

Building Refurbishment in Malaysia

In Malaysia, the demand of building refurbishment grows rapidly as a result of the increased age buildings in number and rapid changing construction technology (Ali *et. al.,* 2009). Whereby, obsolescence is the process of an asset going out of use due to the outdated building systems and services (Douglas, 2004). The old buildings obsolete and hence, require refurbishment to maintain or enhance the asset values. In particular, the refurbishment projects for historical buildings have to comply with more statutory regulations, which limit the extent of the refurbishment works (Ali & Zakaria, 2012). Subsequently, the statutory requirements may cause project delays and cost overruns due to adjustments that need to be made to design in order to comply with the regulations.

In the past few years, many historical buildings had been preserved, conserved, and converted for other purposes such as information centre, exhibition room, and museum. Many of the historical buildings in Malacca, Malaysia are converted as museum with refurbishment works. In the projects, large amount of refurbishment cost is allocated. Therefore, this paper aims to study on the cost of the museum refurbishment projects.

REFURBISHMENT COST

Building refurbishment involves large amount of capital cost from planning to completion due to its complexity. For example, Hong Kong Housing Authority allocates the annual budget of approximately HK$400 million for the refurbishment projects of four to five shopping centres each year (Yan-chuen & Gilleard, 2000). Somehow, Johnstone (2001) argued that the refurbishment of dwellings has reduced the national average costs to sustain dwelling services by a magnitude of 15%.

Basically, refurbishment project requires accurate and adequate information on cost in order to make a strategic decision towards the refurbishment project (Caccavelli & Genre, 2000). One of the required information is the cost of induced works (Balaras, 2002). Unfortunately, it is often too costly to acquire the information due to the uncertainties such as vague information (Rahmat & Ali, 2010b). Therefore, planning and selection of proper approach in the refurbishment project is significant at the earliest stage (Genre *et. al.,* 2000). For instance, survey and analysis on the existing components are compulsory to study the potential problems, risks, and strategies in the project.

In order to optimise the refurbishment cost, a cost database should be established. However, it is difficult to establish the cost database because of the extremely varied nature of the work carried out in refurbishment projects. Commonly, the projects vary in terms of type, size and site conditions, with an influential impact towards refurbishment cost (Caccavelli & Genre, 2000). Thus, the development of cost database should be differentiated with the type or size of the refurbishment projects.

The conceptual estimate of construction cost is an important element of project planning (Kim *et. al.,* 2012), which is also applicable in refurbishment project. Inevitably, cost estimating needs to be carried out within a limited time period using limited information in an uncertain environment (Gunduz *et. al.,* 2011). Refurbishment projects definitely cannot be denied that contain much more uncertainty.

There are many historical buildings of different eras in Malaysia that should be conserved. The buildings should be conserved as important monuments for future generations. According to Article 1.4 of Burra Charter, conservation is defined as all processes of looking after a place so as to retain its cultural significance (Australia ICOMOS, 1999). Conservation includes the activities that aim at the safeguarding of a cultural resource so as to retain its historic value and extend its physical life (Woon & Mui, 2010). However, some of these buildings are at risk from defects and are not being taken care due to lack of technical knowledge and the high cost of repair and maintenance.

The use of modern building techniques and developments in material technology may be viewed as improvements to a building. However, this may be disputed where such action may affect the appearance of historical buildings (Syed-Mustapha *et. al.,* 2007). Moreover, the lack of costing information for conservation projects has led to difficulty of preparing cost budgeting for conservation projects. Woon and Mui (2010) found that lack of information and lack of understanding of quantity surveyors may cause the estimated project costs to miss out work items that are applicable in conservation projects.

Cost Estimation in Refurbishment Projects

One of the most common estimating methods in conceptual phase or initial stages of the projects is using historical data (Kim *et. al.,* 2012). Therefore, the method is applied in this paper to study the cost data of the museum refurbishment projects and subsequently, to identify the most influential elemental cost in those projects.

Indeed, the construction cost can be estimated through two main methods, namely top-down approach and bottom-up approach. Top-down approach gathers the historical cost data for previous similar projects to estimate the current project; while bottom up approach applies to individual work items or activities when detailed information is available (Schwalbe, 2009; Taylor, 2008).

Then, construction estimating methods are classified into four types, including single-unit rate method, parametric cost modelling method, elemental cost analysis, and quantity survey (Dell'Isola, 2002). Nevertheless, each method has its strengths and weaknesses regarding data requirements, estimate accuracy, and the effort and time required for estimation (Kim *et. al.,* 2012). Hence, practitioners often select the appropriate method based on the available data and time for estimation. The descriptions of the four estimating methods are tabulated in Table 2.

Table 2. Descriptions of construction estimating methods

Estimating Method	Descriptions
Single-unit rate method	The most common in initial budgeting due to its simplicity. It estimates the overall unit cost per gross square meter using methods including the accommodation method and the functional area method. The accommodation method uses the major measure of a facility (i.e., cost per bed for hospitals). The functional area method specifies the functional space types within a building to account for variations in space types for specific purposes
Parametric cost modelling method	Parametric cost modelling method usually applies statistical analysis. This method usually uses a predetermined equation model based on the historical cost data, which is regression analysis
Elemental cost analysis	The elemental cost analysis divides a building into elemental components to estimate the cost of each component using historical data on similar projects. The estimation can be modified by different alternates (e.g., construction methods and materials)
Quantity survey	A quantity survey can be performed when detailed design information is available. Quantities and unit costs or rates (for materials, labour, and equipment) are calculated for each of the individual work items and activities.

RESEARCH METHODOLOGY

This research adopts case studies approach that was adopted by Langston and Langston (2007) to report the cost-related topic in construction industry. Case study is an ideal methodology to provide a holistic in-depth investigation in understanding certain phenomena, or generating further theories for empirical testing (Sekaran & Bougie, 2009). The data for the research are collected from the actual case study of four museums in Malacca, Malaysia, which have undergone the refurbishment works. The selected buildings are the historical buildings that have been converted into museums. These buildings are required to increase the life cycle and value of the buildings, as well as to maintain their heritage and architectural values through refurbishment works. The study focuses in Malacca because this historical city centre has been listed as a UNESCO World Heritage Site since year 2008. The research selects specifically the museums as case studies because the refurbishment cost may extremely vary from different type of buildings (Caccavelli & Genre, 2000).

In order to identify the most influential elemental cost of museum refurbishment projects, elemental cost analysis is selected to analyse the research data. Thus, complete cost data is required for every case study. The sample projects must have breakdown of cost information in contract document or bills of quantity. The cost data of each selected sample projects are extracted from the bills of quantity or the contract document. Thus, the completeness of the bills of quantity is critical in this research to collect accurate and appropriate data.

Subsequently, the collected data of each project is analysed and compared to identify the most influential elemental cost. The case studies are identified by an alphabetical code, as the name of projects needs to be kept private and confidential.

FINDINGS AND DISCUSSION

Project Details

Overall, there were four sample projects selected in this study. Four of the projects were conservation and refurbishment works on museums. The requirements of the projects were to preserve the architectural and heritage values of the buildings (building exterior and façade); to restore the buildings to normal condition (health and safety); and to improve the function and use of the buildings (building services). The background of the museums and the project details such as the contract type, project duration, gross floor area, and contract value were tabulated in Table 3 and Table 4 respectively. Meanwhile, some important dates of the projects are tabulated in Table 5.

Table 3. Background of the museums

Project	Background
Museum A	The building was functioned as Dutch administrative complex formerly and operated as the Anglo-Chinese school later. Currently, the museum exhibits materials related to local and international events of several Malaysian youth organisations, as well as some records of the youth leaders.
Museum B	The building was an official residence of the Dutch Governor and officers. Presently, the museum contains collections of Malacca historical records and local Malay folklores. It traces the growth of literature in Malacca from the period of Malacca Sultanate to the contemporary literacy scene.
Museum C	The building was originally used as the residence for Dutch dignitaries living in Malacca. Currently, the museum exhibits stamps to deliver the knowledge and information regarding the local development, culture, education, sports, flora and fauna, as well as achievement of the country.
Museum D	The building was built during the British era for the officers and administrators based in Malacca. Presently, the museum has become a reference point on issues related to the Malay communities in terms of the socio-economic status. It displays several artefacts from the neighbouring Islamic countries.

Table 4. Project details

Project	Contract Type	Duration (Week)	Gross Floor Area (m^2)	Contract Value (RM)
Museum A	Conventional - Lump Sum BQ	24	1,730.33	1,545,100.00
Museum B	Conventional - Lump Sum BQ	45	1,176.22	1,785,746.00
Museum C	Conventional - Lump Sum BQ	24	330.02	546,750.00
Museum D	Conventional - Lump Sum BQ	24	2,977.50	1,650,740.27

Table 5. Important dates of the refurbishment projects

Project	Tender Date	Site Possession Date	Completion Date
Museum A	07/05/2005	06/02/2006	24/07/2006
Museum B	23/05/2008	11/07/2008	22/05/2009
Museum C	28/02/2003	28/07/2003	12/01/2004
Museum D	23/03/2004	21/06/2004	6/12/2004

The findings showed that all of the projects were contracted with conventional method, which was the lump sum bill of quantity. Thus, the costing of each element could be identified from the bill of quantity.

