# The Sheffield Hallam University Built Environment Research Transactions

2013 Volume 4 Special International Edition ISSN 1759-3190



**Purpose of the Series**

The aim of this publication is to provide an opportunity for students to publish the findings of their undergraduate or postgraduate work. Guidance on publication will be given by staff who will act as second authors. It is hoped that by providing a guided transition into the production of papers that students will be encouraged throughout their future careers to publish further papers. Guest papers are welcomed in any field relating to the Built Environment. Please contact E.A.Laycock@shu.ac.uk. A template will be provided on request.

**Acknowledgements**

The editorial team would like to acknowledge and thank Will Hughes, Reader in Construction Management and Economics, University of Reading for permission to use the ARCOM template and the associated resources.



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Provided courtesy of Ms Thean Kim Sim. Senior Manager (Corporate Communications)

# Editorial

As Editor of this publication it has been a great pleasure to work with staff and students from Tunku Abdul Rahman University College (TAR UC, formerly Tunku Abdul Rahman College), Malaysia. in the production of this second themed Special International Edition. The forward to this edition is again made by Dr Chua Ping Yong.

I would like to extend my thanks as always to the staff of Sheffield Hallam University Built Environment Division who work as part of the editorial team to provide helpful comments and feedback and also to Dr. Sia Mal Kong of TAR UC who played a pivotal role in supporting the students in their ambitions to publish papers in this edition.

Dr Elizabeth Laycock

Editor, Built Environment Research Transactions

# Forward

It is with great pleasure that I write the forward to this special international edition of the Built Environment Transactions which is the second edition created jointly by Sheffield Hallam University, UK and Tunku Abdul Rahman University College (TAR UC, formerly Tunku Abdul Rahman College), Malaysia. I must acknowledge the efforts put in by Prof Paul Watson and his team and Dr Sia Mal Kong (Senior Lecturer at TAR UC) and his team. We in the Faculty of Engineering and Built Environment are extremely grateful for the work they put in and the result of which is a document that we are all proud to see our corporate logo on. As we at TAR UC embark on a new chapter as a University, conducting Bachelor programmes and Post Graduate programmes in the near future, the procedures in preparing the materials in this Research Transaction is one of the good practices that we will, and must, carry on with in this new endeavour.

The majority if not all of the papers presented in this journal are derived from work created in fulfilment of the final year project dissertation by final year students in TAR UC. Together with the Built Environment faculty staff the students' dissertation were condensed into the quality journal papers published in this Transaction. This goes a long way to show the value of the supervised work done by the students as I believe the Research work documented is valuable information for both the built environment industry players as well as researchers. As we at TAR UC endeavour to produce graduates who are knowledgeable, skilled, distinctive, adaptable and creative the work here proves that we have to a certain extent achieved this. May the work continue to flourish as the documents produce herewith are an excellent example of the Industry-Academia partnership, where the work produced can provide avenues to improved procedures in the built environment industry and provide exposure to both faculty staff and students on practices in the industry and how these relate to theory. At times this is an eye opener as theory does not always work smoothly in practice.

Once again thank you to all who have put much effort and work into this Transaction.

Dr Chua Ping Yong
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# CONTENTS

# APPLICATIONS OF INFORMATION TECHNOLOGY IN MALAYSIAN QUANTITY SURVEYING FIRMS

**Yoong-Siu Ching and Mal-Kong Sia [1]**

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This paper presents the findings of a recent study on Information Technology (IT) among registered Quantity Surveying (QS) firms in Malaysia. The study was conducted through self-administered survey questionnaires. The results generated from this study provide rich information on the current state of IT applications used by Malaysian QS firms, and the perceived benefits and barriers experienced by the users in the industry. The findings show that IT is widely used in Malaysian QS firms to support various individual tasks of the QS services at a basic level, rather than streamlining the delivery of QS services as a whole through automation. IT plays a very important role in QS firms as it occupies a significant portion of their daily operational tasks and an overwhelming majority of the respondents are satisfied with the performance of IT applications to deliver the benefits to the users.

Keywords: Applications, barriers, benefits, IT, Quantity Surveying.

## INTRODUCTION

The construction industry is one of the most important industries contributing to Malaysian economic growth. Within the construction industry, the Quantity Surveyor plays a major role in the success determinants of projects, namely cost, time and quality (Ibironke *et al*., 2011). Professional expertise in project financial management is the fundamental basis for success of Quantity Surveying (QS) firms. This can only

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be achieved by proper education, on-the-job training and experience over a wide range of projects (Smith, 2001).

Information Technology (IT) plays an increasingly important role nowadays in construction industry especially in QS firms. In many countries, most of the QS firms have witnessed a paradigm shift from traditional paper-based method of service delivery to electronic information exchange using IT (Ibironke *et al*., 2011). Information Technology can be defined as "any technology that helps to produce, manipulate, store, communicate, and/or disseminate information" (Sawyer and Williams, 2005). It includes hardware, software and devices such as copying machines, faxes, mobile phones and others. According to Bennett (2001), IT can make a better project, better use of resources and better profit. IT could be useful for managers in QS firms to assist in better decision making and enhancing communication (cited in Jaafar *et al*. 2007).

In tandem with this paradigm shift, therefore, Malaysian Quantity Surveyors should change in their work patterns in order to improve their efficiency and develop new markets to maintain competitive advantage and enhance profitability using IT applications. Unlike banking, finance and other market segments, however, the construction industry has struggled to take advantage of IT in a significant way (Mark, 2007). The level of investment in IT has been modest, slow and fragmented, and the uptake of IT in Malaysian QS firms especially has lagged behind that of other industries (Mark, 2007; Stewart *et al*., 2004).

Previous research on IT applications in QS firms include those by Shen, Li, Shen, Drew and Chung (2003), and Shen and Chung (2007) where the studies were carried out in Hong Kong. Smith has also done extensive research about IT applications in Australian QS practices from 2001 to 2010. Ibironke *et al*. (2011) conducted a study on IT applications in Nigeria. In Malaysia, there is a clear lack of studies on IT applications in the QS profession, as only a handful of papers have been written.

Even though IT is getting increasingly important in the QS profession recently, there are still issues relating to IT applications which remain unanswered. According to Betts *et al*. (1999), the fundamental issues relating to IT applications in QS firms which have not been fully addressed include questions on:

(a) what type and size of business have used IT,
(b) what types of IT have been used and what are their functions,
(c) what hardware and software are used,
(d) how successfully IT has been implemented,
(e) what are the main benefits and difficulties encountered, and
(f) what are the future prospects for IT in the construction and real estate industry (cited in Shen et al., 2003).

To address the issues mentioned above, there is thus a need to conduct a research on IT applications in Malaysian QS firms. The research objectives of this paper are thus:

- To investigate the application areas of IT in Malaysian QS firms,
- To determine the benefits of using IT in Malaysian QS firms, and
- To identify the problems encountered in IT implementation in Malaysian QS firms.

## LITERATURE REVIEW

Quantity Surveyors are important members of the design and construction teams in both private and public sectors of a nation (Musa *et al*., 2010). The services provided by the Quantity Surveyor today may be described as the financial management for the project and cost consultancy services to the clients, designers and contractors during the construction process to ensure the resources are utilised to the best advantages of the society (Wills *et al*., 1994; Musa *et al*., 2010).

Traditionally, Quantity Surveyors were employed as preparers of Bills of Quantities (BQ) for tendering purposes. Then their role was quickly extended to include the preparation of valuations for interim certificates and the agreement of the final account with the contractor on the basis of the tender documentation (Wills *et al*., 1994; Ashworth and Hogg, 2007). During the 1960s the Quantity Surveyor's role was enlarged to include design cost planning, which many believed provided the solution to reliance on bills of quantities, while offering the client some form of value for money and cost effectiveness (Wills *et al*., 1994). In more recent times, there is a marked rise in the diversification of services into non-traditional areas such as feasibility studies, life cost analyses, programming, taxation advice, arbitration/mediation, expert witness/appraisal, insurance valuations, risk management, quality management, value management, project/construction management and facility management (Smith, 2004).

The services provided by Quantity Surveyors now cover all aspects of project cost management and procurement. They must be careful and accurate in making calculations, have a systematic and orderly mind and be able to visualise the drawings and details. Dealing with contracts requires a certain amount of legal knowledge, particularly the law of contract (Wills and Trench, 1998).

Many clients are now concerned with the implication of time and the interaction of time and cost (Wills *et al*. 1994). Time, cost and quality are all interchangeable but all three are juxtaposed. Nevertheless, construction clients still want it faster, better and cheaper (Simpson, 2010).

Powell (1998) suggested those who are committed to lifelong learning should ensure that their knowledge and skills are up to date and relevant in order to meet the needs of clients and employers (cited in Ashworth and Hogg, 2007). In this regards, the application of information and communication technologies and the provision of

added value services have become increasingly more important in QS firms (Ashworth and Hogg, 2007).

**Tasks Performed Using IT Applications**

This section reviews the extent of application of IT by QS firms to operate or complete the tasks which can be divided into QS specific tasks, general purpose tasks and information exchange tasks. A total of 25 tasks are summarized in Table 1 from the review of 11 papers.

From Table 1, BQ preparation/production is the most common task found in QS firms. In fact, Shen and Chung (2007) reported that around 60-80% of the QS firms carried out BQ preparation tasks by using IT. Smith (2004) mentioned that the application of software for BQ preparation has increased from 1995 to 2003. In 1995, there were already around 70-80% of the Australian QS firms preparing their BQ by using IT; and in 2003 the response rate was up to around 90%.

The statements in Table 1 indicate that the use of IT by QS firms for preparation of BQ has grown steadily. This is probably due to the benefits from additional facilities that manual systems cannot provide (Brook, 2008). Ashworth and Hogg (2007) commented that this type of documentation relies on the production of working drawings before tender stage and is time consuming to prepare. It is therefore not a practical approach where time is of the essence. However, implementation of IT for BQ preparation can overcome this kind of problem. For example, quantities or rates can quickly be changed with a computer system. It can also produce a summary by using sort codes representing elements or sub-contract packages (Brook, 2008).

Table 1 shows that cost estimating is also a common task using IT. Cost estimating is the process of analysing a specific scope of work and predicting the cost of performing the work. The accuracy of the estimate is a function of how well the specific scope of work is defined and the time available to the QS (Holm *et al*., 2005).

Quantity Surveyors must assemble a large amount of information in an organized manner and perform numerous calculations to prepare a cost estimate. IT can be one of the effective tools for decreasing preparation time and increasing the accuracy of cost estimating. Quantity Surveyors can use computers to organize, store, and retrieve information and to perform many of the calculations necessary to prepare an estimate. It has the ability to store vast amounts of information and to retrieve the information almost instantaneously (Peurifoy and Oberlender, 2002).

| Item | Task | Smith (2001) | Shen *et al.* (2003) | Yusuf and Darmawan (2003) | Smith (2004) | Sun and Howard (2004) | Smith (2006) | Ashworth and Hogg (2007) | Shen and Chung (2007) | Smith (2009) | Smith (2010) | Ibironke *et al.* (2011) | **Frequency** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BQ production/ preparation | x | x | x | x | x | x | | x | | | x | 8 |
| 2 | Cost estimation | x | x | x | x | x | x | | x | | | | 7 |
| 3 | Measurement | x | x | | x | | x | x | | x | x | | 7 |
| 4 | External data exchange | x | x | | x | | | | x | x | x | | 6 |
| 5 | Internal data exchange | x | x | | x | | | | x | x | x | | 6 |
| 6 | Tendering/Tender Evaluation | | x | | | x | x | | x | | | x | 5 |
| 7 | Accounting | x | x | x | x | | | | x | | | | 5 |
| 8 | Final account | | x | | | | | x | x | | | x | 4 |
| 9 | Contract administration | x | x | | x | | x | | | | | | 4 |
| 10 | Project management | x | x | | x | | | x | | | | | 4 |
| 11 | Cost modelling/planning | x | | | | | x | x | | | | x | 4 |
| 12 | Valuation of variation | | x | | | | | | x | | | x | 3 |
| 13 | External communication | | x | | | | | | x | | x | | 3 |
| 14 | Internal communication | | x | | | | | | x | | x | | 3 |
| 15 | Feasibility studies | x | | | x | | | | | | | x | 3 |
| 16 | Cost control/ monitoring | x | | | | x | | | | | | x | 3 |
| 17 | Claims for loss and expenses | | x | | | | | | x | | | | 2 |
| 18 | Drawing management/registration | | x | | | | | | x | | | | 2 |
| 19 | Administration | | x | | | | | | x | | | | 2 |
| 20 | Human resources management | | x | | | | | | x | | | | 2 |
| 21 | Marketing | | x | | | | | | x | | | | 2 |
| 22 | Training | | x | | | | | | x | | | | 2 |
| 23 | Cash flows forecasting | x | | | x | | | | | | | | 2 |
| 24 | Interim payment | | | | | | | | x | | | | 1 |
| 25 | Financial report | | x | | | | | | | | | | 1 |

*Table 1: Tasks Performed using IT Applications*

## Types of IT Applications

From the review of 11 papers on IT in QS practices, the types of IT applications commonly used in QS practices are summarised in Table 2. These IT applications include QS software, emails, word processing, spreadsheets, database, presentation software, internet, LAN, websites and others.

### *Database*

Quantity Surveyors are the most active data users in the construction process. They have their ‘own’ database, which is a subset of a larger construction and commerce

database (Wills et al., 1994). The database is a computerized filing system. It allows the QS to file information and retrieve it in many ways (Brook, 2008).

The range of applications of the database is large in QS firms ranging from elementary filing tasks to the complex manipulation of data. Some of the examples are address lists for contractors, drawing registration, tender registration, cost planning data, Bill of Quantities production and pricing etc. (Brook, 2008). With the database, Quantity Surveyors can find information more easily, more efficiently and more consistently.

### *E-Procurement*

E-procurement is the use of electronic tools and system to increase efficiency and reduce costs during each stage of the procurement process (Cartlidge, 2006). E-tendering provides electronic procurement for the whole tendering process, from advertising the opportunity to the award of contract. This includes the exchange of documents and communications in electronic format (Brook, 2008). It can provide a transparent and paperless process allowing offers to be compared more easily according to specific criteria (Cartlidge, 2006). Currently, the Malaysian government is increasing efforts to bring all the government procurement process online under E-procurement (Elias et al., 2003).

According to Elias et al. (2003), the actual manually-based tender activities in Malaysia take about 73 days. However, under the E- tendering system the participants take only about 30 days to complete the tender life cycle. This shows that E-tendering system has reduced the tender life cycle by about 43 days, and the document flow speed has increased by about 58.8%.