Among the projects, Museum A, C, and D only went through the project duration of 24 weeks; while Museum B went through 45 weeks. The long project duration was the main factor that leading to the high contract value. Whereby, the time variance and cost variance of refurbishment projects are always inter-correlated (Rahmat & Ali, 2010a). For example, the overhead costs of the project increases when the project duration is longer.

Then, the gross floor areas that involved with the refurbishment works for Museum A, B, and D were 1,730.33 m^2, 1,176.22 m^2, and 2,977.50 m^2 respectively. On the other hand, the refurbishment works of Museum C only covered the gross floor area of 330.02 m^2, which was significantly small compared to other projects. The small coverage area would be the reason of lower contract value for refurbishment project of Museum C.

In terms of contract value, the refurbishment project with contract value of more than RM500,000 is considered as large-scale project in Malaysian construction industry (Ali *et. al.,* 2009). From Table 4, it was found that all the projects were large-scale projects. Therefore, it was comparable among the projects in this study. Although the projects were begun and completed in different time as shown in Table 5, there was not much influence on the refurbishment cost or contract value.

Elemental Cost Analysis

The research discovered five main elements that were involved in the refurbishment projects, namely preliminary work, demolition work, superstructure, services, and finishes. The research data summarised the details of each element as follows:

- Preliminary: insurances, preparation and documentation of reports, first aid kit, site/building surveys, water and power supply, signage, project signboard, hoarding, and site cleaning.
- Demolition: dismantle or remove of timber partitions, brick walls, wall panel cladding, ducting, broken timber components, doors and door frames, cabinets, and wall finishes.
- Superstructure: Construction, installation or replace of roof, stairs, external and internal walls, doors, and windows.
- Services: Installation or replace of sanitary appliances, cold water and soil plumbing, electrical, fire protection, air conditioning, and other works.

- Finishes: Installation or replace of floor finishes, ceiling, and wall finishes.

Then, the elemental costs of each project were tabulated in Table 6 and the percentages of the elemental costs were illustrated in Figure 1.

Table 6. Elemental costs of the refurbishment projects in Ringgit Malaysia (RM)

Project	Preliminary	Demolition	Superstructure	Services	Finishes	Total
Museum A	141,700	6,675	253,200	482,540	204,385	1,088,500
Museum B	52,435	15,000	143,099	466,490	191,547	868,571
Museum C	72,750	12,800	193,570	3,700	200,930	483,750
Museum D	115,387	37,475	184,083	710,679	300,159	1347,783

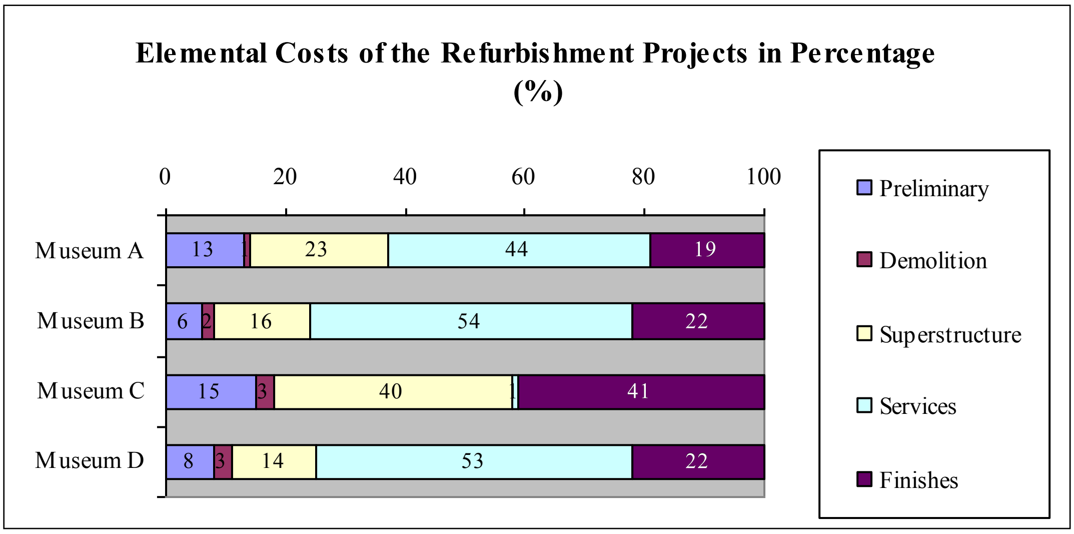

Figure 1. Elemental costs of the refurbishment projects in percentage (%)

In refurbishment projects of Museum A, B, and D, the percentages of cost of services work ranged from 44 percent to 54 percent from the overall refurbishment cost. A very high amount of cost was spent on the services work, which was RM482, 540, RM466, 490, and RM710,679 For Museum A, B, and D respectively. The result indicated that the services work was the most influential elemental cost of museums refurbishment projects. Most of the old buildings experience obsolescence process over the time and the building services are outdated to support the building purpose or function (Douglas, 2004). Therefore, the upgrade of building services becomes the major work of the refurbishment project to restore or enhance the asset values. Among the projects, all dealt with the installation of air-conditioning system, firefighting system, as well as some repair and replacement works on electrical system, sanitary fittings, and plumbing system.

Then, the finishes work was the second influential elemental cost of museum refurbishment projects. In refurbishment projects of Museum B, C, and D, the percentages of cost of finishes work ranged from 22 percent to 41 percent from the overall refurbishment cost. The cost of finishes work for Museum B, C, and D was RM191, 547, RM200, 930, and

RM300, 159 respectively. Indeed, refurbishment projects for historical buildings have to comply with more statutory regulations, which limit the extent of the refurbishment works, specifically the building exterior (Ali & Zakaria, 2012). Hence, the finishes work is usually done for the building interior. However, the finishes work to be done for the building exterior must be careful with selection of materials (Mansfield, 2009). For instance, use of same or similar materials with the existing building materials is the main concern in refurbishment projects to avoid the change in appearance of historical buildings. Sometimes, the cost of the materials is expensive because the source is limited. The refurbishment works on the finishes included wall painting, replacement of wall and floor tiles, timber plank and skirting, carpet, as well as remedial works on damped and cracked wall.

Since one of the purposes of refurbishment is to prolong the building life cycle (Mickaityte *et. al.,* 2008), the superstructure work can be an influential elemental cost of refurbishment projects. Deterioration and decay are inevitable in the built environment. Thus, repair or replace of the building structures need to be done in order to maintain the condition of the building. In this study, the refurbishment projects of Museum A and C involved the cost of superstructure work as much as RM253, 200 and RM193, 570 respectively. They ranged from 23 percent to 40 percent from the overall refurbishment cost. Majority of the cost was spent on the repair and replace of roof structure and element; while some other works were repair and replacement of staircase, door and window.

On the other hand, the costs of preliminary and demolition work were demonstrated as non-influential elemental costs of refurbishment projects. The findings indicated that the costs of preliminary and demolition work were not more than 15 percent from the overall refurbishment cost for all the sample projects. Although these elements are not the influential elements in terms of cost of the refurbishment projects, they are compulsory in every project. Whereby, preliminary and demolition work are the initial stage of refurbishment projects that allow the influential element works to be carried out later on.

In historical building refurbishment project, the most concerned issues are about the dilapidation of the building, safety for occupancy, obsolescence of the building function, and preservation of the architectural heritage values. The research result validates the statement as the most influential elemental costs of these projects are building services, finishes, and superstructure works. Consequently, this paper recommends the practitioners to concern more about these elements in refurbishment projects in order to enhance the building function, occupancy safety, and preserving the architectural heritage value. Furthermore, such works must be in compliance with the statutory regulations, specifically the historical buildings. Based on the findings and discussion, this paper confirms various aims of the building refurbishment, include:

- To preserve the architectural heritage.
- To prolong the building life cycle.
- To increase values of the building.

CONCLUSION

Lack of cost information and understanding causes difficulties in preparation of budgeting for refurbishment projects. Thus, this paper emphasised on determining the influential elemental costs of conservation refurbishment projects to be the future reference of relevant projects. The findings highlighted the building services work as the most influential elemental cost of the refurbishment projects. The other influential elemental costs included finishes and superstructure works. The result demonstrated that the goals of refurbishment project are to enhance the building function and occupancy safety, as well as to preserve the architectural value of the building. The main concerns of having these influential elemental costs were to limit the focus of the practitioners into these elements when carry out the refurbishment works, specifically conservation and refurbishment of the historical buildings. Therefore, proper survey on these existing elements, planning and design of these new elements must be taken into consideration before the refurbishment works begin. In practice, the consideration should be made in terms of cost and statutory requirement to preserve the architectural heritage while increasing the life cycle and value of the buildings. Subsequently, the refurbishment costs can be reduced and the quality of refurbishment works can be improved.