### *Electronic communication tools*

Table 2 shows that the internet, LAN and email are the common electronic communication tools used by the QS profession. According to Thomas (1999), Email is primarily used for the distribution of documentation (including drawings) and the sending of simple or informal messages. It provides an opportunity of communicating quickly and effectively with an individual or group of individuals almost anywhere in the world. It is also possible to ‘attach’ information which can speed up the interchange of relevant documentation and thus improve the quality of service (Ashworth and Hogg, 2007). Many organisations nowadays have also developed their own web pages to market their services and provide general information to clients. In QS firms, the installation of Local Area Network (LAN) enables their staff to work together on group projects and share the use of resources such as printer software packages and file server (Sun and Howard, 2004; Yusuf and Darmawan, 2003).

| Item | IT Application | Thomas (1999) | Smith (2001) | Yusuf and Darmawan (2003) | Shen *et al.* (2003) | Smith (2004) | Sun and Howard (2004) | Smith (2006) | Sommerville and Craig (2006) | Ashworth and Hogg (2007) | Smith (2009) | Smith (2010) | **Frequency** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Software | x | x | x | x | x | x | x | | x | x | x | 10 |
| 2 | Email for external communication | x | x | | x | x | x | x | x | x | | | 8 |
| 3 | Email for internal communication | | x | | x | x | x | x | x | x | | | 7 |
| 4 | Spreadsheets | | x | x | x | x | x | | x | x | | | 7 |
| 5 | Project database | | x | x | x | x | x | | x | x | | | 7 |
| 6 | Internet | | x | x | x | x | x | x | | x | | | 7 |
| 7 | Word processing | | x | x | x | x | | | x | x | | | 6 |
| 8 | Presentation software | | x | x | x | x | x | | x | | | | 6 |
| 9 | Cost database | | x | x | x | x | x | | x | | | | 6 |
| 10 | Videoconferencing | | x | | x | x | | | x | | x | x | 6 |
| 11 | Website | x | x | | | x | x | x | | | | | 5 |
| 12 | LAN | x | x | x | x | | x | | | | | | 5 |
| 13 | Electronic data interchange | | x | | x | x | | | | | x | | 4 |
| 14 | Teleconferencing | | x | | | x | | | | | x | x | 4 |
| 15 | Electronic publishing | | | | x | x | | | | x | | | 3 |
| 16 | Telecommuting | | | | | x | | | | | x | x | 3 |
| 17 | E procurement | | x | | | | x | | | x | | | 3 |
| 18 | Intranet | | x | | x | | x | | | | | | 3 |
| 19 | WAN | x | | x | | | x | | | | | | 3 |

*Table 2: Types of IT Applications*

## Software Packages

QS Software is the most frequently mentioned among the IT applications. Details of the software packages used by major QS profession are summarized in Table 3 and shows MS Excel and MS Word are popular. MS Excel is the most widely used software package for almost all tasks, such as cost estimation, BQ measurement, drawing registration etc. On the other hand, MS Word is frequently used in tasks such as BQ formatting, drawing registration, financial reports, final account and etc. (Shen et al., 2003).

Among the specialized QS software packages, Digitizers and AutoCAD are the most frequently mentioned in the QS profession as measurement tools. A Digitizer is an electronically sensitive drawing board which allows quantity surveyors to scale the dimension directly from drawings into the system (Wills et al., 1994). It is an ideal tool used for measurement.

| Item | Software/Software Content | Thomas (1999) | Smith (2001) | Shen *et al.* (2003) | Yusuf and Darmawan (2003) | Smith (2004) | Sun and Howard (2004) | Smith (2006) | Shen and Chung (2007) | Ashworth and Hogg (2007) | Smith (2009) | Smith (2010) | **Frequency** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | AutoCAD | x | x | | | x | x | x | | x | x | x | 8 |
| 2 | Digitizers | | x | | | x | x | x | | x | x | x | 7 |
| 3 | MS Excel | x | | x | x | | x | | x | | | | 5 |
| 4 | MS Word | x | | x | x | | x | | x | | | | 5 |
| 5 | Ripac | | | x | x | | x | x | x | | | | 5 |
| 6 | Buildsoft | x | | x | x | | | x | x | | | | 5 |
| 7 | Everest | | | x | x | | x | x | x | | | | 5 |
| 8 | MS Project | x | | | x | | x | | x | | | | 4 |
| 9 | Atles | | | x | x | | | | x | | | | 3 |
| 10 | Masterbill (MB3+) | x | | | x | | x | | | | | | 3 |
| 11 | Building Information Modelling (BIM) | | | | | | | | | | x | x | 2 |
| 12 | Lotus | x | | | | | | | | | | | 1 |
| 13 | CATO | | | | x | | | | | | | | 1 |
| 14 | QSM | | | | x | | | | | | | | 1 |
| 15 | Cost X | | | | | | | x | | | | | 1 |
| 16 | Eclipse | | | | | | | x | | | | | 1 |

*Table 3: Software Packages*

The use of Digitizers for measurement has traditionally been very low in the profession. In 1999, up to 79% of the firms never used Digitizers and only 5% used them daily (Smith, 2001; 2004). Smith (2009), however, noted that due to the advances in CAD automatic-quantities generation capability, Digitizers are now viewed by many as being old fashioned and some firms have replaced Digitizers with CAD-based technology.

Buildsoft, Masterbill and Ripac are quite commonly used by QS practices for cost estimation tasks. These programs allow quantity surveyors to produce cost estimates quickly by linking BQ with unit cost information from standard and user-defined cost resource databases (Sun and Howard, 2004).

Building Information Modelling (BIM) is a software content available in the construction industry which is been mentioned only in Smith (2009) and Smith (2010), where 90% of firms stated that they had not used BIM in their projects. In Malaysia the uptake of BIM is still at its infancy stage. A BIM pilot project was implemented by the Public Works Department of Malaysia in 2010 on the National

Cancer Institute project in Putrajaya. Other projects initiated by private agencies include IDEA House by Sime Darby Properties, Multi-Purpose Hall by Universiti Tun Hussein Onn Malaysia, Educity Sports Complex and Hotel Ancasa (Lembaga Pembangunan Industri Pembinaan Malaysia, 2011).

**Advantages of Using IT**

The introduction of IT in the construction industry has raised the benefits for QS firms. An overwhelming majority of the respondents in Hong Kong generally agreed that IT could help them in the provision of QS services (Shen *et al*., 2003; Shen and Chung, 2007).

The survey by Shen *et al*. (2003) showed that 80% of the respondents from Hong Kong strongly agreed or agreed that IT could improve the quality of QS services, 87% of the QS firms in Hong Kong strongly agreed or agreed that the adoption of IT can shorten the time of providing the QS services, and 93% of respondents strongly agreed or agreed that the implementation of IT could reduce the cost of providing QS services.

Shen and Chung (2007) carried out another similar survey in 2007. The results showed that 83% of the respondents from Hong Kong strongly agreed or agreed that IT could improve the quality of QS services, 78% of the QS firms strongly agreed or agreed that the adoption of IT can shorten the time of providing the QS services, and 61% of respondents strongly agreed or agreed that the implementation of IT could reduce the cost of providing QS services.

Yusuf and Darmawan (2003), and Ibironke *et al*. (2011) also mentioned that IT applications not only can save time and cost in business and also improve the quality of production. They can also give professionals competitive advantage by providing better customer satisfaction or expanded services in relation to feasibility, time and cost planning using expert systems (Smith, 2001; Yusuf and Darmawan, 2003; Ibironke *et al*., 2011). Smith (2001) and Ibironke *et al*. (2011) also found that the adoption of IT can enhance the productivity of the QS profession, such as streamlined data entry and data management, automated quantities and cost calculations, the use of Digitisers for measurement etc.

From review of literature mentioned above, the advantages of using IT for QS profession include:

- Improve the quality of QS services,
- Shorten the time of providing QS services,
- Reduce the cost of providing QS services,
- Gives professionals competitive advantage, and
- Enhance the productivity of the QS profession.

**Problems of IT Implementation**

This section reviews the problems encountered in the implementation of IT in the QS profession. Shen *et al*. (2003) mentioned high installation cost of software, training problems and lack of suitable QS software as the most significant difficulties inhibiting the use of IT in the QS profession in Hong Kong. Shen *et al*. (2003) also indicated that lack of experience in IT applications, lack of computer standards for the QS profession, security problems, high installation cost of hardware and lack of technical support for the QS profession were problems encountered by the QS profession in Hong Kong in using IT to operate and complete their works. However, the respondents disagreed that lack of support from senior management, high running costs and risk of unemployment were problems faced in IT adoption.

Shen and Chung (2007), on the other hand, listed the top three most significant problems encountered by the QS profession in Hong Kong as high initial software cost, high initial hardware cost, and lack of suitable software. Other problems mentioned include high running costs, lack of technical support for the QS profession, lack of support from senior management, lack of experience in IT and security problems. However, the respondents were neutral on training problems, and they disagreed that risk of unemployment was a problem.

Ibironke *et al*. (2011) noted that the major constraints of IT use in the Nigerian QS practices are the rate of virus attack leading to loss of data, high initial cost of acquisition, fear of technology making the profession redundant and irregular power supply. The rate at which software becomes outdated and requires updating is ranked last as a barrier to the adoption of IT.

From review of the literature mentioned above, the obstacles faced in the implementation of IT in QS practices include:

- High initial and installation cost of software,
- High initial and installation cost of hardware,
- Training problems,
- Lack of suitable software for the QS profession,
- Lack of experience in IT applications,
- Lack of a computer standard for the QS profession,
- Security problems,
- Lack of technical support from senior management,
- High running cost,
- Lack of technical support for the QS profession,
- Risk of unemployment,
- Rate of virus attack leading to loss of data, and
- Turnover of IT staff.

## RESEARCH METHODOLOGY

Self-administered questionnaires were used in this study for data collection. The questionnaire was designed based mainly on Shen *et al*. (2003), Shen and Chung (2007), and Yusuf and Darmawan (2003). There are four main sections in the questionnaire, as described below:

a) Section A: Information on respondent and company
   There are four questions in Section A which was designed to obtain general information about the respondents and their companies. One question requests the designation of respondents. Another question asks for the total number of full time employees in the company. The next two questions request that each respondent indicate the total number of years his/her company was in business and the total number of years of experience the respondent has used IT.
b) Section B: Perceived benefits of using IT in QS firms
   There are two questions in Section B which was designed to identify the advantages or benefits of using IT in the QS profession. The questions request that respondents indicate the extent of their satisfaction with the benefits of using IT and their overall satisfaction with the performance of IT applications in their companies.
c) Section C: IT usage
   There are two questions in Section C which was designed to investigate the daily utilisation of IT in the respondents' companies. The questions request that respondents indicate the IT applications used in their companies and the extent of IT used in operational tasks.
d) Section D: IT implementation
   There are four questions in Section D which was tailored to investigate IT implementation in Malaysian QS companies. The questions request information on software packages used in QS tasks in the respondents' companies, the extent of their agreement with the criteria listed in selecting software packages and the obstacles that hinder IT implementation in their companies. The last question requests that respondents indicate the primary areas of IT investment for in next five years.

The targeted population for this research was Registered QS firms. In Malaysia, there are two national professional bodies for Quantity Surveyors, namely Royal Institution of Surveyors Malaysia (RISM) and Board of Quantity Surveyors Malaysia (BQSM). At the time of survey, there were 145 QS firms registered with RISM, and 336 QS firms registered under BQSM. However, there was overlapping due to the fact that companies could be registered under both professional bodies. After thorough comparison, it was confirmed that all the QS companies registered with RISM were also registered under BQSM. Therefore, the population for this survey was the QS firms registered under BQSM. Based on the list of registered QS firms obtained from BQSM webpage, a total of 200 out of the 336 registered QS firms were selected as the sample, representing about 59.5% of the registered QS firms in Malaysia. The survey instrument package consisting of a cover letter, a questionnaire and a stamped self-

addressed envelope was mailed to all the selected registered QS firms. The proper survey started on 29th August 2012. A period of one month was given to the respondents to answer the questionnaires and return back by using the self-addressed envelope provided. The dateline for the respondents to return completed questionnaires was on 29th September 2012. A total of 41 completed questionnaires were received, giving a response rate of 20.5% (41 out of 200). There were some missing data as a few respondents did not complete certain items in the questionnaire.

## RESULTS

The demographic details of the respondents are shown in Table 4. Of the 41 respondents, 15 respondents (36.6%) are from the senior management and 22 respondents (53.7%) are quantity surveyors. The other 4 respondents (9.8%) did not indicate their designations. The high percentage of respondents from the senior management indicates that they regard IT as very important in their companies.

| Designation in company | Frequency | Percentage |
|---|---|---|
| Proprietor | 1 | 2.4 |
| Principal | 6 | 14.6 |
| Partner | 2 | 4.9 |
| Managing Director | 1 | 2.4 |
| Director | 5 | 12.2 |
| Senior Quantity Surveyor | 9 | 22.0 |
| Quantity Surveyor | 10 | 24.4 |
| Assistant Quantity Surveyor | 3 | 7.3 |
| Others | 4 | 9.8 |

*Table 4: Demographic details of respondents*

The total number of fulltime employees working in the respondents' companies is shown in Table 5. There are 33 companies (80.5%) which employ less than 25 employees. There are 7 companies (17.1%) which have more than 25 but less than 75 employees. There was 1 company with more than 100 employees. The results show that most of the Quantity Surveying firms in Malaysia participating in the survey are small with less than 25 employees in their companies.

| Number of full-time employees | Frequency | Percentage | Cumulative Percentage |
|---|---|---|---|
| 1 - 24 | 33 | 80.5 | 80.5 |
| 25 - 49 | 5 | 12.2 | 92.7 |
| 50 - 74 | 2 | 4.9 | 97.6 |
| 75 - 100 | 0 | 0.0 | 97.6 |
| > 100 | 1 | 2.4 | 100.0 |

*Table 5: Total number of full-time employees in respondent's company*

Table 6 shows the total number of years that the respondents' companies have been in business / operation. 9 companies (22.0%) have only been in business for less than 10 years. 5 companies (12.2%) have been operating for more than 10 years but less than 15 years. However, there are 27 companies (65.9%) which have been in business for more than 15 years. The results show that the majority of companies (27 out of 41 or 65.9%) are very experienced in quantity surveying consultancy works.