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COMPARATIVE STUDY ON CHEMICAL COMPOSITION OF COAL ASH AMONGS MALAYSIAN COAL-FIRED POWER PLANTS

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Abstract

In this study, the chemical compositions of coal bottom ash and fly ash were analyzed and compared with previous studies. This study would provide the necessary information of properties to be used as supplementary cementitious materials for a partial replacement of cement in typical concrete and mortar. The coal ash samples were obtained from Sultan Azlan Shah power plants in Manjung, Perak. The samples were collected and analyzed for eight parameters. The average values of the coal bottom ash parameters obtained were SiO_2 (34.09%), Al_2O_3 (9.31%), Fe_2O_3 (12.39%), CaO (11.88%), MgO (5.28%), SO_3 (0.91%), Na_2O (0.12%), and K_2O (0.51%). In this study, the SiO_2, SO_3 and K_2O of coal bottom ash were found to be within the range compared to previous study. Meanwhile, Al_2O_3, Fe_2O_3, CaO, MgO and Na_2O of bottom ash from the present study were out of the range and the values obtained from previous studies were found to be 20.75-23.00%, 13.70%-37.10%, 9.00%-11.10%, 0.87-3.20% and 0.13-0.29%, respectively. The chemical composition of fly ash, another type of power plants residue, were 45.83% (SiO_2), 28.57% (Al_2O_3), 2.99% (Fe_2O_3), 1.41% (CaO), 0.41% (MgO), 0.19% (SO_3), 0.19% (Na_2O) and 0.57% (K_2O). The chemical composition of Al_2O_3 of coal fly ash was 28.57%, while from previous studies the range was 26.50-30.00%. Meanwhile, other oxides of coal fly ash were not in the range as published compared to previous studies. According to ASTM C 168, the coal bottom ash in this study was Class C and the coal fly ash was Class F.

Keywords: *Chemical composition; Bottom as; Fly ash; Cement replacement*

INTRODUCTION

Coal is the largest source of energy for the generation of electricity worldwide, accounting for approximately 36% of the world's electricity production (Haq *et. al.,* 2014). The coal ash is a by-product of the combustion of pulverized coal in thermal power plants as a residue in the combustion process and steam generation system (a boiler). It refers to any solid materials or residues of the coal waste products such as fly ash and bottom ash. Coal fly ash is fine particles rise with the flue gases, is captured and recovered as fly ash. The size of coal fly ash may vary from less than 1 μm to more than 80 μm and the density of individual particles is less than 1 Mg/m^3 hollow spheres to more than 3 Mg/m^3 according to ACI Committee 232 (Abubakar and Baharudin, 2012). Meanwhile, bottom ash is formed in pulverized coal boilers that are too large to be carried in the flue gases. The bottom ash is formed when the ash adheres as hot particles walls, agglomerates and then falls to the base of the furnace at a temperature around 1200°C (Todorovic, 2006), which is then collected in water-filled hoppers and removed from the bottom of the boiler furnace. The size of bottom ash ranges from gravel to fine sand with very low percentage of silt-clay sized particles. The bottom ash is usually a well-graded material, although variation in particle size may be encountered (Abubakar and Baharudin, 2012). Coal fly ash forms about 80 to

90% of the unburned material or ash, while coal bottom ash forms the remaining 10 to 20% (Umar Abubakar *et. al.,* 2012).

A large quantity of coal ash is produced from the coal-power plants. In Malaysia, there are four thermal power plants, namely Sultan Azlan Shah/Manjung (2,100 MW), Sultan Salahuddin Abdul Aziz/Kapar (2,400 MW), Tanjung Bin (2,100 MW) and Jimah (1,400 MW) (Muhardi *et. al.,* 2012). The large quantity of coal ash will be a disposal concern to the power plant companies with regards to the requirement for storage space. However, the available landfill space in the surrounding area of power plants is limited and becoming exhausted. There is a significant problem for locating new landfill sites. Thus, this will increase the company's expenditure as there is a need to dispose this hazardous substance in large storage areas (Diana *et. al.,* 2013). Coal ash creates grave risks to human health if exposed to all living things and environment. When coal ash spills, leaks or leaches into nearby groundwater or waterways, the toxins contained within may pose serious health risks to nearby communities. Coal ash contains many toxic contaminants including arsenic, lead, mercury, hexavalent chromium, and selenium, as well as aluminum, barium, boron, and chlorine (Dangerous Water: America’s Coal Ash Crisis).

In order to minimize the disposal space, it has become a practice to sort, reuse and incinerate waste materials (Juric *et. al.,* 2006). According to the American Coal Ash Association, coal bottom ash has been used largely for structural, embankment and other application as presented in Table 1 (ACCA, 2012). Bottom ashes are used widely in the structural field, followed by blended cement, concrete product, road bases and also as aggregate.

However, in other countries such as Korea, the recycling of bottom ash is much less. The bottom ash has been utilized only in a few applications in Korea. According to Korean Coal Ash Recycling Association, approximately one million tonne of bottom ash have been produced in 2007, and only about 3% was recycled. As a result of imbalance demand and supply of bottom ash, a huge amount of bottom ash is currently placed in ash ponds. This was done in order to minimize the disposal cost, but valuable land space is consumed instead (Koh, 2008). This scenario shows that proper management of bottom ash disposal is required in order to minimize the hazard. One of the solutions is to recycle the bottom ash for other purposes.

Currently in Malaysia, there is still lack of commercial application of coal bottom ash and mostly abandoned in the landfills unlike fly ash that has been used in cement industries (Umar Abubakar *et. al.,* 2012). The potential application of fly ash is controlled by its chemical composition and fineness, while the potential application of bottom ash is determined by its physical characteristic such as grain size, staining potential and colour (Kula, *et. al.,* 2001). Thus, with adequate milling coal bottom ash could act as pozzolanic material and can be used in Portland cement production (Barbhuiya *et. al.,* 2009).

Table 1. Utilization of bottom ash in tones (ACCA, 2012)

Use by category	**Bottom ash (Tonnes)**	**Fly ash (Tonnes)**
Concrete/concrete product/grout	732,260	11,779,021
Blended cement/raw feeder for clinker	1,287,343	2,281,211
Structural fill/embankment	1,716,196	3,083,441
Road bases/sub-bases	352,469	193,711
Aggregate	381,657	0

Table 1 shows the most widespread practice in reusing the coal ash. According to the American Coal Ash Association, coal ash is beneficial in blended cement/feed for clinker (ACCA, 2012). The chemical composition of coal ash composed of oxides particularly as it contains quite high silicon dioxide (SiO_2) and calcium oxide (CaO), where they are possible as cementitious materials for the application in concrete (Compolant *et. al.,* 2004). Their utilization will improve concrete properties and preserves the environment. In manufacturing cement, the raw materials are mainly limestone, clay and iron ore. The composition of limestone provides mainly calcium in the form of CaO, and clay provides SiO_2 together with small amounts of aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3). In previous research, it is recommended to replace up to 30% weight of cement by coal fly ash and to use such binder, where a low strength of concrete elements is required (Barbhuiya *et. al.,* 2009).

This paper intends to conduct a chemical composition study on coal ashes in order to provide information on their potential to be used as a supplementary cementitious materials in concrete and mortar. The chemical composition analysis of coal ash are required before these materials can be safely and effectively utilized as supplementary cementitious materials. Thus, in this study, comparison of chemical composition of coal ash between the current byproduct of combustion of coal-fired Manjung Power Plants, and studies conducted previously on other electricity generating power plants in Malaysia.

MATERIALS AND METHODS

The coal bottom ash and coal fly ash were obtained from coal-fired Sultan Azlan Shah/ Manjung Power Plant in Perak, Malaysia. In the power plant, the bottom ash falls from the furnace into a water basin located beneath the boiler. It is extracted by a submerged chain conveyor to remove the ash from the bottom of the furnace to other location. On the chain conveyor, several spots of wet coal bottom ash samples were collected from three boiler towers. The samples were collected and kept in polyethylene bags which were closed tightly and transported to the laboratory. The physical property of coal bottom ash is that it has a coarser texture rather than sandy texture in the case of the fly ash. The color of the particles is generally dull black and porous in appearance. In the laboratory, the coal bottom ash was dried in an oven at 105 ± 5^0C for 24 hours. In order to improve the pozzolanic property of bottom ash, it was sieved through a 300 μm sieve to remove coarser particle and then ground using a laboratory scale ball mill for 8 hours. Similar approaches were previously used to improve the reactivity of palm oil fuel ash for use as supplementary cementitious materials in engineered cementitious composites (Altwair *et. al.,* 2012; Megat Johari *et. al.,* 2013; Altwair *et. al.,* 2014), high strength concrete (Megat Johari *et. al.,* 2012; Mohammed *et. al.,* 2014) and alkali activated binder (Yusuf *et. al.,* 2014; Mijarsh *et. al.,* 2014; Yusuf *et. al.,* 2014 (b)).

In the case of the coal fly ash particles, they travel with the flue gases and move away from the high-temperature combustion zone in the power plant. Dry coal fly ash which was collected by particulate collector, was sampled from several spots during the dry fly ash sampling. The dry coal fly ash samples were kept in polyethylene bags which were closed tightly and transported to the laboratory. The particles were fine grains and the colour was usually dark to dark gray.