| Number of years in business | Frequency | Percentage | Cumulative Percentage |
|---|---|---|---|
| < 5 | 5 | 12.2 | 12.2 |
| ≥ 5 and < 10 | 4 | 9.8 | 22.0 |
| ≥ 10 and < 15 | 5 | 12.2 | 34.1 |
| ≥ 15 and < 20 | 9 | 22.0 | 56.1 |
| ≥ 20 | 18 | 43.9 | 100.0 |

*Table 6: Total number of years in business / operation*

Table 7 shows the total number of years that the respondents' companies have been using information technology (IT). 4 companies (9.8%) have only used IT for less than 4 years in their daily operations. 2 companies (4.8%) have used IT for more than 4 years but less than 8 years. However, there are 35 companies (85.4%) which have used IT for more than 8 years. In fact, the results show that more than half of the respondents (27 companies or 65.9%) have used IT for more than ten years. This implies that IT has been applied in the Malaysian QS profession since 2002 or earlier.

| | Frequency | Percentage | Cumulative Percentage |
|---|---|---|---|
| < 2 | 2 | 4.9 | 4.9 |
| ≥ 2 and < 4 | 2 | 4.9 | 9.8 |
| ≥ 4 and < 6 | 1 | 2.4 | 12.2 |
| ≥ 6 and < 8 | 1 | 2.4 | 14.6 |
| ≥ 8 and < 10 | 8 | 19.5 | 34.1 |
| ≥ 10 | 27 | 65.9 | 100.0 |

*Table 7: Total number of years in using IT*

| Perceived benefits of using IT | Frequency | | | | | Total | Mean | Rank |
|---|---|---|---|---|---|---|---|---|
| | 1 ED | 2 D | 3 N | 4 S | 5 ES | | | |
| IT can shorten the time of providing QS services | 0 | 0 | 2 | 26 | 13 | 41 | 4.27 | 1 |
| IT can improve the quality of QS services | 0 | 0 | 4 | 29 | 7 | 40* | 3.98 | 2 |
| IT can improve communication and its quality | 0 | 0 | 6 | 25 | 9 | 40* | 3.98 | 2 |
| IT can provide better customer satisfaction | 0 | 0 | 10 | 27 | 3 | 40* | 3.73 | 3 |
| IT can reduce the cost of providing QS services | 0 | 1 | 15 | 21 | 3 | 40* | 3.57 | 4 |
| IT can reduce the number of staff (cost saving in staff) | 0 | 2 | 13 | 23 | 2 | 40* | 3.54 | 5 |
| Overall satisfaction with performance of IT applications | 0 | 0 | 5 | 33 | 2 | 40* | NA | NA |

Note: * There was one item of missing data.
ED = Extremely Dissatisfied, D = Dissatisfied, N = Neutral,
S = Satisfied, ES = Extremely Satisfied. NA = Not applicable.

*Table 8: Respondent's satisfaction with the benefits of using IT*

The results on perceived satisfaction of respondents on the benefits of using IT in their companies are shown in Table 8, ranked according to mean values of the 5-point Likert scale used. 39 respondents felt "satisfied and extremely satisfied" that using IT can reduce the time of providing QS services, with a mean value of 4.27. 36 respondents felt "satisfied and extremely satisfied" that IT can improve the quality of QS services. 34 respondents felt "satisfied and extremely satisfied" that IT can improve communication and its quality. Both these benefits are ranked second with a mean of 3.98. On whether IT can provide better customer satisfaction, 30 respondents felt "satisfied and extremely satisfied", with a mean value of 3.73. On whether IT can reduce the cost of providing QS services, 24 of the 40 respondents were "satisfied and

extremely satisfied", with 15 respondents being neutral and one respondent dissatisfied. Lastly, on whether IT can reduce the number of staff (or cost saving in staff), 25 respondents were "satisfied and extremely satisfied", 2 respondents dissatisfied, and the other 13 respondents did not comment on this benefit. The findings clearly demonstrate that most of the respondents were either satisfied or extremely satisfied on the benefits of using IT in the QS profession, with some being neutral in their perceptions on these benefits. There were only a low percentage of respondents who were dissatisfied with some of the benefits listed. When the respondents were asked of their overall satisfaction with the performance of IT applications, 87.5% of the respondents were either satisfied or extremely satisfied, with the remaining 12.5% being neutral in their opinion.

The results on 15 different types of IT applications commonly used in Malaysian QS companies are shown in Table 9, ranked according to descending percentage values. The top nine commonly used IT applications are spreadsheets, word processor, email for external communication, email for internal communication, intranet/LAN, internet/groupware, cost databases, presentation software, and cost estimation software.

| IT applications used in QS company | | Frequency | % | Rank |
|---|---|---|---|---|
| 1. | Spreadsheets | 38 | 92.7 | 1 |
| 2. | Word processor | 35 | 85.4 | 2 |
| 3. | Email for external communication | 32 | 78.0 | 3 |
| 4. | Email for internal communication | 29 | 70.7 | 4 |
| 5. | Intranet/ LAN | 29 | 70.7 | 4 |
| 6. | Internet/ Groupware | 28 | 68.3 | 5 |
| 7. | Cost databases | 27 | 65.9 | 6 |
| 8. | Presentation software | 25 | 61.0 | 7 |
| 9. | Cost estimation software | 21 | 51.2 | 8 |
| 10. | Document management system | 20 | 48.8 | 9 |
| 11. | Project database | 19 | 46.3 | 10 |
| 12. | Electronic data interchange | 14 | 34.1 | 11 |
| 13. | Electronic publishing | 10 | 24.4 | 12 |
| 14. | Videoconferencing | 9 | 22.0 | 13 |
| 15. | Project planning software | 8 | 19.5 | 14 |

*Table 9: Common IT applications used in QS Companies (n = 41)*

To determine the extent to which IT was used for operational tasks as specified in Table 10, the respondents were asked to select the options of 'not available', less than 20%, between 20%-40%, between 40%-60%, between 60%-80%, and more than 80%. Based on the percentage utilisation of more than 40%, the top nine operational tasks using IT are interim payment, final account, cost estimation, valuation of variation, administration, external communication, BQ production, accounting, and tendering.

| Operational tasks in QS company | Frequency | | | | | | Total frequency (from 60% to 100% | Rank |
|---|---|---|---|---|---|---|---|---|
| | Not applicable | Less than 20% | 20-40% | 40-60% | 60-80% | More than 80% | | |
| Interim payment | 2 | 3 | 0 | 0 | 9 | 27 | 36 | 1 |
| Final account | 2 | 3 | 0 | 0 | 10 | 26 | 36 | 1 |
| Cost estimation | 2 | 2 | 1 | 2 | 9 | 25 | 36 | 1 |
| Valuation of variation | 2 | 2 | 1 | 3 | 9 | 24 | 36 | 1 |
| Administration | 4 | 0 | 1 | 4 | 11 | 21 | 36 | 1 |
| External communication | 4 | 0 | 2 | 7 | 5 | 23 | 35 | 2 |
| BQ production | 2 | 0 | 5 | 1 | 7 | 26 | 34 | 3 |
| Accounting | 7 | 0 | 1 | 3 | 11 | 19 | 33 | 4 |
| Tendering | 2 | 2 | 5 | 4 | 8 | 20 | 32 | 5 |
| Internal data exchange | 10 | 0 | 2 | 2 | 7 | 20 | 29 | 6 |
| Contract Administration | 3 | 1 | 9 | 4 | 6 | 18 | 28 | 7 |
| Human resources management | 7 | 3 | 4 | 10 | 5 | 12 | 27 | 8 |
| Internal communication | 8 | 1 | 6 | 4 | 5 | 17 | 26 | 9 |
| Claims for loss and expense | 8 | 0 | 7 | 7 | 5 | 14 | 26 | 9 |
| Project Management | 13 | 0 | 3 | 6 | 8 | 11 | 25 | 10 |
| Drawing management | 12 | 5 | 1 | 7 | 6 | 10 | 23 | 11 |
| External data exchange | 15 | 0 | 0 | 2 | 6 | 18 | 22 | 12 |
| Training | 21 | 0 | 1 | 4 | 5 | 10 | 19 | 13 |
| Marketing | 23 | 2 | 1 | 2 | 5 | 8 | 15 | 14 |

*Table 10: Operational tasks in QS Company (n = 41)*

Table 11 shows the results on the software packages used for major QS tasks in the respondents' companies. MS Excel or software developed from Excel is the most widely used software package for the QS tasks listed. This is followed by MS Word, which is frequently used in tasks such as tender evaluations, financial reports, interim payments and contract administration. Among the specialized software packages, Buildsoft is the most frequently used package for cost estimation, BQ measurement and BQ formatting. The results show that MS Project, Masterbill, CATO and Ripac are seldom used in Malaysian QS companies. There is no company using software packages such as BIM, Atles and Everest. Other software packages used by Malaysian QS companies include AutoCAD, Binalink, Cost X and NISA in their routine tasks.

| QS Tasks | Excel or In-house software developed using Excel | Microsoft Word | Microsoft Project | Build-soft | Master-bill | CATO | Ripac | Others |
|---|---|---|---|---|---|---|---|---|
| 1. Cost estimation | 34 | 8 | 1 | 6 | 1 | 1 | - | 4 |
| 2. BQ measurement | 30 | 2 | 1 | 5 | 1 | 1 | 1 | 7 |
| 3. BQ formatting | 28 | 8 | 1 | 5 | 1 | 1 | - | 4 |
| 4. Drawing registration | 26 | 7 | 1 | 1 | - | - | - | 2 |
| 5. Tender evaluation | 35 | 17 | 2 | 1 | - | - | - | 2 |
| 6. Financial report | 36 | 13 | 1 | 0 | - | - | - | 1 |
| 7. Interim payment | 36 | 13 | 1 | 0 | - | - | - | 2 |
| 8. Final account | 36 | 12 | 1 | 2 | - | - | - | 1 |
| 9. Valuation of variation | 36 | 7 | 1 | 2 | - | - | - | 1 |
| 10. Claims for loss/expense | 30 | 8 | 1 | 0 | - | - | - | 1 |
| 11. Contract Administration | 28 | 17 | 2 | 0 | - | - | - | 2 |

*Table 11: Software packages used in QS tasks*

The results on criteria used in selecting software packages in their companies are shown in Table 12, ranked according to mean values of the 5-point Likert scale used. The top three criteria used by Malaysian QS companies in selecting software packages are user-friendliness, compatibility and flexibility. In addition, initial cost, running cost, training, past experiences and security are also important criteria. However, other factors such as advice from other users, clients or consultants, and company policy only play minimal roles in software selection. On the other hand, most of the QS companies disagree that government policy is a criteria in selecting software packages.

The results on obstacles that hinder IT implementation in Malaysian QS companies are summarised in Table 13, ranked according to mean values of the 5-point Likert scale used. The top three most significant hindrances encountered by QS firms are high initial software cost, high initial hardware cost and training problems. These are followed by security problems, high running cost and lack of technical support from senior management. Other problems tend to have less impact on the implementation of IT in the QS companies. However, the respondents opined that lack of suitable software and risk of unemployment are not obstacles to the implementation of IT in the Malaysian QS companies.

Table 14 briefly summarises the primary areas of IT investment for the respondents' companies for the next five years. From the results shown, 39 respondents (95.1%) would choose to invest in IT for QS services, 63.4% (23 respondents) and 26 respondents (63.4%) would invest in IT for communication and data exchange, and IT for office administration respectively.

| Criteria for selection | | Frequency | | | | | Total | Mean | Rank |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 SD | 2 D | 3 N | 4 A | 5 SA | | | |
| 1. | User friendliness | 0 | 0 | 5 | 18 | 18 | 41 | 4.32 | 1 |
| 2. | Flexibility | 0 | 0 | 5 | 23 | 13 | 41 | 4.20 | 2 |
| 3. | Compatibility | 0 | 0 | 6 | 25 | 10 | 41 | 4.10 | 3 |
| 4. | Running cost | 0 | 2 | 15 | 18 | 6 | 41 | 3.69 | 4 |
| 5. | Initial cost | 0 | 6 | 10 | 19 | 6 | 41 | 3.61 | 5 |
| 6. | Training | 0 | 0 | 11 | 25 | 3 | 39* | 3.61 | 5 |
| 7. | Past experiences | 1 | 0 | 15 | 24 | 1 | 41 | 3.59 | 6 |
| 8. | Security | 0 | 0 | 13 | 23 | 3 | 39* | 3.56 | 7 |
| 9. | Advice from other users | 0 | 2 | 17 | 20 | 0 | 39* | 3.29 | 8 |
| 10. | Company policy | 0 | 3 | 14 | 18 | 3 | 38* | 3.29 | 8 |
| 11. | Advice from consultants | 0 | 2 | 17 | 19 | 0 | 38* | 3.20 | 9 |
| 12. | Advice from clients | 0 | 3 | 18 | 17 | 0 | 38* | 3.12 | 10 |
| 13. | Government policy | 2 | 7 | 18 | 10 | 0 | 37* | 2.68 | 10 |

Note: * There were some missing data.
SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree,
SA = Strongly Agree.

*Table 12: Criteria in selecting software packages*

| Obstacles hindering IT implementation | | Frequency | | | | | Total | Mean | Rank |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 SD | 2 D | 3 N | 4 A | 5 SA | | | |
| 1. | High initial software cost | 0 | 0 | 2 | 23 | 14 | 39* | 4.31 | 1 |
| 2. | High initial hardware cost | 0 | 1 | 3 | 23 | 11 | 38* | 4.16 | 2 |
| 3. | Training problems | 1 | 5 | 12 | 16 | 5 | 39* | 3.49 | 3 |
| 4. | Security problems | 1 | 7 | 10 | 14 | 6 | 38* | 3.45 | 4 |
| 5. | High running cost | 1 | 9 | 4 | 21 | 3 | 38* | 3.42 | 5 |
| 6. | Lack of technical support from senior management | 2 | 5 | 11 | 14 | 5 | 37* | 3.41 | 6 |
| 7. | Lack of technical support for QS profession | 1 | 7 | 15 | 14 | 1 | 38* | 3.18 | 7 |
| 8. | Lack of computer standards for the QS profession | 1 | 9 | 13 | 12 | 2 | 37* | 3.14 | 8 |
| 9. | Lack of experience in IT applications | 1 | 8 | 16 | 12 | 1 | 38* | 3.11 | 9 |
| 10. | Turnover of IT staff | 1 | 10 | 15 | 11 | 1 | 38* | 3.03 | 10 |
| 11. | Lack of suitable software for the QS profession | 1 | 14 | 13 | 8 | 2 | 38* | 2.89 | 11 |
| 12. | Risk of unemployment | 3 | 14 | 13 | 6 | 2 | 38* | 2.74 | 12 |

Note: * There were some missing data
SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree,
SA = Strongly Agree.

*Table 13: Obstacles hindering IT implementation in QS Company*

| Area of IT investment | | Frequency | % | Total | Rank |
|---|---|---|---|---|---|
| 1. | IT in QS services | 39 | 95.1 | 41 | 1 |
| 2. | IT in communication and data exchange | 26 | 63.4 | 41 | 2 |
| 3. | IT in office administration | 23 | 56.1 | 41 | 3 |
| 4. | None | 1 | 2.4 | 41 | 4 |

*Table 14: Primary areas of IT investment in the next five years*

# CONCLUSION

This study reveals that the senior management in Malaysian QS firms regards IT as very important in their profession, as they constitute a high percentage of the respondents in the survey. It is found that IT is widely used in Malaysian QS firms, with 85.4% of the respondents having used IT in their practices for more than 8 years. In fact, 65.9% of the respondents have implemented IT in their companies earlier than 2002. 87.5% of the respondents are satisfied with the overall performance of IT applications, as they believe IT can shorten the time of providing QS services, improve the quality of QS services, improve communication and its quality and provide better customer satisfaction.

IT is intended for better and more proficient information management and exchange. The IT applications commonly used in Malaysian QS firms are spreadsheets, word processor, emails for external communication and internal communication, intranet/ LAN, internet/groupware, cost databases, presentation software, and cost estimation software. The top nine operational tasks using IT are interim payment, final account, cost estimation, valuation of variation, administration, external communication, BQ production, accounting, and tendering. The Malaysian Government is moving towards e-tendering, and the finding seems to suggest that the Malaysian QS firms engage in the National E-tendering Imperative (NeTI) in the effort to integrate every process of the entire construction tendering supply chain.

The IT applications are mainly used to support various individual tasks of the QS services at a basic level, rather than to streamline the production of QS services as a whole through automation. A very good example is the extensive use of MS Excel or in-house software developed using MS Excel for QS tasks shown in Table 11. Advanced QS software packages are not widely used as revealed from the survey. Only a few of the respondents are using Buildsoft. Buildsoft is used mainly for measurement such as cost estimation, BQ measurement and BQ formatting. The majority of the QS firms rely on MS Excel and MS Word to perform the tasks from the pre-contract stage to completion of the project. For tasks such as tender evaluation, financial report, and final account they prefer to use MS Excel. This could be because MS Excel is readily available and accessible to everyone to generate the format of documents that the clients required. Simultaneously it reduces the time for double handling because conversion of the file is needed if Buildsoft is used.

The top three criteria used by Malaysian QS companies in selecting software packages are user-friendliness, compatibility and flexibility. Other important criteria

include running cost, initial cost, training, past experiences and security. As a result, when the respondents were asked to indicate the barriers to IT implementation in Malaysian QS firms, the top five hindrances mentioned are high initial software, high initial hardware cost, training problems, security problems, and high running cost. In spite of these barriers, however, 95.1% of the respondents would choose to invest in IT for QS services in the next five years, and the majority of them would invest in IT for communication and data exchange, as well as for office administration.

To promote the use of IT among the QS profession, it is hoped the Malaysian professional boards, namely RISM and BQSM, should take the initiative to promote IT-based applications such as BIM among the QS profession within the construction industry. In such an intense competitive environment nowadays, Malaysian QS firms should adopt IT to improve and promote their services, such as electronic publishing and electronic data interchange instead of the traditional approach for marketing purposes. It can also encourage paperless environments as data can be obtained in a short time without meetings or appointments, and the QS professionals can handle their services very efficiently with the advances in IT developments and innovations.

A longitudinal survey should be carried out among all the QS firms registered with BQSM to assess the uptake of BIM in the Malaysian QS profession using an improved questionnaire with AUTOCAD as one of software packages and a higher response rate. The findings of this study are significant and will serve as a benchmark study of the best QS practices in Malaysia.

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# PERCEPTIONS OF MALAYSIAN CONTRACTORS ON BENEFITS OF CONSTRUCTION WASTE MANAGEMENT

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Construction waste management is defined as a tool for controlling disposal costs of construction wastes, as well as facilitating examination of other alternative disposal methods such as recycling and reusing in order to reduce wastes that are finally discharged to landfills. Extra construction materials are usually planned due to the lack of consideration given to waste reduction during planning and design stages. A large amount of construction wastes are produced by the construction sector due to high demands in implementing major infrastructure projects and housing developments in Malaysia. Therefore, there is a need to carry out research on construction waste management to provide a clearer understanding of it. It is crucial to investigate the factors causing construction waste generation and the major benefits of waste management. This research also seeks to identify how different project characteristics affect the perception of the benefits of construction waste management as well as the difficulties faced when implementing a waste management plan.

Keywords: waste management, construction, contractors, Malaysia

## INTRODUCTION

Urbanisation has generally increased the standards of living of Malaysians but it has also caused an increase in construction wastes generated (Chua *et al*. 2011). Construction works are carried out to meet market demands and the end-users due to

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increasing population and urbanisation. As a result of new constructions, renovation and demolition of buildings and structures, construction wastes are produced rampantly and the amount is increasing.

Construction wastes are mixture of materials resulting from construction works. Waste management encompasses collection, transporting, storage, treatment and disposal of waste. It is defined as a comprehensive, integrated, and rational system approach towards achievement and maintenance of acceptable environment quality and support of sustainable development (Bilitewski *et al*. 1994). The construction industry consumes large amounts of natural resources, which are actually not properly utilised owing to the amount of wastes generated. In Malaysia, construction waste is one of the single largest waste streams. Despite a number of government policy initiatives to address the issue, sustainable resources and waste management on construction sites remain a low priority for the majority of the contractors (Minks 1994). With the demands in implementing major infrastructure projects in Malaysia, together with many commercial building and housing development projects, a large amount of construction wastes is being produced by the construction sector. As construction wastes have a major impact on environment, therefore waste minimization is an area of concern in the implementation of waste management in the Malaysian construction industry (Begum *et al*. 2007).

With decreasing landfill spaces and increasing environmental concerns and regulations, public works officials are sifting through the waste streams for new ways to manage waste disposal. The generation of construction and demolition wastes in Malaysia is a critical issue and there is a need to minimize them in order to alleviate environmental burden.

The objectives of this paper are thus:

- to identify the benefits of implementing waste management plan in the Malaysian construction industry,
- to investigate the factors leading to generation of wastes on construction sites,
- to determine the difficulties faced by the Malaysian contractors in implementing waste management plan, and
- to investigate how different project characteristics affect the benefits from waste management plan.

## LITERATURE REVIEW

The Malaysian construction industry contributes significantly to the quality of life of Malaysians. The sector accounts for about 3-5% of the Gross Domestic Product and provides employment for around 700,000 people, which is about 10% of the total labour force (Chamhuri and Siti 2002). The industry has continued to grow, benefiting the country's economy and provides the main infrastructure towards the country's development. Under the 9th Malaysia Plan (from 2006 to 2010), the Malaysian

government gave a much needed boost to the construction industry, where a total of 880 projects worth RM 15 billion were tendered out (Yusoff 2010). The breakdowns of these 880 projects included a total of 450 primary and secondary schools, roads, bridges, water supply projects in Terengganu and the Integrated Transportation Terminal in Gombak (The Star 2006). The Malaysian construction industry has thus generated employment opportunities, with money injected into the nation's economy by creating foreign and local investment opportunities.

Despite these contributions, however, the industry has also been linked to adverse environmental impacts as this industry is responsible for one of the single largest waste streams in the country (Effie *et al*. 2011). The growth in construction activities generated construction wastes which are rapidly becoming environmental problems with serious consequences. Most of the construction and demolition wastes in Malaysia are not recycled but ended up in land filling activities (Yusoff 2010). As a developing country which aspires to achieve a developed country status by 2020, Malaysia is faced with the challenges posed by construction wastes (National Economic Advisory Council 2010). Hence, implementation of a construction waste programme could be one of the effective solutions for the industry as well as the whole country, which ultimately will lead to a reduction in costs incurred during construction process.

**Waste Management**

The Malaysian construction industry generated a lot of construction wastes which may cause significant damage to the environment. The amount of wastes generated from construction projects can be as high as 15% of all the materials used in the whole project (Muluken 2008). Consequently, the urgency for minimization of construction wastes has been elevated, and waste minimization and sustainable waste management have become current national issues. According to Muluken (2008), the most important step in the waste management process is reducing the amount of wastes generated, followed by reusing, recycling, composting, burning and as a last resort, land filling.

Construction waste management will improve the performance of the industry in terms of quality and sustainability. The waste management process consists of materials reduction in the design and planning stages. Reducing scrap and waste at the construction sites, as well as re-using and recycling of materials (which the contractors cannot re-use themselves) are important processes in reducing construction wastes.

**The Origin of Construction Waste**

The construction industry uses a large amount of resources. If the life cycle of each of these materials used on site is examined closely, a relatively large portion of the materials is wasted because of poor material control. Construction wastes are generated in many ways at various stages of the construction process, created both directly and indirectly and by the various parties involved at each stage. Waste characterisation and quantities differ from each of these processes as a function of the

type, size, method, materials and location of the project. The quantities and types of waste materials generated at typical job sites will strongly influence the exploration and development of waste management alternatives apart from disposal (Muluken 2008).

Urio and Brent (2006) classified the factors leading to generation of construction wastes into six main categories, namely, design, procurement, material handling, operation, residual-related and other. Construction wastes weaken the efficiency, effectiveness, value and profitability of the construction activities. Yahya and Boussabaine (2006) stated that the main input towards the initiation of waste generated during construction activities were actually inappropriate preparation and handling, incorrect processing of the materials and misuse. This is evident in the use of pre-casting works and system formwork.

In addition, there is no mandatory requirement for construction companies to practice sustainable resource and waste management (Effie *et al*. 2011). Construction materials may be discarded because they do not meet specifications, are damaged or contaminated. Waste may also be generated simply due to excess of construction materials.

The root factors that lead to the generation of construction wastes should be identified in order to reduce the amount of construction and demolition wastes as well as to conserve them. These construction wastes will be greatly reduced if better management of materials is practised at the construction sites.

**Benefits of Implementing Waste Management**

The Malaysian Government recognizes that appropriate waste management is essential to achieve sustainable development (National Economic Advisory Council 2010). According to El-Haggar (2007), proper construction waste management will provide economic benefits by decreasing the cost of the project through proper implementation of a waste management plan. Hwang and Yeo (2011) found that cost saving and profit maximization are the main advantages of implementing waste management in the Singapore construction industry. An increased emphasis on waste reduction, reuse and recycling may produce favourable outcomes such as cost saving. Unnecessary purchase of new construction materials may result in additional costs. Less waste generated from construction projects will help in reducing disposal costs and landfill charges, eventually cutting down the total project costs. Hence, the cost saving can in turn maximize the profit.

Apart from economic benefits, waste management may positively contribute to various advantages as mentioned by Hwang and Yeo (2011). The demand for landfill spaces will be reduced during the implementation of waste management. The reduction in the amount of construction waste sent to landfills for disposal can lead to less demand for landfill and reduction of serious environmental impacts such as noise, pollution as well as emission and residues from incinerators. Better control of resources may be achieved with the reduction in waste as well as improvement of the entire resource management performance. Besides improvement in performance in

resource management, implementing waste management as a company's policy not only helps the company to enhance its public image as "environmentally-friendly" but also enhances its impression on clients. The productivity of the construction industry can be improved by avoiding delays caused by reordering and repurchasing of materials that have been wasted once. By selecting materials of good quality and durability, significant amount of waste generation caused by replacement of poor quality material during the life cycle of facilities can be avoided.

**Difficulties in Implementing Waste Management Plan**

Waste management has become more complicated as our society becomes more dependent on modern technology. Despite efforts by the Malaysian Ministry of Housing and Local Government, awareness regarding waste management in the local construction industry is still low (Effie *et al*. 2011). As the construction industry is labour-intensive, awareness in waste management grows with the attitudes and perceptions of its workers. Kulatunga *et al*. (2006) stated that workers' involvement during the pre-contract stage has a major influence on the prevention of construction waste. The attitude of the workforce is essential to the management as it determines their behaviour and provides an insight into their motivating values and beliefs. The workers' involvement during the post-contract stage will influence the minimisation of waste by ordering construction materials according to the correct quality and quantities. However, the attitudes and behaviours of workers are difficult to control, thus it is a challenge and also a major obstacle for the contractors to implement waste management at their respective sites (Kulatunga *et al*. 2006).

In addition, according to Addis (2009), there is a lack of awareness and appreciation of best practices for environmentally-sound management of waste. This may be the major constraint in the implementation of construction waste management. The low level of awareness towards construction waste management causes the generation of waste in large amount. Hence, proper knowledge of waste management should be instilled among the workers to practice site waste management during their works.

**Characteristics of Construction Projects**

As every construction project is unique in its way of development, the benefits from waste management may also differ from project to project. According to Hwang and Yeo (2011), project characteristics have major impacts on the benefits of construction waste management. The key characteristics are project size, project nature, project type, duration of project, and key materials used in the project. However, it is very hard to gauge and justify the extent with definite values. Furthermore, there is no definite characteristic that has the greatest impact on the benefits of implementing construction waste management.

Construction projects can be categorized based on total project cost. The categories of the project will be: from RM 5 million and below, between RM 5 million to RM 15 million, between RM 15 million to RM 50 million and lastly from RM 50 million and above.

In terms of project nature, construction projects can be grouped according to residential, commercial, infrastructure, and institutional. Residential projects include residential buildings intended to provide lodging to the occupants. On the other hand, commercial projects include office buildings and shopping malls for business purposes. Infrastructure projects include tunnels, railways and roads. Lastly, institutional projects include schools and religious buildings.

The type of construction waste is one of the project characteristics which affect the benefits of construction waste management (Hwang and Yeo 2011). A 2003 update showed an increase to 164,000 million tons annually, of which 9% is construction waste, 38% is renovation waste while the remainder 53% is demolition waste. Hence, different types of projects are expected to have different impacts on the benefits of a waste management plan. The duration of a construction project has a direct relationship with the amount of time in which a waste management plan can be implemented. Therefore, it is one of the characteristics of the construction projects.

The key materials used in construction projects will also affect the perception of the benefits of waste management, consider for example steel and concrete. Steel construction has excellent low waste credentials during building life cycle and generates very little waste. Therefore, there is little or virtually no waste from steel products on a construction site. Although concrete waste from construction, renovation and demolition can be recycled, it is difficult to separate aggregates for reuse in new structural concrete components. This shows that key materials used in various construction projects affect the perception on the benefits of the waste management plan implemented.