The chemical compositions of these two types of ashes were determined by X-ray fluorescence (XRF) spectrometer in the laboratory of School of Materials and Minerals Resources Engineering, Universiti Sains Malaysia, Nibong Tebal, Pulau Pinang, Malaysia. The XRF is a non-destructive method for the elemental analysis and it is one of the most popular methods for quantitative analysis of elemental composition of a material (Chand *et. al.,* 2009). Through XRF, multiple elements could be successfully analyzed at femtogram level sensitivity (Chang-Jin *et. al.,* 2010). The chemical compositions of the coal bottom ash and coal fly ash are finally obtained and shown in Table 2.

RESULTS AND DISCUSSION

It is necessary to determine the chemical compositions of coal ash because of the difference percentage of compositions may lead to changes in pozzolanic reactivity of the ashes which subsequently may influence the mechanical properties of the resulting mortar or concrete in which the particular ash is utilized. The chemical compositions of the coal ashes obtained in this study are given in Table 2, whereby the results are the average values for the analyzed elements. These results are compared with the typical chemical compositions of ASTM Type 1 cement (Table 3) and also the chemical compositions of coal ashes from other power plants in Malaysia as reported in several previous studies. The chemical compositions for coal fly ash and coal bottom ash reported in the previous studies are given in Table 4 and Table 5, respectively.

Table 2. Chemical composition of coal ashes from Manjung Power Plant

Chemical elements (by weight %)	Coal Bottom ash	Coal Fly ash
SiO_2	34.10	45.83
Al_2O_3	9.31	28.57
Fe_2O_3	12.39	2.99
CaO	11.88	1.41
MgO	5.28	0.41
SO_3	0.91	0.19
Na_2O	0.12	0.19
K_2O	0.51	0.57
$SiO_2+Al_2O_3+Fe_2O_3$	55.80	77.39

Table 3. Chemical composition of Portland Cement (Altwair *et. al.,* 2012)

Elements (wt. %)	Type I Cement
SiO_2	20.90
Al_2O_3	5.27
Fe_2O_3	3.10
CaO	62.80
MgO	1.52
SO_3	2.73
Na_2O	0.16
K_2O	0.63
P_2O_2	0.13
Loss of ignition (LOI)	0.87

Table 4. Chemical composition of coal bottom ash samples from previous studies in Malaysia

Chemical elements (wt. %)	**Tanjung Bin Power Plant (Muhardi *et. al.,* 2010)**	**Jimah Power Plant (Fawzan, 2010)**	**Kapar Power Plant (Naganathan *et. al.,* 2012)**
SiO_2	42.7	49.4	9.78
Al_2O_3	23.0	22.3	20.75
Fe_2O_3	17.0	13.7	37.1
CaO	9.8	9.0	11.1
MgO	1.54	0.87	3.2
SO_3	1.22	0.68	-
Na_2O	0.29	0.13	-
K_2O	0.96	1.0	-
$SiO_2+Al_2O_3+Fe_2O_3$	82.7	85.4	67.6

Table 5. Chemical composition of coal fly ash from previous studies in Malaysia

Chemical elements (wt. %)	**Tanjung Bin Power Plant (Muhardi *et. al.,* 2010)**	**Tanjung Bin Power Plant (Awang *et. al.,* 2011)**	**Kapar Power Plant (Naganathan *et. al.,* 2012)**
SiO_2	51.8	47.1	56.58
Al_2O_3	26.5	30.0	27.83
Fe_2O_3	8.50	7.34	4.00
CaO	4.81	7.21	4.30
MgO	1.10	1.52	1.40
SO_3	0.60	0.32	-
Na_2O	0.67	0.72	-
K_2O	3.27	1.62	-
$SiO_2+Al_2O_3+Fe_2O_3$	86.80	84.44	88.41

COMPOSITION OF COAL BOTTOM ASH

The oxide composition analysis of the coal bottom ash in the present study as portrayed in Table 2 indicates that the bottom ash is rich in SiO_2 (34.1%), followed by Fe_2O_3 (12.39%), CaO (11.88%), Al_2O_3 (9.31%), MgO (5.28%) and other oxides in much smaller composition of less than 1%. The analysed bottom ash registers sum of SiO_2+Al2O_3+Fe_2O_3 of 55.80%. Based on this value and according to ASTM C 618, the bottom ash could be classified as Class C mineral admixture, whereby the sum of $SiO_2+Al_2O_3+Fe_2O_3$ is greater than the stipulated minimum value of 50%. This class of coal ash mineral admixture, in addition to having pozzolanic property, it also possesses some cementitious properties. This is supported by the high lime (CaO) content of 11.8% (greater than 10%) which provides the cementitious properties, i.e. upon exposure to water the ash could undergo chemical reaction as in the case of Portland cement. Nonetheless, the quantity of CaO in the bottom ash is significantly lower than that typically found in a Type I or Ordinary Portland cement. Table 3 shows that the composition of CaO in a Type I cement is 62.80%, which is far higher than the value of 11.88% registered by the bottom ash. Other major oxides in the cement include SiO_2, Al_2O_3 and Fe_2O_3 with compositions of 20.90%, 5.27% and 3.10%, respectively, which is lower than the corresponding composition of oxides in the bottom ash. Hence, despite the fact that the bottom ash is both pozzolanic and cementitious, the cementing ability should presumably be far less than that of Portland cement, therefore it is not suitable to be used as a sole binder for concrete; i.e. it should be used as a supplementary binder to Portland cement.

Previous studies by Muhardi *et. al.,* (2010), Fawzan *et. al.,* (2010) and Naganathan *et. al.,* (2012) on bottom ashes obtained from Tanjung Bin Power Plant, Jimah Power Plant and Kapar Power Plant, respectively exhibited varying oxide compositions amongst the different the bottom ashes (Table 4). The SiO_2 content ranged from as low as 9.78% to as high as 49.4%, whereas the Al_2O_3 and Fe_2O_3 ranged from 20.75%-23.0% and 13.7%-37.1%, respectively. Hence, the SiO_2 content of the bottom ash in the present study is within the range recorded by bottom ashes from other power plants in Malaysia. Nonetheless, the content of Al_2O_3 and Fe_2O_3 is less than that of the bottom ashes from other power plants. In the case of MgO, the composition of 5.28% recorded in the present study is higher than that reported in previous studies. The sum of $SiO_2+Al_2O_3+Fe_2O_3$ of bottom ashes from the previous studies is higher than that of the present study. Similar to the bottom ash in the present study, the coal bottom ashes from the Tanjung Bin Power Plant and Jimah Power Plant were of Class F, while the bottom ash from Kapar Power Plant belonged to Class C. Based on the oxide compositions, the bottom ashes from the previous studies exhibit their potentially better quality and pozzolanic reactivity than that of bottom ash from the present study. This could be attributed to the different types and quality of the coal used in the different power plants.

COMPOSITION OF COAL FLY ASH

The results in Table 2 portrays that the fly ash composes of 45.83%, 28.57% and 2.99% of the major oxide compositions, namely SiO_2, Al_2O_3 and Fe_2O_3, respectively. The composition of CaO of 1.41% in the fly ash is much smaller than that of the bottom ash. The sum of $SiO_2+Al_2O_3+Fe_2O_3$ of 77.39% indicates that fly ash belongs to Class F mineral admixture class according to ASTM C 618, which is mainly pozzolanic in nature.

Nonetheless, the major oxide compositions are lower than previously found in fly ashes from Tanjung Bin Power Plant [(Muhardi *et. al.,* 2010); (Awang *et. al.,* 2011)] and Kapar Power Plant (Naganathan *et. al.,* 2012) as shown in Table 5. The sum of SiO_2+Al_2O_3+Fe_2O_3 for the fly ash from of Tanjung Bin Power Plant and Kapar Power Plant is 86.80% (Muhardi *et. al.,* 2010) and 88.41% (Naganathan *et. al.,* 2012), respectively. Based on the major oxide compositions, the fly ashes from the other power plants also belong to Class F mineral admixture. The higher compositions of the major oxides contributing to the pozzolanic property in the fly ashes from the other power plants as reported in the previous studies indicate their potentially superior pozzolanic reactivity. Again, this difference could be attributed to the different type and quality of the coal used in the different power plant.

CONCLUSIONS

Coal fly ash that is produced from thermal power plants in Malaysia, has become a practice to reuse it as a partial replacement of cement in typical concrete and mortar. Substitution of cement with fly ash has led to an increase in the quantity of concrete and mortar. On the other hand, coal bottom ash is still abandoned in landfills due to lack of commercial applications. Thus, the potential use of coal bottom ash in concrete and mortar, still needs further study in order to recycle the waste residues. The recycling of coal ash will minimize the disposal space, while protecting the environment at the same time. Another benefit is to reduce air pollution by decreasing the emission of CO_2 and other gases in cement production.