## RESEARCH METHODOLOGY

In this study, self-administered questionnaires were used for data collection. The reason for using a questionnaire survey was that the opinion of respondents could be acquired in a structured manner. According to Castelo Branco (2007), questionnaires are the most common method used to identify the practice of companies. Leedy and Ormrod (2010) opined that questionnaires allow the respondents to respond to the questions with assurance that their responses will be anonymous, and this will allow them to be more truthful. The questionnaires were designed based on literature such as Urio and Brent (2006) and Hwang and Yeo (2011), and consist of five main sections:

Section A: Information of Respondent

Question 1, Question 2 and Question 3 in this section respectively requested the respondent to indicate the company name, his designation in the company and his experience in the construction industry.

Section B: Construction Waste Management Plan

This section covers questions that could be used for producing descriptive statistics regarding “familiarity”, “implementation level” and “satisfaction level” of respondent with construction waste management plans implemented. Question

4 and Question 5 were designed to ascertain the degree of familiarity with construction waste management plan while Question 6 was designed to find out the types of waste management plans implemented by the various construction companies. Question 7 requested that the respondent indicate the extent of satisfaction with the benefits of waste management plans implemented, whereas Question 8 requested that the respondent indicate the overall satisfaction with the performance of waste management plans implemented.

Section C: Effects of Project Characteristics on Benefits of Waste Management Plan

Question 9 in this section requested the respondent to indicate the level of agreement on the effects of project characteristics on the benefits from a waste management plan. As the characteristics of construction projects can be categorised in several groups and these affect the perceptions on benefits of the waste management plan implemented, thus Question 9 was developed to ascertain the level of agreement on the effects of the project characteristics on benefits from waste management plans.

Section D: Causes of Construction Wastes

Question 10 in this section was designed to identify the causes of construction wastes at project sites.

Section E: Difficulties in Implementing Waste Management Plan

Question 11 in this section was designed to identify the level of agreement with the difficulties faced by respondents when implementing waste management plans.

A total of 200 sets of questionnaires were sent in two batches by post (first batch was on 15th October 2012, and the second batch was on 18th November 2012) to 200 construction companies selected by convenience sampling technique. The respondents were given two weeks to respond and send back the completed questionnaires in stamped self-addressed envelopes. Convenience sampling is a non-probability sampling technique where study subjects are selected because of their convenient accessibility and proximity to the researcher (Joan 2009). It cuts cost, reduces labour requirements and gathers vital information quickly (William *et al*. 2010). Because the study population (Malaysian contractors) is broad and due to time constraints, the questionnaires were only sent to construction companies in Peninsular Malaysia. Therefore construction companies from Sabah and Sarawak were excluded from this study. 75 sets were sent to the Northern Region, 30 sets sent to the East Coast Region, 55 sets sent to the Central Region and 40 sets sent to the Southern Region. Table 1 gives the distribution of questionnaires sent to each state in the various regions and the completed questionnaires received. The first author followed up by calling up the respondents in order to increase the response rate. A total of 42 completed questionnaires were received, giving a response rate of 21%. Table 1 shows that 29 of the 42 completed questionnaires came from Kuala Lumpur, Penang and Selangor.

| Region | State | Questionnaires Sent | Questionnaires Received |
|---|---|---|---|
| Northern | Kedah | 15 | 2 |
| | Perlis | 15 | 1 |
| | Penang | 35 | 10 |
| | Perak | 10 | 1 |
| East Coast | Kelantan | 10 | 1 |
| | Terengganu | 10 | 1 |
| | Pahang | 10 | 3 |
| Central | Selangor | 20 | 8 |
| | Kuala Lumpur | 35 | 11 |
| Southern | Negeri Sembilan | 15 | 1 |
| | Johor | 10 | 2 |
| | Melaka | 15 | 1 |
| | Total | 200 | 42 |

*Table 1: Distribution of Questionnaires Sent to Each Region*

# RESULTS

Table 2 shows the designations of the respondents in the survey. Out of the 42 respondents, Project Manager and Quantity Surveyor each accounts for 21.43%, 16.67% are Contractors, whereas Project/Site Engineer and Site Supervisor each accounts for 7.14%. Project Director and Clerks of Work each accounts for 4.76%. There was only one subcontractor among the respondents. The other designations included QA/QC Executive, Corporate Manager, Technical Head, General Manager and Contract Manager who accounts for 14.29% or 6 of the 42 respondents.

In Table 3, 12 respondents indicated that they have been involved in the construction industry between 10 to 14 years, whereas 11 respondents indicated they have less than 5 years of working experience. The third largest group of respondents have 5 to 9 years of working experience. There are 5 respondents who indicated that they have between 15 to 19 years of working experience, whereas another 5 respondents indicated that they have more than 20 years of working experience in construction industry.

| Designation | Frequency | Percentage |
|---|---|---|
| Project Director | 2 | 4.76% |
| Project Manager | 9 | 21.43% |
| Project/Site Engineer | 3 | 7.14% |
| Contractor | 7 | 16.67% |
| Quantity Surveyor | 9 | 21.43% |
| Subcontractor | 1 | 2.38% |
| Clerks of Work | 2 | 4.76% |
| Site Supervisor | 3 | 7.14% |
| Others | 6 | 14.29% |

*Table 2: Designations of Respondents*

| Number of Years of Working Experience | Frequency | Percentage |
|---|---|---|
| < 5 years | 11 | 26.19% |
| ≥ 5 years and < 10 years | 9 | 21.43% |
| ≥ 10 years and < 15 years | 12 | 28.57% |
| ≥ 15 years and < 20 years | 5 | 11.90% |
| ≥ 20 years | 5 | 11.90% |

*Table 3: Working Experience of Respondents in Construction Industry*

When the respondents were asked of their familiarity with construction waste management plans (CWMPs), 66.67% of the 42 respondents are "Familiar" to "Very familiar" with CWMPs, whereas one-thirds or 33.33% of the 42 respondents are "Less Familiar" and "Not Familiar" with CWMPs. The results are shown in Table 4.

| Familiarity with CWMP | Frequency | Percentage |
|---|---|---|
| Not Familiar | 7 | 16.67% |
| Less Familiar | 7 | 16.67% |
| Familiar | 23 | 54.76% |
| More Familiar | 4 | 9.52% |
| Very Familiar | 1 | 2.38% |

*Table 4: Familiarity with Construction Waste Management Plan*

When the respondents were asked to indicate the extent of construction waste management plans implemented on construction sites, 64.3% or 27 respondents indicated that their companies implemented CWMP, whereas 35.71% did not. The types of CWMPs implemented in these 27 companies are shown in Table 5, ranked according to mean values of the 5-point Likert scale used.

Note: I/R = Infrequently/Rarely, Oc/S = Occasionally/Sometimes, Of/F = Often/Frequently.

| Waste Management Plans | Frequency | | | | | Total | Mean | Rank |
|---|---|---|---|---|---|---|---|---|
| | 1 Never | 2 I/R | 3 Oc/S | 4 Of/F | 5 Always | | | |
| Reduce/Minimisation | 0 | 1 | 3 | 9 | 14 | 27 | 4.33 | 1 |
| Reuse | 0 | 1 | 8 | 9 | 9 | 27 | 3.96 | 2 |
| Sold as scrap | 0 | 2 | 7 | 10 | 8 | 27 | 3.89 | 3 |
| Recycle | 0 | 6 | 6 | 8 | 7 | 27 | 3.59 | 4 |
| Disposal in landfill | 6 | 8 | 8 | 5 | 0 | 27 | 2.44 | 5 |
| Disposal by composting | 8 | 8 | 4 | 7 | 0 | 27 | 2.37 | 6 |
| Disposal by burning | 11 | 7 | 6 | 1 | 2 | 27 | 2.11 | 7 |

*Table 5: Types of Waste Management Plans Implemented (n = 27)*

Based on mean values, reduction or minimisation is the main waste management plan implemented with 23 respondents mentioned that they "always and often" practise reduce or minimisation. Reusing of construction wastes also accounts for a significant share of the waste management plans implemented in the Malaysian construction industry as 18 of the 27 respondents indicated they often or always reuse construction wastes. Selling construction wastes as scrap is also popularly practised as 18 of the 27 respondents often or always sell construction wastes as scrap, which has the 3rd highest mean value. Recycling is also a popular option as there are 15 respondents who often or always recycle construction wastes at their construction sites. On the other hand, the other three types of waste management outcomes included in the

questionnaire, namely disposing construction wastes in landfill, disposal by composting and disposal by burning are rarely practised by the respondents.

| Perceived Benefits of WMP Implemented | Frequency | | | | | Total | Mean | Rank |
|---|---|---|---|---|---|---|---|---|
| | 1 ED | 2 D | 3 N | 4 S | 5 ES | | | |
| Reduced environmental impacts. | 0 | 0 | 0 | 12 | 15 | 27 | 4.56 | 1 |
| Cost savings. | 0 | 0 | 4 | 13 | 10 | 27 | 4.22 | 2 |
| Image improvement. | 0 | 1 | 3 | 15 | 8 | 27 | 4.11 | 3 |
| Improved resource management. | 0 | 1 | 5 | 13 | 8 | 27 | 4.04 | 4 |
| Improved sustainability of construction materials. | 0 | 0 | 6 | 15 | 6 | 27 | 4.00 | 5 |
| Profit maximisation. | 0 | 0 | 11 | 9 | 7 | 27 | 3.85 | 6 |
| Reduced demand for landfill spaces. | 0 | 1 | 9 | 11 | 6 | 27 | 3.81 | 7 |
| Productivity improvement. | 0 | 3 | 8 | 9 | 7 | 27 | 3.74 | 8 |
| Quality improvement. | 0 | 1 | 9 | 14 | 3 | 27 | 3.70 | 9 |

*Note: ED= Extremely Dissatisfied, D= Dissatisfied, N= Neutral, S= Satisfied, ES= Extremely Satisfied*
*Table 6: Respondents' Satisfaction with the Benefits of CWMPs (n = 27)*

The results on perceived satisfaction of respondents on the benefits of construction waste management plans implemented in the 27 companies are shown in Table 6, ranked according to mean values of the 5 point Likert scale used. The top five benefits indicated by respondents are reduction in environmental impacts, cost savings, improvement in image, improved resource management and improved sustainability of construction materials. Quality improvement also benefited from waste management plans as indicated by the respondents, even though it is at the bottom of the list. When the 27 respondents were asked to indicate their overall satisfaction with the performance of waste management plans implemented by their companies, 66.7% (18 respondents) indicated that they are satisfied, and only 7.4% (2 respondents) indicated their dissatisfaction. The other 7 respondents are neutral in their responses.

Proper implementation of construction waste management plans helps to reduce the environmental impacts as all the 27 respondents indicated they were "extremely satisfied and satisfied" with this benefit in their construction activities. A total of 23 respondents indicated they are "extremely satisfied and satisfied" with both the cost savings obtained and the improvement in the company's image, whereas a total of 21 respondents highlighted that they are "extremely satisfied and satisfied" with the benefits on improvement in resource management and improved sustainability of construction materials.

The results on the causes of construction wastes at project sites are shown in Table 7, ranked according to mean values of the 5-point Likert scale used. Based on mean values, the top four causes of construction wastes indicated by all the 42 respondents are poor site management, poor site supervision, lack of a waste management plan, and lack of onsite material control.

| Item | Causes of Construction Waste at Project Sites | Frequency | | | | | Total | Mean | Rank |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 SD | 2 D | 3 N | 4 A | 5 SA | | | |
| A | Poor site management. | 0 | 2 | 4 | 23 | 13 | 42 | 4.12 | 1 |
| B | Poor site supervision. | 0 | 1 | 6 | 22 | 13 | 42 | 4.12 | 1 |
| C | Lack of waste management plan. | 0 | 2 | 8 | 15 | 17 | 42 | 4.12 | 1 |
| D | Lack of onsite material control. | 0 | 2 | 6 | 21 | 13 | 42 | 4.07 | 2 |
| E | Poor coordination of all parties during design stage. | 0 | 1 | 8 | 24 | 9 | 42 | 3.98 | 3 |
| F | Design changes. | 0 | 2 | 9 | 20 | 11 | 42 | 3.95 | 4 |
| G | Lack of coordination of responsibilities between contractor and subcontractors. | 0 | 3 | 5 | 25 | 9 | 42 | 3.95 | 4 |
| H | Lack of influence of contractor. | 0 | 4 | 6 | 20 | 12 | 42 | 3.95 | 4 |
| I | Lack of attention to the standard size of specific products. | 0 | 2 | 10 | 19 | 11 | 42 | 3.93 | 5 |
| J | Use of incorrect material. | 1 | 3 | 6 | 21 | 11 | 42 | 3.90 | 6 |
| K | Wastes from uneconomical shape. | 0 | 2 | 9 | 22 | 9 | 42 | 3.90 | 6 |
| L | Materials storage and internal transport. | 0 | 4 | 7 | 21 | 10 | 42 | 3.88 | 7 |
| M | Waste from application process. | 0 | 2 | 11 | 20 | 9 | 42 | 3.86 | 8 |
| N | Errors by tradesman. | 0 | 2 | 13 | 17 | 10 | 42 | 3.83 | 9 |
| O | Lack of knowledge about construction during design activities. | 0 | 4 | 11 | 16 | 11 | 42 | 3.81 | 10 |
| P | Damage by subsequent trade. | 1 | 2 | 10 | 23 | 6 | 42 | 3.74 | 11 |
| Q | Over-mixing of materials. | 0 | 3 | 13 | 18 | 8 | 42 | 3.74 | 11 |
| R | Material delivery procedures. | 0 | 5 | 13 | 13 | 11 | 42 | 3.71 | 12 |
| S | Inappropriate storage on site. | 0 | 4 | 11 | 20 | 7 | 42 | 3.71 | 12 |
| T | Criminal waste due to theft. | 1 | 5 | 9 | 19 | 8 | 42 | 3.67 | 13 |
| U | Supplier error. | 1 | 5 | 12 | 14 | 10 | 42 | 3.64 | 14 |
| V | Off-cuts. | 0 | 4 | 15 | 15 | 8 | 42 | 3.64 | 14 |
| W | Error in contract documentation. | 1 | 4 | 13 | 16 | 8 | 42 | 3.62 | 15 |
| X | During transport on the site. | 0 | 6 | 12 | 20 | 4 | 42 | 3.52 | 16 |
| Y | Equipment problems. | 0 | 2 | 21 | 15 | 4 | 42 | 3.50 | 17 |
| Z | During transport to the site. | 1 | 6 | 13 | 16 | 6 | 42 | 3.48 | 18 |
| AA | Accidents. | 1 | 9 | 11 | 15 | 6 | 42 | 3.38 | 19 |
| AB | Inclement weather. | 0 | 5 | 19 | 16 | 2 | 42 | 3.36 | 20 |
| AC | Others: Over design by consultant | - | - | - | 1 | - | - | - | - |

Note: SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree

*Table 7: Causes of Construction Wastes at Project Sites (n = 42)*

The results on the difficulties faced in implementing waste management plan by Malaysian contractors are given in Table 8, ranked according to mean values of the 5-point Likert scale used. Based on mean values, the top three difficulties faced were low perception of workers of waste management, minimal allocation of financial assistance for waste management, low awareness of the contractors of waste management, and it is not an obligation for contractors to implement ISO 14001 in the Malaysian construction industry. At the bottom of the nine difficulties listed were the absence of regulatory requirements to reduce and manage construction wastes in the Malaysian construction industry, and the misconception of contractors that a waste management plan would result in extra cost being incurred.

| Difficulties Faced | Frequency | | | | | | Total | Mean | Rank |
|---|---|---|---|---|---|---|---|---|---|
| | - NA | 1 SD | 2 D | 3 N | 4 A | 5 SA | | | |
| Perception of workers on waste management is low. | 0 | 0 | 0 | 4 | 31 | 7 | 42 | 4.07 | 1 |
| The allocation of financial assistance for waste management is minimal. | 0 | 0 | 0 | 7 | 26 | 9 | 42 | 4.05 | 2 |
| Awareness of the contractors on waste management is low. | 0 | 0 | 1 | 5 | 29 | 7 | 42 | 4.00 | 3 |
| It is not an obligation to implement ISO 14001 in the Malaysian construction industry. | 0 | 0 | 2 | 6 | 24 | 10 | 42 | 4.00 | 3 |
| No incentives are given to contractors to carry out the waste management plan. | 2 | 0 | 2 | 6 | 25 | 7 | 42 | 3.93 | 4 |
| The allocation of technical assistance for waste management plan is minimal. | 0 | 0 | 1 | 9 | 24 | 8 | 42 | 3.93 | 4 |
| Lack of enforcement of local waste management legislation. | 0 | 0 | 5 | 7 | 22 | 8 | 42 | 3.79 | 5 |
| There are no regulatory requirements to reduce and manage waste in the Malaysian construction industry. | 0 | 0 | 7 | 9 | 19 | 7 | 42 | 3.62 | 6 |
| Waste management plan would result in extra cost being incurred. | 0 | 2 | 7 | 13 | 17 | 3 | 42 | 3.29 | 7 |

Note: NA = Not Applicable, SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree

*Table 8: Difficulties Faced in Implementing Waste Management Plans (n = 42)*

The results on the effects of project characteristics on benefits obtained by the 27 respondents on construction waste management plans are given in Table 9, ranked according to the mean values of the 5-point Likert used. The top project characteristics which has the greatest effect on benefits from CWMP is “key materials used in project”, with a mean value of 4.07, followed by “project type” and “project duration”.

| Project Characteristics | Frequency | | | | | Total | Mean | Rank |
|---|---|---|---|---|---|---|---|---|
| | 1 SD | 2 D | 3 N | 4 A | 5 SA | | | |
| Key materials used in project | 0 | 1 | 6 | 24 | 11 | 42 | 4.07 | 1 |
| Project type | 0 | 1 | 10 | 20 | 11 | 42 | 3.98 | 2 |
| Project duration | 0 | 1 | 10 | 23 | 8 | 42 | 3.90 | 3 |
| Project size | 0 | 3 | 9 | 27 | 3 | 42 | 3.71 | 4 |
| Project nature | 0 | 4 | 10 | 26 | 2 | 42 | 3.62 | 5 |

Note: SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree

*Table 9: Effects of Project Characteristics on Benefits from CWMP (n = 42)*

## CONCLUSION

On the benefits of implementing waste management in the Malaysian construction industry, 9 benefits were identified through literature review and the results shown in Table 6. Based on these, reducing environmental impacts was identified as the main benefit of an implemented waste management plan, followed by cost savings and

image improvement. This indicates that local contractors are more concerned with the environmental benefits. The other benefits of waste management identified in the study include improved resource management, improved sustainability of construction materials, profit maximisation, reduced demand for landfill space, improved productivity, and improved quality of the works. This indicates that there are usually multiple benefits from implementing a construction waste management plan.

However, the stakeholders in the Singapore construction industry chose cost savings as the most important benefit, followed by profit maximisation (Hwang and Yeo 2010). In other words, financial benefits were recognised as the principal waste management benefits, and these benefits contributed to almost 73% of the responses from the 66 respondents who participated in this study. Hence, stakeholders in the Singapore construction industry were more concerned about financial benefits rather than the environmental benefits, indicated by their Malaysian counterparts.

On the factors leading to the generation of construction wastes, 28 causes were identified from the literature review and results are shown in Table 7. From the 28 causes listed in Table 7, more than half of the 42 respondents either "agreed or strongly agreed" that all these 28 causes would lead to the generation of construction wastes on project sites, even though there are some respondents who indicated that they "Disagreed" and "Strongly disagreed". From the results, one can conclude that good site management and site supervision, onsite material control and a waste management plan are essential and effective in the management of wastes generated at the project sites. Accidents and inclement weather were ranked the bottom two causes of construction wastes on project sites. Even though it was not listed, one respondent expressed that overdesign by consultants would lead to generation of construction wastes. It seems that a good control on overdesign would benefit the project owner.

On the difficulties faced by the contractors in implementing a waste management plan, 9 difficulties were identified through literature review and the results shown in Table 8. Most of the respondents agreed that the perception of construction workers on waste management plans is low, hence it is difficult to implement waste management plan at the jobsites. It is followed by minimal allocation of financial assistance for waste management, no obligation for Malaysian contractors to implement ISO 14001, and the low awareness of Malaysian contractors on construction waste management. In addition, lack of enforcement of local waste management legislation and that no incentives are given to contractors to carry out the waste management plan have also been indicated by most of the respondents as the difficulties faced in implementing waste management plans on construction sites.

On the effects of project characteristics on the benefits from construction waste management implemented, 5 project characteristics were identified from the literature review and the results are given in Table 9. Most of the respondents agreed that the key materials used in the projects, project types, and project durations are the three main characteristics affecting the benefits from the waste management plan

implemented. However, there were some respondents who disagreed that project size and project nature are the characteristics that affect the benefits of waste management plans. Overall, the respondents' perception on the effects of project characteristics on benefits from a construction waste management plan is relatively high, with a mean value of more than 3.62. The efficiency of a waste management plan implemented by the Malaysian construction industry can be maximised when key materials such as steel is used in their construction works, owing to the fact that steel can be recycled repeatedly without any degradation in terms of quality, properties or performance.

Construction waste management plan (CWMP) provides a useful framework for sustainable resource management, offering environmental, social and financial benefits. The principal CWMPs implemented by the 27 respondent companies in this study are reduction or minimisation of wastes generated from construction activities, reusing of materials left over, selling the construction wastes as scrap, and recycling. Waste minimisation or reduction, quoted as fundamental for sustainable development and an increase in source efficiency (Mallak and Ishak 2012), was found to be the main method used in this study and should be recognised as a key area for action in managing construction wastes generated at project sites. The major benefits of implementing CWMPs include reduction in environmental impacts, cost saving, improved company image and resource management, improved sustainability of construction materials, profit maximization, reduced demand for landfill spaces, productivity and quality improvement.

As recommendations from this study, Malaysian contractors should implement waste management plans more frequently and vigorously in order to reduce the generation of construction wastes. At the same time, the Malaysian Government should organise more campaigns or workshops among the construction fraternity on the benefits of implementing construction waste management plans in order to increase the awareness of the various stakeholders. It is also important to enforce local waste management legislations to ensure the effectiveness of its implementation. Lastly, incentives should be given by the Malaysian Government to encourage more contractors to implement waste management plans in order to resolve the perennial problems created by construction wastes.

Due to the time constraints, it must be noted that this study was conducted only on 200 construction companies located in Peninsular Malaysia. For future research, characteristics of a project such as contractual arrangements, procurement methods, and clients' requirements that were not investigated in this paper should be considered. It is also recommended that other useful methods and tools to quantify actual benefits from waste management plan should be explored.

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# A STUDY ON CONSTRUCTION WASTE MANAGEMENT: STEPS TOWARDS SUSTAINABLE DEVELOPMENT IN MALAYSIA

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For centuries, despite all the profits gained, the construction industry remains one of the main causes to global warming, environmental pollution and degradation. Despite the government continuously applying efforts and initiatives to address this issue, construction waste still remains the largest single waste stream in Malaysia. The concept of construction waste management is reduce, reuse, recycle and recovery of waste materials. The aim of the research is to underline the importance of construction waste management in sustainable development. Factors such as the lack of implementation, weak enforcement and lack of consciousness of responsibility among the governing authorities contribute to the disconnection between policy and practice resulting in gaps in meeting targets. The interview method has been adopted to carry out this research. Several recommendations have been proposed by interviewees such as Government should take the lead to implement construction waste management within the construction industry. These include providing public and private incentives, and strict enforcement of guidelines to ensure successful implementation of the project in relation to construction waste management leading towards more sustainable development in Malaysia.

Keywords: Construction Waste, Management, Implementation, Enforcement, Incentives, Resource use, Sustainable Development, Malaysia

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# INTRODUCTION

For centuries, the construction industry has been one of the main contributors towards the nation's development. It provides necessary infrastructure and physical structures either for commerce, services or utilities. Despite all the profits gained, the construction industry remains as one of the main causes to global warming and environmental pollution. Unsustainable use of depleting natural resources for building materials and generation of construction waste are the negative impacts of the construction industry on the natural world. Globally, it is estimated that approximately 10 to 30 per cent of waste disposed in the landfill originates from the construction and demolition activities stated by Fishbein in year 1998(cited in Papargyropoulou et al. 2011). Despite government continuously put efforts and initiative to address this issue, construction waste still remains the largest single waste stream in Malaysia.

The aim of this research paper is to underline the importance of construction waste management in sustainable development. The objectives include: (1) Study Malaysian government's effort in addressing construction waste management specifically and sustainable development as a whole; (2) Find out the level of awareness of construction practitioners and commitment to sustainable construction waste management; and (3) Suggest further recommendations to improve awareness and applications of sustainable construction waste management.

# OVERVIEW

The concept of sustainable development arose since the 1970s. This topic continued to be discussed until the World Commission on Environment and Development was formed which is also known as Brundtland Commission Report, 1987. Since then, there has been increased awareness of environment and sustainability agendas (Abidin, 2009). Any sustainable development should address environmental issues in order to improve the quality of people's lives while not damaging the local and global environments to the detriment of all living fauna and flora.

At the same time, Malaysia is faced with the challenge of decoupling economic growth and waste generation stated by National Economic Advisory Council, 2010 (cited in Papargyropoulou et al., 2011). They also stated that construction waste has been highlighted by Malaysian for some time, due to poor management and handling practices which eventually affect the environment as well as the public. According to Giegrich and Vogt (2004), meet some kind of benefit for human needs is inevitably linked with the extraction and processing of resources, materials and substances. They also said that those products will eventually turn into forms of waste and probably could be reused as other intended purposes. The study by Papargyropoulou et al. (2011) states that the Malaysian government will be committed to sustainable waste management as an aspect of sustainable development in the Tenth Malaysia Plan.

### Principles of Waste Management

Waste is defined as any substance or material discarded or intended or required to be discarded (Waste Framework Directive 2008 cited by DEFRA, 2011; Environment

Agency, 2011). Waste management is the collection, transport, processing or disposal, managing and monitoring of waste substances.

According to Hand's study (2006), waste is assessed according to the waste hierarchy as shown in Figure 1 and 2 where reducing or avoiding waste generation are the most preferable options (Osmani et al.,2008; Peng et al. 1997). The Nagapan et al.(2012) study indicated that preventing construction waste generation at the source is the most crucial and a preferable method throughout the whole development process. In Singapore, a study was conducted by Ekanayake and Ofori 2000 (cited in Agyekum 2012, p. 139) on construction material waste source evaluation which divided construction waste into three main categories of material, labour and machinery waste. However, the current research focuses on material wastage only. Therefore, before any development can be commenced, the proper steps of prevention of waste have to be identified.

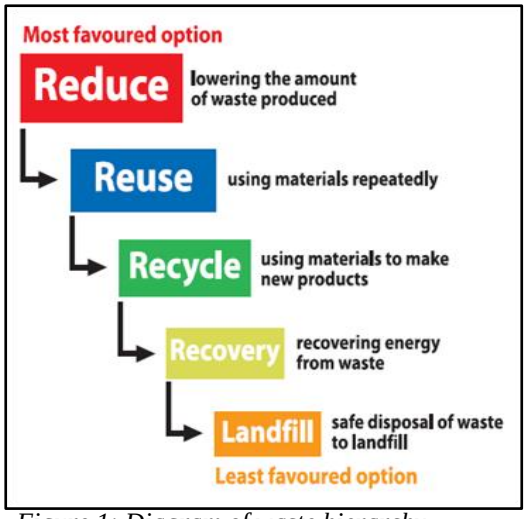


*Figure 1: Diagram of waste hierarchy*

*(Waste Aware, 2009 and Hand, 2006)*

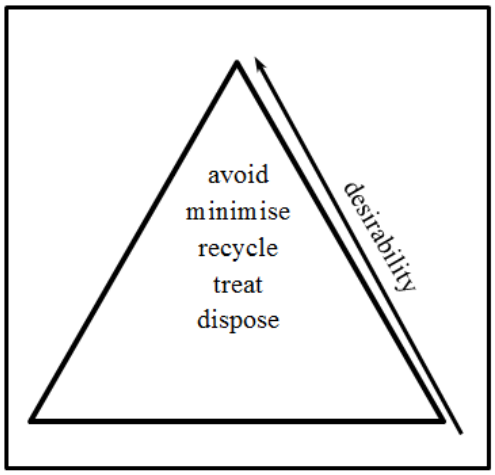


*Figure 2: Diagram of waste hierarchy*

*(Wolsink cited in Nagapan et al., 2012)*

*Reduce*

Mustaffa Kamal's research (2009) defined source reduction as consuming and throwing away less. In other words, waste prevention also known as source reduction which must be implemented throughout the project from tendering and commencing a development until completion of a project. From Weinrach's study in 2002, sources reduction involves the use of processes, practices to reduce or eliminate the generation and the toxicity of pollutants and waste. However, it is not limited to material substitution, process substitution or elimination. Waste reduction is actually the most preferable method which looks for ways waste can be prevented in the first place by identifying potential wastes early in the design stage. For example Just-in-time (JIT) for site production aims to improve work flow and avoid the waste associated with overproduction (Pheng & Hui cited by Wild, 2006).