In the present study, the examination of the chemical composition of coal bottom ash and coal fly ash samples from Sultan Azlan Shah Power Plant were categorized in Class C and Class F, respectively. Class C ash generally possesses cementitious as well as pozzolanic properties and Class F ash generally possesses large pozzolanic properties. The chemical composition of coal bottom ash was comparable with results from other studies conducted in Malaysia. It was found that others elements such as Al_2O_3, Fe_2O_3, CaO, MgO, and Na_2O were not in the range like previous research. Meanwhile, for coal fly ash, the oxides which are SiO_2, Fe_2O_3, CaO, MgO, SO_3, Na_2O, K_2O but Al_2O_3 were not in the range of the previous research.

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LIGHTWEIGHT AGGREGATE USING SEWAGE SLUDGE AND SEWAGE SLUDGE ASH – A REVIEW

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Abstract
This paper reviews previous research studies on lightweight aggregate (LWA) produced from sewage sludge (SS) and sewage sludge ash (SSA). SS is a solid waste produced after the separation of liquids and solids in wastewater treatment process. The incineration of SS produces ashes known as SSA. Both SS and SSA are inevitable wastes produced in every country. The disposal options of SS in ASEAN countries are different from countries like Europe and America. In ASEAN countries, open dumping is the most common disposal option. However, the increasingly stringent environmental laws restrict the disposal of SS and SSA. By the 19th century, many researchers have recognized the reuse potential of these materials and started to reuse them to produce LWA. In this paper, the physical and chemical properties as well as heavy metals leaching characteristics of raw SS and SSA are reviewed. The manufacturing principle of LWA, microstructure, physical, chemical and mechanical properties including heavy metals leaching aspect of SS and SSA LWA are summarized. It is observed that both the LWA manufactured from SS and SSA possess physical and mechanical properties which are comparable to commercially available LWA.

Keywords: *Sewage sludge (SS); Sewage sludge ash (SSA); Lightweight aggregate (LWA)*

INTRODUCTION

Concrete is one of the most broadly used construction material worldwide. Wong (2012) has stated that the annual worldwide production of concrete solely for development and construction purpose is approximately 25 billion tons. According to Alexander and Mindess (2005), aggregates occupied about 70 to 80 percent of concrete volume. As an estimate, out of these 25 billion tons of concrete produced yearly, about 17.5 to 20 billion tons of natural aggregates are being exploited for the production of concrete.

Starting from the 21st century, the continual increment of waste generation is a serious issue faced by the society. According to Global Environment Centre (2014), solid wastes produced in Malaysia every day is 23,000 tons and is expected to reach 30,000 tons by the year 2020. Sewage sludge (SS) is one of the inevitable solid wastes produced in every country. This solid waste is obtained from the separation of liquids and solids from the wastewater treatment process (Fytili and Zabaniotou, 2008). The incineration of SS produces ashes known as sewage sludge ash (SSA).

The gigantic consumption of natural stone and rising problem of wastes management have driven researchers to steer their attention into the production of artificial aggregates from wastes materials as natural stone replacement in concrete (Güneyisi *et. al.,* 2013). Both SS and SSA have a promising potential to be used as raw materials to produce artificial lightweight aggregate (LWA). LWA produced from SSA involves extra treatment stage (both combustion and sintering), while LWA production from SS only involves sintering stage. As such, the production of LWA from SSA induces more construction and operation cost than raw SS (Chiou *et. al.,* 2006; Wang *et. al.,* 2009b).

CHARACTERISTICS OF SS AND SSA

Physical Properties

SS is infamous for its foul rotten-egg smell. This odorous smell is due to hydrogen sulphide gas, which is produced from the anearobical digestion of organic and inorganic compounds that contains sulphur in acid conditions (Lu and Lau, 1996). Generally, the SS possesses specific gravity of 1.0 – 1.08 and density of 1020 – 1080kg/m^3 (Sperling, 2007). Due to different wastewater composition and treatment applied in wastewater treatment plant, the characteristics of SS also varies (Liu *et. al.,* 2011). SS can be classified as organic clay or silt (OH) based on ASTM Standard D 2487 (Unified Soil Classification System), based on the Atterberg limits and particle size distribution as shown in Table 1. Also, SS possesses relatively high moisture content of 106.9 – 720.0% and organic content of 54.62 – 70.00% (Table 1).

Table 1. Typical Physical Properties of Sewage Sludge

Properties	Liew *et. al.,* (2004)	O'kelly (2006)
Moisture content (% dry mass)	106.9	720.0
Specific gravity	-	1.55
Bulk density (kg/m^3)	-	1020
Atterberg		
Liquid limit (%)	70	315
Plastic limit (%)	n.a.	55
Plasticity index (%)	n.a.	260
Particle size distribution (%)		
Gravel	-	-
Sand	37.85	-
Fines	62.15	90.00
Loss on ignition (%)	54.62	70.00

n.a., not analysed;

Chemical Properties

The chemical composition of SS and SSA is as illustrated in Table 2. From the table, it can be observed that SSA has 66 – 93% of silica (SiO_2) and 74 – 95% of alumina (Al_2O_3), higher than the raw SS. Both SiO_2 and Al_2O_3 are important because they are the components that form the skeleton of the sintered aggregate and improve its strength. However, the elevated content of SiO_2 and Al_2O_3 in aggregate increases the required sintering temperature because these components possess higher melting point (Mun, 2007; Xu *et. al.,* 2008). On the other hand, the flux content (Fe_2O_3, K_2O, Na_2O, CaO and MgO) for SSA is almost similar to that of SS. The presence of flux is needed in sintered aggregate because they have lower melting point as compared to SiO_2 and Al_2O_3, which decreases the required sintering temperature. In spite of this, the flux reduces the strength of the sintered aggregate (Xu *et. al.,* 2009).

Both SS and SSA are classified as hazardous materials because their heavy metals concentrations are much higher than the regulatory threshold in various countries (Chiou *et. al.,* 2006; Mun, 2007, Wang *et. al.,* 2009b; Wang, 2012; Liu *et. al.,* 2012; Tuan *et. al.,* 2013; Tsai *et. al.,* 2006; Lin *et. al.,* 2006). As such, when the raw SS and SSA are directly applied on land, their toxicity would pollute the soil as well as the groundwater sources and consequently create grave threat to the human health, animals and soil fertility (Smith *et. al.,* 1996; Lu and Lau, 1996).

Table 2. Chemical compositions of sewage sludge and sewage sludge ash from different countries

Type	Sewage Sludge (SS)			Sewage Sludge Ash (SSA)		
Country	China	Korea	Taiwan	Singapore	USA	Taiwan
Author (Year)	Wang *et. al.,* (2009b); Wang (2012); Liu et al (2012); Xu *et. al.,* (2008)	Mun (2007)	Tuan *et. al.,* (2013)	Tay *et. al.,* (1991); Yip and Tay (1990)	Bhatty and Reid (1989)	Tsai *et. al.,* (2006); Lin *et. al.,* (2006); Chiou *et. al.,* (2006)
Composition (wt.%)						
SiO_2	9.24 - 56.06	52.00	36.20	8.01 – 14.10	27.03	44.89 - 63.31
Al_2O_3	2.97 - 11.83	20.94	14.40	4.23 – 5.59	14.36	11.62 - 15.38
Fe_2O_3	3.68 - 23.40	8.98	9.20	6.00 – 8.66	8.22	6.81 - 7.46
K_2O	1.12 - 5.33	3.11	2.50	0.58 – 0.64	0.63	1.46 - 2.93
Na_2O	0.00 - 7.30	1.30	0.00	0.22 – 0.30	0.52	0.04 - 0.70
CaO	1.39 - 10.69	4.06	6.60	2.50 – 3.10	20.97	1.80 - 6.49
MgO	0.53 - 10.68	2.21	2.90	0.76 – 0.81	3.21	0.10 - 2.01
TiO_2	0.32 - 0.73	0.94	1.20	-	2.85	0.09
P_2O_5	0.33 - 32.98	5.31	15.00	-	20.20	7.02 - 18.68
MnO	0.07 - 0.11	0.12	-	0.08 – 0.15	-	-
LOI	62.90 - 65.36	10.17	-	-	0.20	-
Cl	-	-	-	0.02 - 0.03	-	-
SO_3	0.22	-	11.00	0.78	0.84	1.02

DISPOSAL OPTIONS OF SS AND SSA IN ASEAN COUNTRIES, EUROPE AND AMERICA

Malaysia, like other ASEAN countries, open dumping is the primary disposal option, in which half of the total municipal solid waste (including sewage sludge) is disposed through this disposal option (Table 3). This trend is commonly seen in developing countries due to the inadequacy of trained labourers and is a cheap disposal option (Ali *et. al.,* 2014). Conversely, in developed countries like Europe and North America, land application (agriculture and re-cultivation) is the main sludge disposal option, followed by incineration and sea disposal, as illustrated in Figure 1. Sewage sludge contains high amount of organic matter and plant nutrients such as nitrogen (N), Calcium (Ca), Magnesium (Mg) and phosphorus (P), which are vital for plant growth (Kroiss *et. al.,* 2011; Singh and Agrawal, 2008).

Table 3. Disposal option of municipal solid waste in ASEAN countries (Jenny, 2004)

Country	**Disposal Methods (%)**				
	Composting	**Open dumping**	**Landfilling**	**Incineration**	**Others**
Indonesia	15	60	10	2	13
Malaysia	10	50	30	5	5
Myanmar	5	80	10	-	5
Philippines	10	75	10	-	5
Singapore	-	-	30	70	-
Thailand	10	65	5	5	15
Vietnam	10	70	-	-	20

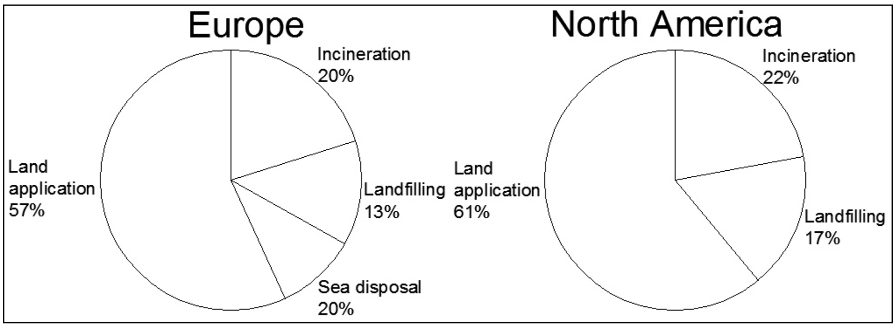


Figure 1. Sewage sludge disposal options in Europe and North America (Kroiss *et. al.,* 2011)

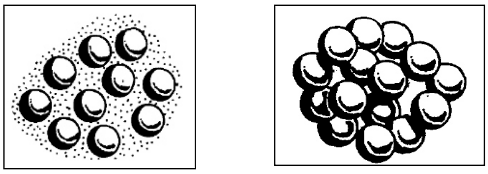
Beside from the useful nutrients for plant growth, SS also contains high amount of heavy metals such as lead, cadmium, nickel, chromium and copper (Singh and Agrawal, 2008). Consequently, the long-term land application of SS creates soil contamination due to accumulation of heavy metals and metalloids (Wuana and Okieimen, 2011). Also, the sites for landfilling and reclamation are growing scarce due to rapid urbanization (Lu and Lau, 1996; Merino *et. al.,* 2007). This led to incineration as an alternative. Incineration is able to reduce the volume and weight of wastes up to 75 – 95%, respectively to prolong 10 – 20 times the life span of landfill sites (Lau, 2004). However, this disposal option induces extravagant cost, toxic gas emissions and ash disposal problem (Lu and Lau, 1996). High moisture content of SS also creates difficulties in reclamation, incineration and recycling of sludge (Mun, 2007). Moreover, the increasingly stringent standards for environmental protection exert limitations on the disposal options of SS. For instance, the London Dumping Convention (1975) prohibited the ocean disposal worldwide and Korea government banned the direct reclamation of SS since June 2003 (Mun, 2007; Lu and Lau, 1996). Therefore, many researchers have recognized SS as a highly potential material for re-use instead of direct disposal (Lu and Lau, 1996).

MANUFACTURING CONCEPT OF LWA

Bijen (1986) has established the main steps to manufacture LWA as: a) mixing of raw materials, b) agglomeration or pelletization (by agitation or pressure), c) hardening or binding of particles (by sintering, autoclaving or cold-bonding) and d) further processing.

Two main concepts for manufacturing of LWA are agglomeration and hardening of particles. The purpose of agglomeration is to consolidate particles and then form larger mass of green pellets. As for hardening, it serves to form bonds (Figure 2) between the particles. The matrix bond is formed through autoclaving and cold-bonding. In matrix bonding, the particles of raw materials are embedded into a matrix through the reaction between particles of raw materials and binding materials (i.e. ordinary Portland cement), as illustrated in Figure 2(a). On the other hand, the material bridge bond is formed through sintering, where the particles of raw materials are fused together at elevated temperature, as shown in Figure 2(b) (Bijen, 1986).

Bloating is an expansion phenomenon which is very important in the production of LWA by sintering process (Bhatty and Reid, 1989). This bloating concept, in brief, is the melting of raw materials at elevated temperature which generates proper viscosity and produces a gas; the bloated or expanded LWA is then formed when the gas pressure is higher than the needed gas pressure to resist the viscosity of melted raw materials (Mun, 2007; Riley, 1951). According to Riley (1951), this phenomenon greatly depends on the balance between SiO_2, Al_2O_3 and flux contents of the raw materials. It is stated that the bloating range of expansive clay contains SiO_2 of 48 – 70%, Al_2O_3 of 8 – 25% and flux of 4.5 – 31%. Xu *et. al.,* (2008) and Zou *et. al.,* (2009) have produced LWA from water and wastewater sludge and it is concluded that, the raw materials should contain SiO_2 of 14 – 26%, Al_2O_3 of 22.5 – 45%, Fe_2O_3 of 5 – 8%, CaO of 2.75 – 7% and MgO of 1.6 – 4%, in order to produce LWA with a good bloat. Tsai *et. al.,* (2006) have discovered good bloat occurred in LWA made from SSA when the SiO_2, Al_2O_3 and flux are in the range of 35 – 44%, 10 – 26% and 36 – 44% respectively. Thus, the required SiO_2, Al_2O_3 and flux contents for LWA to bloat are different between SS, SSA and expansive clay.



(a) Matrix bonding (b) Material bridge bonding

Figure 2. Matrix bonding of particles (Bijen, 1986)

PROPERTIES OF LWA MANUFACTURED FROM SS AND SSA

According to Cheeseman and Virdi (2005), the individual LWA pellets should have ideal characteristics of: a) a strong sintered ceramic core, but low in density and porous; b) a layer of dense shell to reduce water absorption and; c) a near spherical shape to enhance fresh concrete properties. Tuan *et. al.,* (2013) have advocated the above statement and have added that a good LWA should also be strong enough to prevent itself from being crushed during concrete mixing. The raw materials used by various researchers to produce LWA from SS and SSA are presented in Table 4. The SS used to make LWA is between 20 – 82%. Other materials used include pulverized fly ash (PFA), blast furnace slag (BFS), river silt, coal ash (CA) and clay, which range between 18 – 80%. The sintering temperature and duration of LWA of SS is 970 – 1210°C and 10 – 35min, respectively. As for LWA made from SSA, the SSA utilized is able to reach a maximum of 100% without additional materials, with sintering temperature and duration of 700 – 1085°C and 10 – 2400min, respectively. This is because sufficiently strong pellets can be produced from SSA alone without using any binders (Bhatty and Reid, 1989).

Physical Properties

Shape and Texture

The shape of artificial LWA made from SS and SSA is more uniform. Pelletization by agitation and pressure produce both spherical and cylindrical pellets, with smooth surface texture as shown in Table 4. According to Bhatty *et. al.,* (1992), the spherical and smooth SSA pellets enhance the workability of concrete mixes and enable a more compact concrete. The spherical pellets also improve the aesthetical value of surface finishing (O'Flynn, 2000). Pelletization through crushing produce angular shaped pellets and possess rough surface texture (Table 4). O'Flynn (2000) has stated that angular pellets with rough surface texture form a better bond with cement paste to produce higher tensile strengths.

Bulk Density

Voids exist between aggregates as a result of irregularity in particles shape, which is affected by size distribution, shape and packing arrangement of particles (Mullen, 1978). Brink and Timms (1996) have defined bulk density as the mass of a given unit volume of particles. In LWA, bulk density is a useful indicator of variation of aggregate's relative density which subsequently affects the LWAC mix design (John, 2006). The bulk density of LWA made from SS and SSA typically ranges from 575 – 820 kg/m^3 and 480 – 730 kg/m^3, respectively (Table 4). The bulk density of LWA made from SS and SSA are comparable with other commercial artificial LWA such as Solite with bulk density of 720 – 880 kg/m^3 (Nawy, 2001) and Arlita with bulk density of 550 – 750 kg/m^3 (González-Corrochano *et. al.,* 2009). Only Wang *et. al.,* (2009b) have produced LWA from SS with much higher bulk density than other researcher (Table 4), with bulk density between 1480 – 1540 kg/m^3. It is similar to the bulk density of natural crushed stone of 1440 – 1520 kg/m^3 (Nawy, 2001).

Specific Gravity

Specific gravity is the ratio of the weight of a given volume of material to the weight of an equal volume of water (Mullen, 1978). The specific gravity of LWA made from SS is 1.03 – 1.25, as presented in Table 4. It is slightly lower than the specific gravity of other commercial artificial LWA partially made from SS, such as Minergy and Trefoil, with specific gravity of 1.42 – 1.52 and 1.45 – 1.70, respectively (Sarabèr *et. al.,* 2012). On the other hand, the specific gravity of LWA made from SSA is 0.75 – 1.6. Both LWA produced from SS and SSA are generally lower than 2. Only Tay *et. al.,* (1991) have reported the specific gravity of LWA made from SSA higher than 2, which is between 2.77 – 2.82. This range of specific gravity is comparable to that of normal weight aggregate (NWA), typically range in between 2.50 – 2.70 (Gambhir, 2004).