*Reuse*

Reuse technique is defined as re-employment of materials which can be used in the same and or in other forms of application. After identifying how to prevent waste, identifying what waste can be salvaged for reuse on current or other projects (Mustaffa Kamal, 2009). Reuse does not involve reprocessing or transforming the particular item which is seemed to be even better than recycling (Da et al. 2008, p. 126). Generally, reusing building materials cut down the need to further process to come out with second hand usable product (Tchobanoglous et al. 2002). Re-use of system formwork is a common example in the local construction industry.

*Recycle*

According to the EU Waste Framework Directive cited by DEFRA (2011), only substances or materials that are classified as waste can be recycled. Hence, recycling is known as a waste-disposal method which consists of collecting and reusing construction wastes (Haluzan, 2010). A recent study of utilisation of recycled and waste material conducted by Bolden et al. (2013) indicated recycled concrete was the most popular recycled material at 54% as compared to purchasing natural stones or aggregate. This can save precious finite resources, which lowers the environmental impact and amount of energy consumed (Mustaffa Kamal, 2009; Tchobanoglous et al., 2002).

*Recovery*

Mustaffa Kamal's study (2009) defined a recovery technique as a process of generating energy from waste materials that cannot be reduced, reused or recycled. A variety of waste recovery techniques can be done such as through briquetting, incinerating, pyrolysis, gasification and biodigestion. In the study of Tchobanoglous et al. (2002, p. 18) the waste-to-energy technique was identified as the third option of waste management. According to Weinrach (2002), a study has been conducted on pollution prevention and waste minimisation which described that third option of waste management options is a waste treatment which usually occurs after source reduction and recycling opportunities have been exhausted. Generally, recovery is technique to transform the waste to go through a combustion process to generate useful energy either in the form of steam or electricity (Tchobanoglous et al.,2002, p. 1.8-1.10)

*Disposal*

Waste disposal involves burying the inefficiently used materials (DEFRA, 2011). To date, landfills have been the most common methods of organised waste disposal in construction site. To provide a safe disposal option for waste, the Landfill Directive and Landfill Tax have played an important role in controlling hazardous waste that may cause harm to human health or the environment.

**An Overview of Malaysia Policies to Sustainable Construction Waste Management**

Sustainable waste management aims to address pressures on the environment with growing waste generation and disposal rates. In 2005, the "National Strategic Plan for

Solid Waste Management" was adopted forming the basis and foundation of solid waste management policy for subsequent years and practice in peninsular Malaysia until 2020 described by United Nations Development Programme, 2008 (cited in Papargyropoulou et al., 2011. The Government has introduced several policies to address this pressing issue including the Solid Waste and Public Cleansing Management Act 2007 as shown in Table 1. These two new federal institutions have been approved by the Malaysian Parliament on 17 July 2007 which aims to provide executive power to the Federal Government to control solid waste management and public cleansing from local government (EA-SWMC, 2009).

| Authorities | Laws / Acts / Standard | Scope | Remarks |
|---|---|---|---|
| Ministry of Housing and Local Government | Solid Waste and Public Cleansing Management Act 2007 (Act 672) | This act is to provide and regulate the management of controlled solid waste and public cleansing for the purpose of maintaining proper sanitation. | The solid waste is defined inclusively in the construction solid waste |
| Ministry of Works | Standard Specifications for Buildings Works (2005 Edition) Clause 46.3 | This standard is only applied to contract works awarded using JKR procurement approach. | Clause 46.3 (clearance, cleaning and making good ) completion states it is the duties of the contractor to gather up and clear away all rubbish / garbage / construction waste as it accumulates during the progress of the Works at least twice each week at times approved by the Superintending Officer. |
| Ministry of Natural Resources and Environment | Environmental Quality Act 1974 (Act 127) -Part IV Section 24 (2b) | This act is to prevent, abatement, control pollution and to enhance environment within Malaysia | Part IV Section 24 (2b) (prohibition and control of pollution) states a person deem as pollute soil or land if disposal solid waste can be obnoxious and offensive to human beings; effects underground water; detrimental soil and surface of land. |
| Construction Industry Development Board | Pembinaan Malaysia Act 1994 (Act 520) - Part IX Section 35 (2) | This act is to provide functions relating to the construction works | Part IX Section 35(2) (enforcement and investigation) describes investigation officer have power to enter construction site at any times to inspect the construction works. |

*Table 1: Authorities involved in construction waste management*

(Act 672, Act 127, Act 520 and Standard Specifications for Buildings Works cited in Nagapan *et. al.*, 2012)

The Tenth Malaysia Plan (10th MP) was tabled in Parliament on 10 June 2010. This 10th MP has emphasised the Reduce, Reuse and Recycle (3R) programme to improve solid waste management incorporated with the private sector commitment. Under the National Waste Minimisation Master Plan 2006-2020, one of the objectives is to reduce the amount of solid waste disposed in Malaysia (EA-SWMC,2009). In order to replace the status of 95% landfills and 5% of recovery in year 2009, the national

target a minimum of 20% for waste recycling and 15% for treatment in year 2020 (see Figure 3). However, lack of marketing of the recycled material and awareness programs to introduce the availability and applicability of the recycled materials are limited (Bolden, 2013). Hence, minimising construction waste is one of the challenges in Malaysia.

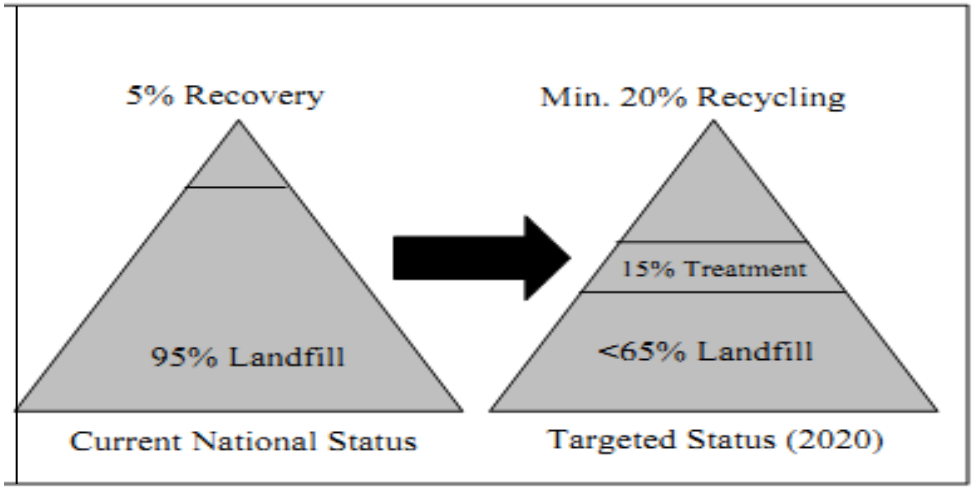


*Figure 3: Current and targeted challenge in Malaysia (EA-SWMC 2009)*

**Awareness of Construction Practitioners and Commitment to Sustainable Waste Management**

A study from Begun *et al.* in 2009 (cited by Papargyropoulou *et al.*, 2011) stated that waste reducing, reusing and recycling practices are limited in the construction sector without mandatory requirement for construction companies to practise sustainable construction waste management and illegal dumping is still an issue for the government.

In response to government, the Construction industry Development Board (CIDB) has been formed; one of its aims is to transform the industry's commitment towards more sustainable development and environmentally responsible industry with a series of training courses, workshops and awareness raising events have been organised and held for educating the key players in the industry, mainly contractors (Papargyropoulou et al., 2011).

Based on the past study done by Mahayuddin (2008, p. 485) shows that the legislation of proper construction waste management has not been as stringent as those for municipal solid wastes in the state of Ipoh, Malaysia. Unlike the other countries where various laws and regulations been provided to regulate the negative impacts caused by the construction industry. Unfortunately, only partial success has been attained for example Singapore has imposed a fine of up to S$50,000 on conviction of illegal

dumping and S$50,000 for repeat offenders and imprisonment for up to 12 months as described by Ekanayake et al. (2004, cited in Mahayuddin, 2008, p. 485).

Papargyropoulou et al. (2011) concluded that although number of policies and voluntary initiatives supporting the sustainable waste management has been reinforced in the Malaysian construction industry, the reality still remains challenging. Simultaneously, the growth of the industry provides an opportunity for wide used of sustainable waste practices, contributing to the country's aspirations for sustainable development.

For years, Site Waste Management Plans (SWMPs) have been used in most developed countries such as the US, UK and AS. It provides a framework helping the contractors or project managers to plan, monitor, forecast, and record various type of construction waste that is likely to be produced in a development project, as well as assist in setting up appropriate management actions that reduce the amount of waste rather than go for landfilling as described by WRAP (2007, cited in Papargyropoulou et al., 2011).

SWMPs have had wide uptake by construction players as an important tool to minimise the destructive impacts of the construction industry towards not only the environment but also the nations' economies (Papargyropoulou et al., 2011). To ensure the plans are working effectively requires cooperation between all construction practitioners involved which includes the client/employer, contractor, architect/ designer, engineer, sub-contractors, workers and even the suppliers for various stages of a development as shown in Table 3. In England 2008, SWMPs became a mandatory requirement which is compulsory for any project which exceeded £300,000 (WRAP 2009).

| Project Stage | SWMP Actions |
|---|---|
| Project Set Up | • Enter project details |
| Concept Design | • Record waste prevention actions |
| Detail Design | • Forecast waste<br>• Record waste reduction actions |
| Pre Construction | • Specify waste carriers<br>• Plan waste destinations<br>• Record waste management and recovery actions |
| Construction | • Enter actual waste arisings, reduction, recovery and management activities.<br>• Carry out training, monitoring and recording. |
| Post Construction | • Compare actual against forecast waste management activities<br>• Assess performance based on KPIs<br>• Suggest improvement for next project |

*Table 2: Proposed outline of SWMP (Adapted from WRAP Site Waste Management Plan Template version 2.3 cited in Papargyropoulou et al., 2011)*

## RESEARCH METHODOLOGY

The two research methods used in this research project are literature review and interview.

An extensive literature review is essential to study the Malaysian government's effort to address construction waste management specifically and sustainable development as a whole and to find out contractors' awareness and commitment to sustainable construction waste management. This information is collected from books, journal, article from internet etc.

Qualitative research method has been adopted to collect data.. A set of semi-structure interview question is further carried out through face to face, tele-interview from 6 non-probabilistic purposive targeted interviewees. The interviewees are from Kuala Lumpur and Selangor areas who possessed the knowledge on how to manage the waste on site. Site staff, contractor or contractor's representative, site agent, architect or consultant's representative were selected to sit for interview sessions. The questions included: (a) understanding concept of construction waste management, (b) awareness and commitment of construction practitioners to sustainable construction waste management; and (c) suggestions to improve construction waste management.

## DISCUSSION AND RESULT ANAYLSIS

Coding is used for analysing the data collected from interviewees in this research to ensure their confidentiality from respective company. Table 3 shows the interviewee background. Size of the firm is measured by number of employees. Where employees exceeded 50 this was classified as a large firm, Small and medium firms were classified based on the Malaysia Small and Medium Enterprise (SME) definitions as shown in Table 4.

| Coding | Designation | Years of experience | Head count | Size of firm |
|---|---|---|---|---|
| Interviewee A | Contractor | 6 | 100 | Large |
| Interviewee B | Architect | 26 | 30 | Medium |
| Interviewee C | Architect | 35 | 10 | Small |
| Interviewee D | Contractor | 25 | 7 | Small |
| Interviewee E | Contractor | 16 | 60 | Large |
| Interviewee F | Contractor | 11 | 100 | Large |

*Table3: Detail of interviewees*

| Sector / Size | Primary Agriculture | Manufacturing | Services Sector |
|---|---|---|---|
| Micro | Less than 5 employees | Less than 5 employees | Less than 5 employees |
| Small | Between 5 & 19 employees | Between 5 & 50 employees | Between 5 &19 employees |
| Medium | Between 20 & 50 employees | Between 51 & 150 employees | Between 20 & 50 employees |

*(Source: National SME Development Council, 2005)*

*Table 4: Malaysia Small and Medium Enterprise (SME) definitions based on the number of employees*

**Understanding Concept of Construction Waste Management**

Of all the companies interviewed, four companies explained that they did not practise construction waste management due to not being concerned in this field, being a small company, having a lack of practice, or having no experience regarding how to manage the waste material. Only two companies currently practised the management of waste materials on site. Interviewees C and F applied waste management plans for their projects to eliminate environmental problems and create cost savings.

The awareness of waste management remains low in the local construction industry. This may be due to limited project cases regarding reuse and recycling of waste material, worry about the quality of recovered material, lack of knowledge of just-in-time systems, and lack of implementation or leading programme held by the Government. Uppaluri (2006) further reinforced this finding as he stated that most of the local authorities have lack of awareness in construction waste management. He also proposed that awareness programmes are needed to improve the waste management practices.

**Reduced, Reused, Recycled, Recovery, and Disposal of Site Waste**

Notwithstanding the lack of awareness on the concept of construction waste management, some of the interviewees shared their ideas on how normally they handle those waste materials on site. For instance, Interviewee A explained that the scrap bars are usually stacked in the scrap yard according to grade and size; prior to being sent to the steel factory for recycling purposes. The scrap bars will be reformed e.g. Into steel billets, reinforcing bar, and wire rod at the scrap treatment plant or rolling mill (Pacific Steel, 2008). To reduce cutting waste on site, Interviewee E used cut-to-size steel wire mesh for their projects. However, this is dependent on the size and type of buildings.

Interviewee D mentioned that they reuse the concrete waste as crusher run for the temporary access roads and used fuel waste as mould oil for timber formwork. Interviewee E also mentioned that they reused timber and plywood for formwork up

to four times, and the use depended on the nature of works. According to Estate Management (2011) the waste formwork can be used as temporary formwork for concrete, fencing around sites, pallets and packaging for building materials. The waste timber can be chipped down into wood chips or recovered into biomass energy. However, findings show that most of the construction firms are completely unwilling to recycle or disposal waste timbers being used in construction. Most of the waste timber produced on site and packaging materials are often burned at the project site. This is due to tipping fees and landfill costs are much higher than cost of burning. Interviewee D further explained that open burning is usually allowed in rural areas after 7pm with the conditions of being closely monitored and controlled.