Water Absorption

Water absorption is an effective indicator of the quality of the sintered LWA because it correlates with the compressive strength and density of the sintered LWA. A decrease in water absorption signifies a decrease in open pores due to better densification and thus, creates a greater compressive strength of the sintered LWA (Wang *et. al.,* 1998).

The water absorption of LWA made from SS and SSA lies between 1.2 – 20.5% and 2.49 – 19.16%, respectively (Table 4). According to Yip and Tay (1990), the corresponding water absorption for Leca and Aglite is 20 and 24%, respectively. The water absorption for some of the LWA made from SS and SSA is low, with the lowest water absorption of 1.2% only (Table 4). Normally, the acceptable water absorption capacity of LWAs is less than 20% (Wei *et. al.,* 2008; Wei *et. al.,* 2011). Golias *et. al.,* (2012) have stated that concrete can harness the benefits provide by internal curing when the concrete mix proportion is properly adjusted to account for the water absorbed by the LWA before setting. The internal curing increase of hydration in concrete mix induces higher compressive strength, lower water absorption, lower electrical conductivity, lower autogenous shrinkage and lower tendency of early-age cracking.

Table 4. Physical properties of LWA from sewage sludge and sewage sludge ash

Author (Year)	Raw Materials	Binder	Sintering Temp. (°C)	Retention Time (min)	Pelletiz-ing Method	Pellet Shape	Texture	Pellet Size (mm)	Bulk Density (kg/m^3)	Specific Gravity	Water Absorp-tion (%)	Poro-sity (%)
Sewage Sludge LWA												
Chiou *et. al.*, (2006)	DSS (20 - 30%), SSA (70 - 80%)	-	1050	10	Agitation	Round	Smooth	4.75 – 9.50	780 – 820	-	9.03 – 11.81	-
Xu *et. al.*, (2006)	SS (25%), Clay (75%)	Water glass (15%)	1000	10	Agitation	Round	-	3 - 6	575	1.03	10	-
Mun (2007)	SS (75%), Clay (25%)	-	1050 - 1150	10 - 15	Agitation	Round	-	5 - 10	750	-	10	-
Xu *et. al.*, (2008)	SS (55%), WTS (45%)	Water glass (20%)	1000	35	Agitation	Round	-	5 - 8	725	1.25	18	36
Wang *et. al.*, (2009b)	DSS (75 - 82%), CA (18 - 25%)	-	1100	30	Pressure	Cylinder	Smooth	D(20.4), H(14)	1480 – 1540	-	3 - 5	-
Wang *et. al.*, (2009a)	SS (44.4%), Clay (5.5%), PFA (50.1%)	-	1000	10	Agitation	Round	-	8 - 10	610	-	-	-
Wang (2012)	SS (50%), BFS (20%), Clay (30%)	-	1000	20	Agitation	Round	-	4 - 6	785	-	20.5 (1h)	-
Liu *et. al.*, (2012)	SS (50%), FA (50%), River silt (30%)	-	1210	30	Balled by hand	Round	Smooth	10	700	-	6	-
Tuan *et. al.*, (2013)	SS (70%)	Waste glass (30%)	970	20	Pressure	Round	Smooth	4.75 – 9.50	800.3	1.2	1.2	-
Sewage Sludge Ash LWA												
Bhatty & Reid (1989)	SSA	-	1060 - 1085	10 - 30	Agitation	Round	-	15	480 – 670	0.75 - 1.07	2.49 – 2.88	-
					Crushed	Angular	-	4.75 – 9.5	500 – 730	1.11 - 1.32	9.36 – 19.16	-
Yip & Tay (1990)	SSA	-	1080	480	Crushed	Angular	Rough	5 - 20	60	0.9 - 1.1	7.82 – 9.60	63.3 - 69.2
Tay *et. al.*, (1991)	SSA (60 - 90%), Clay (10 - 40%)	-	1050 - 1080	2400	Crushed	Angular	Rough	20	622 – 660	2.77 – 2.82	6.1 – 6.58	7.6 - 48.2
Wainwright & Cresswell (2001)	SSA (64%), SS (27%), Clay (20%)	-	700 - 800	-	Agitation	Round	-	-	630 (dry) 730 (SSD)	1.6	15.5	-

Note: D = diameter, H = height

Chemical Properties

Frost Resistance

A limited amount of literature is reported on the chemical properties of LWA made from SS and SSA. Chiou *et. al.,* (2006) have investigated on the chemical soundness of LWA made from SS, by measuring the weight loss rate of LWA when they are soaked repeatedly in saturated magnesium sulphate solution for 5 times, in order to stimulate the ice crystallization effect in saturated aggregate. Results showed that the developed LWA with good bloating effect possess soundness of 1.11 – 1.34%, which is much lower than regulatory value of 18%. It signified that the LWA of SS is excellent in resisting chemical decomposition.

Mechanical Properties

Most of the researchers have reported the mechanical properties of LWA in individual crushing strength. The concept of this test is clearly illustrated by Gesoğlu *et. al.,* (2012) in which an individual pellet is placed between two parallel plates and diametrically loaded until failure occurred. The compressive strength of LWA is calculated by using ratio between load and the surface area of the sintered LWA (Wang *et. al.,* 2009b). As for spherical pellets, the compressive strength is computed through the following formula:

$$S = \frac{2.8P_c}{\pi X^2} \qquad \text{(Equation 1)}$$

Where P_c is the fracture load and X is the distance between loading points (Yashima *et. al.,* 1987). The crushing strength of LWA made from SS and SSA is 2.53 – 40MPa and 0.75 – 14.19MPa, respectively (Table 5). This range of crushing strength is comparable to the other commercial LWA such as Leca of 1.5 – 4.5MPa (de Gennaro *et. al.,* 2007) and Liapor of 1 – 15MPa (Liapor, 2014).

Referring to Table 5, Tay *et. al.,* (1991) have produced LWA from SSA with 10% fines value of 12.5 – 17.6 kN. Mun (2007) has reported the mechanical strength of LWA manufactured from SS with crushing value of 35.5%, abrasion loss of 18.5% and impact value of 32.1%. Its abrasion loss is slightly lower than that of crushed stone which is normally within 20 – 25% (Alengaram *et. al.,* 2013).

Table 5. Mechanical properties of LWA from sewage sludge and sewage sludge ash

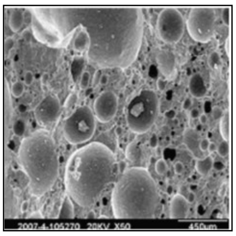
Author (Year)	Individual Crushing Strength (MPa)	10% Fines Value (kN)	Crushing Value (%)	Abrasion Loss (%)	Impact Value (%)
Sewage Sludge LWA					
Chiou *et. al.,* (2006)	*2.53 - 10.18	-	-	-	-
Mun (2007)	-	-	35.50	18.50	32.10
Xu *et. al.,*(2008)	14.07	-	-	-	-
Wang *et. al.,* (2009b)	19.30 - 23.69	-	-	-	-
Wang *et. al.,* (2009a)	9.00 – 14.00	-	-	-	-
Liu *et. al.,* (2012)	40.00	-	-	-	-

Tuan *et. al.,* (2013)	5.27	-	-	-	-
Sewage Sludge Ash LWA					
Bhatty & Reid (1989)	0.75 - 2.11	-	-	-	-
	2.01 - 14.19	-	-	-	-
Yip & Tay (1990)	13.00	-	-	-	-
Tay *et. al.,* (1991)	-	12.50 - 17.60	-	-	-

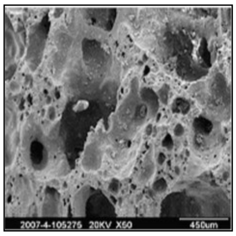
Note: The value mark with asterisk (*) is calculated by using Equation 1

Microstructure

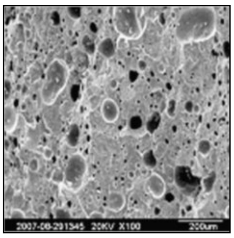
Wang *et. al.,* (2009b) and Chiou *et. al.,* (2006) have reported that LWA from 100% dewatered sewage sludge bloated at lower temperature, but the microstructure of this LWA is porous and loose (Figure 3(a) and (b)) which resulted in low compressive strength. This is accountable to the high organic content in SS and low SiO_2 and Al_2O_3 content and high flux content, as mentioned earlier. As such, SS needs to be amended with material(s) that possesses high SiO_2 and Al_2O_3 content (Wang *et. al.,* 2009b) such as coal ash, PFA, clay and etc. However, Wang *et. al.,* (2009b) have showed that the amended LWA with coal ash required higher temperature to bloat, as shown in Figure 3(c) and (d).



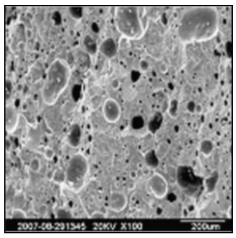
(a) SS - 1050°C, 30min (x50)



(b) SS - 1080°C, 30min (x50)



(c) SS + 18% CA - 1100°C, 30min (x50)



(d) SS + 25% CA- 1100°C, 30min (x50)

Figure 3. Microstructure of sintered SS product (Wang, 2009b)

Leaching Characteristics of Sintered LWA

Dutch NEN 7341 test testified the maximum immobilization efficiency through sintering is achievable, as shown in Table 6. The raw SS and SSA are hazardous materials with heavy metals more than regulatory threshold, as shown in Table 7. From this table, the raw SS has Cd of 1.4 – 5.92 mg/kg, Cr of 9.51 – 83.61 mg/kg, Cu of 33.32 – 710.53 mg/kg, Ni of 88.62 mg/kg, Pb of 0.28 – 126.82 mg/kg and Zn of 76.57 – 164.02 mg/kg. As for the raw SSA, it possesses Cd of 8.9 – 10.3 mg/kg, Cr of 75.7 – 77.3 mg/kg, Cu of 420.3 – 432.6 mg/kg, Pb of 199.4 – 201.7 mg/kg and Zn of 6.05 – 230.8 mg/kg. Sintering is an effective way of immobilizing these heavy metals into the matrix of LWA. In fact, sintering is the only hardening process utilized by researchers in producing LWA from SS and SSA. The heavy metals of sintered product are all below the standard limit after sintering, with maximum immobilization efficiency achieving 100% for arsenic (As), Cd, Cr, Cu, Pb, cobalt (Co) and titanium (Ti), as presented in Table 7.

Table 6. Maximum immobilization efficiency through sintering (Yang *et. al.,* 2008)

Heavy metals	Immobilization Efficiency (%)
Na, Sr, Zn	>95
Ca, K, Cu	90 – 95
Si, Al, Sn	80 – 90
Fe, Mn, B, Pb, Cd	70 – 80
Mg, Ba, Sb, Cr	50 – 70

Table 7. Leaching characteristics of aggregate in raw and sintered state

Author (Year)	Condition	Heavy Metal Composition											
		As	Cd	Cr	Cu	Ni	Pb	Zn	Co	Mo	Ti	Mn	Hg
Sewage Sludge LWA													
Chiou *et. al.*, (2006)	**Raw (mg/kg)**	**-**	**1.60 ± 0.13**	**9.51 ± 0.11**	**33.32 ± 1.28**	**-**	**0.28 ± 0.09**	**176.57 ± 2.97**	**-**	**-**	**-**	**-**	**-**
	Sintered (mg/L)	-	ND	ND	0.539 ± 0.117	-	0.098 ± 0.026	0.402 ± 0.003	-	-	-	-	-
Mun (2007)	**Raw (mg/kg)**	**71.21**	**5.92**	**83.61**	**710.53**	**88.62**	**126.82**	**1648.02**	**15.68**	**113.46**	**1204.33**	**1094.02**	**-**
	Sintered (mg/L)	ND	ND	ND	ND	1.07 - 5.28	ND	0.28 - 0.50	ND	0.7	ND	0.28 - 0.36	-
Wang *et. al.*, (2009b)	**Raw (mg/kg)**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
	Sintered (mg/L)	0.001	0.001	0.022	0.0058	0.009	0.056	0.279	-	-	-	-	-
Wang (2012)	**Raw (mg/kg)**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
	Sintered (mg/L)	-	< 0.001	0.028	-	-	< 0.05	-	-	-	< 0.002	-	-
Liu et al (2012)	**Raw (mg/kg)**	**-**	**1.4**	**180**	**240**	**-**	**21**	**670**	**-**	**-**	**-**	**-**	**0.66**
	Sintered (mg/L)	-	0	0.0077	0.269	-	0	0	-	-	-	-	0
Tuan *et. al.*, (2013)	**Raw (mg/kg)**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
	Sintered (mg/L)	-	0.05	0.02	0.69	-	0.47	2.54	-	-	-	-	-
Sewage Sludge Ash LWA													
Tsai *et. al.*, (2006)	**Raw (mg/kg)**	**-**	**10. 3 ± 0.5**	**77.3 ± 2.5**	**420.3 ± 10.2**	**-**	**201.7 ± 5.2**	**2308.2 ± 16.5**	**-**	**-**	**-**	**-**	**-**
	Sintered (mg/L)	-	0.07 ± 0.01	ND	0.63 ± 0.01	-	ND	6.05 ± 0.13	-	-	-	-	-
Lin *et. al.*, (2006)	**Raw (mg/kg)**	**-**	**8.9 ± 0.1**	**75.7 ± 3.3**	**432.6 ± 9.3**	**-**	**199.4 ± 4.3**	**-**	**-**	**-**	**-**	**-**	**-**
	Sintered (mg/L)	-	0.02 - 0.04	ND	0.39 - 0.61	-	ND	2.55 - 7.04	-	-	-	-	-
Regulatory threshold													
Wang *et. al.*, (2009b)	Environmental quality standards for surface water III (mg/L)	≤ 0.05	≤ 0.005	≤ 0.05	≤ 1	≤ 0.02	≤ 0.05	≤ 1	-	-	-		-
	China National Standard (mg/L)	-	< 1	< 15	-	-	-	-	-	-	-	-	-
Wang (2012)	Standards for Hazardous Waste (GB5085.3-2007) (mg/L)	-	1	1	100	-	5	100	-	-	-	-	0.1
Liu *et. al.*, (2012); Tuan *et. al.*, (2013)	Taiwan EPA Regulatory (mg/L)	-	1	5	15	-	5	-	-	-	-	-	-

CONCLUSIONS

The artificial LWA manufactured from SS and SSA is reviewed through 58 literatures in this paper. Few conclusions as listed below are extracted from the review:

1. The raw SS is relatively high in moisture and organic content up to 720% and 70%, respectively. The raw SS has specific gravity of 1.0 – 1.08 and density of 1020 – 1080 kg/m^3.
2. The raw SS and SSA possess almost similar content of silica, alumina and flux content. In leaching aspect, both the SS and SSA possess high amount of cadmium (Cd), chromium (Cr), copper (Cu), Nickel (Ni), lead (Pb) and zinc (Zn).
3. The major management option for ASEAN countries is through open dumping, while in the Europe and North America, it is through land application.
4. The two most important factors in manufacturing method of artificial LWA are agglomeration and hardening stage. Researchers have manufactured LWA from SS and SSA through agglomerations by pressure and agitation method. Sintering is the only hardening process used in manufacturing LWA from SS and SSA.
5. The portion of SS used to make LWA lies within 20 – 82%, and sintered at temperature 970 – 1210°C, with duration between 10 – 35min. As for LWA made from SSA, the SSA portion can reached fully 100% and sintered at temperature 700 - 1085°C, with duration of 10 – 2400min.
6. LWA made from SS and SSA is in spherical and cylindrical shape, with smooth texture. LWA formed by crushing after sintering is irregular in shape, with rough texture.
7. The LWA made from SS and SSA has bulk density of 575 – 1540 kg/m^3 and 480 – 730 kg/m^3, respectively. The specific gravity of both LWA produced from SS and SSA is generally lower than 2, except for one source that has reported specific gravity of LWA made from SSA of 2.77 – 2.82.
8. Water absorption of LWA made from SS and SSA depends on the pores formed during manufacturing process. Isolated pores with vitrified surface absorb less water as compared to open pores. Researchers have reported water absorption of LWA made from SS and SSA as 1.20 – 20.50% and 2.49 – 19.16%, respectively.
9. The LWA made from SS has excellent frost resistance, with chemical soundness of 1.11 – 1.34%, which was much lower than regulatory value of 18%.
10. The LWA manufactured from SS and SSA has individual crushing strength of 2.53 – 40.00 and 0.75 – 14.19MPa, respectively. LWA made from SS possessed crushing value of 35.5%, abrasion loss of 18.5% and impact value of 32.1%. Whereas, LWA produced from SSA possessed 10% fines value of 12.5 – 17.6kN.
11. LWA produced from SS and SSA contains 100% SS has microstructure which is porous and loose, with low compressive strength. It needs to be amended with other materials to form stronger pellets.
12. LWA made from SS and SSA has the heavy metals immobilized through sintering process. The maximum immobilization efficiency of 100% for As, Cd, Cr, Cu, Pb, Co and Ti is achieved through sintering.

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GUIDE TO AUTHORS

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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.

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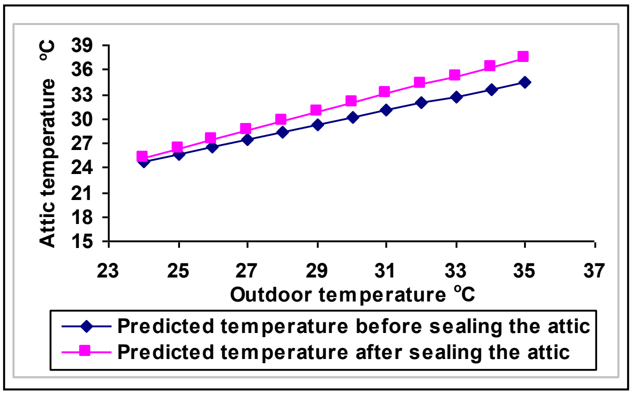

Figure 8. Computed attic temperature with sealed and ventilated attic

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Table 1. Recommended/Acceptable Physical water quality criteria

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

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

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

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