From the perspective of the Architect, Interviewee B promoted that Industrialised Building System (IBS) shall be adopted more frequently in Malaysia. IBS increase site management control and enables use of building components manufactured at factory which reduces the amount of waste produces on site. Mohamad et al., (2009) further explained that IBS reduces the dependency on foreign labour, increase productivity, and improves construction quality by using automated systems. Nevertheless, Interviewee B also highlighted that IBS can effectively reduce the usage of timber and other raw materials for the environments sake. However, he explained IBS is still in its infancy in Malaysia. Slow adoption of IBS is mainly due to financing practice which does not support the system, poor skills and knowledge, and lack of incentives given to both public and private sectors.

Results of the interview present a limited knowledge of SWMPs and weaknesses of practice in construction waste management. None of the interviewees discussed how they reducing the amount of waste produced by careful management of stores and JIT system.

**Level of Awareness and Commitment on Construction Waste Management**

Most of the interviewees' companies had limited knowledge and practices on how to manage site waste. Neither workshops nor training was provided to enhance the knowledge and skills in adopting construction waste management plans.

Table 5 shows responses of the company interviewed on the barriers of implementing construction waste management. The findings indicated that the main barrier results in poor implementing construction waste management was lack of awareness on construction waste management at 4.83 out of a total of 5 points; followed by lack of implementation in the Malaysian Construction industry, lack of incentives from the Malaysian Government, and unfamiliarity with the concept of construction waste management at 4.50, 4.50 and 4.33 respectively.

When interviewees were asked about any other reasons of ineffective implementing construction waste management; none of the interviewee's comments on the expertise required and particular technology needed.

| Statements | No. of response | Likely barriers | | | | | Average | Rank |
|---|---|---|---|---|---|---|---|---|
| | | Not a barrier | Slightly barrier | Neutral | Fairly barrier | Extremely barrier | | |
| Lack of awareness on construction waste management | 6 | 0 | 0 | 0 | 1 | 5 | 4.83 | 1 |
| Lack of incentives from Malaysia Government | 6 | 0 | 0 | 0 | 3 | 3 | 4.50 | 3 |
| Unfamiliar with the concept of construction waste management | 6 | 0 | 0 | 0 | 4 | 2 | 4.33 | 4 |
| Lack of implementation in Malaysia Construction industry | 6 | 0 | 0 | 1 | 1 | 4 | 4.50 | 2 |

*Table 5: Barriers of implementing construction waste management*

Corporate Training Materials (2011) explained that the training programs will focus on behavioural competencies that improve interpersonal skills which build relationships of trust, empathy, and productive interactions. Uppaluri (2006) added it is better to conduct training programmes by giving preference to best technical proposals; enacting bylaws and strictly monitoring their adherence; and establishing professional certification. The following section illustrates the perception of construction waste management training and frequency of training needed. Table 6 shows the analysis of how important is the waste training programme and its frequency is.

| Frequency | No. of responses | Important of waste training programme | | | | | Average | Rank |
|---|---|---|---|---|---|---|---|---|
| | | Not at all important | Least important | Neutral | Slightly important | Extremely important | | |
| Once a month | 6 | 5 | 1 | 0 | 0 | 0 | 1.17 | 4 |
| Once quarterly | 6 | 2 | 3 | 1 | 0 | 0 | 1.83 | 3 |
| Once in half year | 6 | 0 | 0 | 0 | 2 | 4 | 4.67 | 1 |
| Once a year | 6 | 0 | 1 | 3 | 2 | 0 | 3.17 | 2 |

*Table 6: The important and frequency of waste management training programme*

From the companies interviewed, most interviewees agreed such training should be conduct once in half year; followed by once a year. Training conducted once a month and quarterly was found to be not at all important and least important respectively. Interviewee C specifically pointed that waste management training is not important as most local contractors are reluctant to change and unwilling to invest in short courses. He claimed that conducting various training programme was more meaningful to them if compared to lengthening the duration of waste management training programmes. Hence, understanding the needs and type of training is essential to meet the training objectives and guarantee the money is being well spent.

In the construction industry, poor management practice and lack of higher expectations have contributed to unproductive and unhealthy attitudes (Collough and Bencon, 1993). Ruttenberg and Lazo (2004) study revealed that language differences are a barrier to effective communication. In the Malaysian construction industry, most employers are reliant on Indonesia workers. English is the most widely spoken in training programmes. The challenge to Indonesian workers is difficulty in understanding English as they are only able to communicate in Bahasa Indonesia or Bahasa Malaysia. As such, the awareness of handling waste and understanding of the environmental impact effects remains relatively low in Malaysia as compared to UK.

**Towards Effective Implementation of Construction Waste Management**

New construction methods and a sluggish economy made the construction industry become very challenging (Vincenzo, 2012). Interviewee F specifically pointed out that the cost and manpower involved might be higher than the saving from the salvageable waste. This is further supported by Interviewee C who stated that cost and time are the challenges that their company is faced with. Nevertheless, Interviewee D mentioned that attitude towards workers is very important which required a good management team to manage such plan.

Despite of all the challenges, the construction project is still continuing develop. It is, thus recommended that the tangible benefits be demonstrated by those who have adopted WARP and SWMPs in the UK and EU. Interviewees D and E further added this should focus on how the strategy helps in site layout, workflow and project cost savings.

Government plays an important role in developing the framework of construction waste management. Interviewee F suggested that the Government and its related departments/authorities shall lead the industry through promoting education, raising public awareness and training, as well as offering incentive and award to participants who adopting the waste management system. Interviewee C highlighted that the policy or act should include clear guidelines and enforcements that make up the strategy. For instance, Section 34 of the Clean Neighbourhoods and Environmental Protection Act 2005 requires developers and contractors of construction and demolition projects to prepare site waste management plans (Estate Management, 2011).

Moreover, the authorities should re-regulate the rules of the Environment Quality Act 1974 (Act 127) particular to P.U.(A) 460/2003 Environmental Quality (Declared Activities) (Open Burning) Order 2003 (Environment Quality Act 1974, 2003). Landfill tax on disposal of waste should be imposed to encourage waste producers to produce less waste and to recover more value from waste.

To effect the implementation of construction waste policy, Interviewee C further explained that construction participants must comply with the rules and regulations given to turn the waste to recycled construction materials or other products. As the recommendation given by WRAP (n.d.) client project managers need to ensure all requirements and performances for waste outcomes are discussed during the project

brief and well written in tender/contract documents. The SWMP should be reviewed on project completion, and used as learning for future projects.

Additionally, the Construction Industry Development Board (CIDB) in Malaysia should also take a step towards increasing promotion for construction waste management to deliver sustainable practices for the benefit of the society, economy and the environment.

## CONCLUSIONS AND RECOMMENDATIONS

A review of several studies showed that there are five types of construction waste management which consist of reduce, reuse, recycle, recovery and disposal of material. SWMPs are a very important tool and should be adopted with strict enforcement imposed to ensure future projects to deal with wastes more responsibly.

This paper has presented the concept of construction waste management plans which are rarely implemented in Malaysia. There is a greater likelihood of adoption of construction waste management by construction practitioners if there is the correct level of encouragement, incentives, promotion and training provided. The level of awareness could be increased with training programme, motivation, guidance, strict rules and regulations enforced bylaws in Malaysia.

Several recommendations are proposed so that sustainable waste management can be successfully implemented in Malaysia. The Government and authorities should take the lead in implementing construction waste management within the construction industry and public sector. This includes providing training, reward incentives, increasing landfill tax, and re-regulate the current practice of environment rules and guidelines.

Construction practitioners should support the creation of legislation making SWMPs compulsory as it would ensure the success of their projects and allow them to deal with their wastes more responsibly. These will benefit the society, economy and environment as a tool to achieving more sustainable development in Malaysia. The construction practitioners should also review the strategy and use the lessons as project-based learning models for future projects.

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# A CRITICAL EVALUATION OF RADIANT COOLING UTILIZATION IN MALAYSIA

**Kim-Hong Sor and Seng-Kong Han [4]**

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Even though it was introduced thousands of years ago in Europe, radiant cooling system is classified as green technology, by reason of its sustainable potential and energy saving benefits. Radiant cooling technology is deemed to have a great market and growth potential in Europe and in parts of Asia with a hot climate. Malaysia is one of the countries in Asia that experiences a classic tropical hot and humid climate throughout the year, thus, the market growth potential is immense. However, integration of radiant cooling in Malaysia is not as popular here as in Europe, thus there must be various kinds of factors that hinder the development of a radiant cooling system. This paper therefore attempts to identify the application of a floor embedded hydronic radiant cooling system, which is the type most commonly applied in Malaysia and its advantages are compared with conventional HVAC system. Research was based on recent interviews carried out with relevant professionals and a case study conducted on the Energy Commission's Diamond Building in Putrajaya, Malaysia, which had received the highest Platinum rating under Malaysia's Green Building Index and Singapore's Green Mark rating tools. Not limited to the above, the problems encountered in radiant cooling development in Malaysia also play an important part in this research. To be successful radiant cooling technologies must overcome these problems to enhance their market adoption, and the burden of proof on the benefits of radiant cooling system is crucial for its acceptance and implementation.

Keywords: radiant cooling, HVAC, condensation, thermal comfort.

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## INTRODUCTION

The use of radiant heating and cooling is not new. Over 2000 years ago, the Romans were using under floor radiant heating and thermal mass heat storage in their hypocausts. In Turkey, stream water was diverted through channels in walls and floors to cool palaces in the warm summers (Sawers 2001). In past decades, Architects, Engineers and Contractors have acknowledged the benefits of hydronic radiant technology as an efficient, energy-saving and highly comfortable means of heating. These same advocates are now discovering that a radiant heating system can be altered to circulate cooled fluid to provide superior energy savings and comfort during periods of warm weather as well (Weslunt 2012). A radiant cooling system is potentially suitable for hot climates. In most tropical countries, the demand for cooling indoor air is growing because of the effects of global climate change and increasing comfort expectations by occupants. Radiant cooling shows advantages in comfort and efficiency similar to radiant heating, which is quiet, with no significant air circulation patterns, offering extremely high levels of comfort and operating efficiencies that can cut operating costs in half, when compared with an air-conditioning system. Owing to these factors, the integration of a radiant cooling system in buildings seems a sound way forward (Lim *et al*. 2009). However, there are a lot of limitations in radiant cooling application. Currently, radiant heating and cooling systems have remained a small, niche market, a 'luxury' item reserved mainly for the upper classes (Hudoba 2012). Radiant cooling systems have successfully been used in parts of Europe since the 1900s. Nevertheless, it has not seen the same success in the United States because the early installations in the 1950s and 1960s experienced failure through condensation. This is the main issue that is causing some engineers and related professionals to have negative impressions of the technology (Cunniff 2009). The success of radiant cooling in Europe does not make it to Malaysia. Even with a green mindset, the lack of knowledge of the building sector's professionals of radiant cooling and weak public awareness has led to low applications of radiant cooling in Malaysia. Radiant cooling can even be deemed to be an underutilized technology owing to potential condensation if the system is left to run unchecked. This is especially true in humid climates like Malaysia. Today, radiant heating is a well-accepted method of providing heating in a building. Radiant cooling, however, is far less understood and misapplications in the past have hindered its acceptance. Recently, several buildings in Malaysia have been constructed with floor embedded hydronic radiant cooling systems.

The aims of this article are to:

- study the concept of radiant floor cooling by an embedded water-based system in Malaysia,
- identify the advantages and disadvantages in application of radiant cooling systems, and
- review the benefits of a radiant cooling system in term of energy savings, cost saving and beneficial impact on the environment.

# LITERATURE REVIEW

A radiant cooling system is a type of hydronic HVAC system in which chilled water circulates through embedded multilayer composite pipes in the building components. It can be embedded in walls, ceilings and floors, or through manufactured panels positioned on the walls or ceiling, ventilating the room thorough radiation and natural convection. With a radiant cooling system, people inside the building are cooled by radiant heat transfer from their bodies to adjacent cooled surfaces. The chilled water draws the sensible heat inside the room and sends it to a cooled surface for heat exchange. Its operation is similar to radiant heating, only in reverse mode. Radiant heating refers to a system in which the energy moves from the warmer surface to the cooler area needing warming. Conversely, radiant cooling refers to a system in which the energy moves toward a cooler surface from a warmer area to cool it. Both contribute to maintain the comfortable temperature in a space. Radiant cooling even uses the same system of piping as the heating system.  Figure 1 and 2 shows the application concept of hydronic radiant floor cooling system:

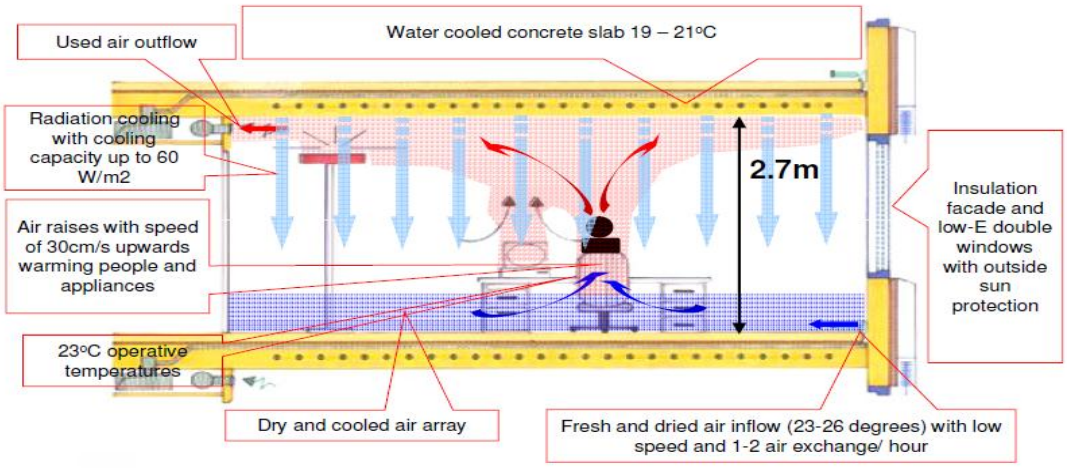


*Figure 1: Concept application of radiant floor cooling system (1) (Holcim Indonesia 2011)*

The major difference between a radiant cooling system and an air-conditioning system is the heat transport mechanism. The former system uses a combination of radiation and convection to absorb the heat, while the latter one uses convection only to distribute cooled draft.

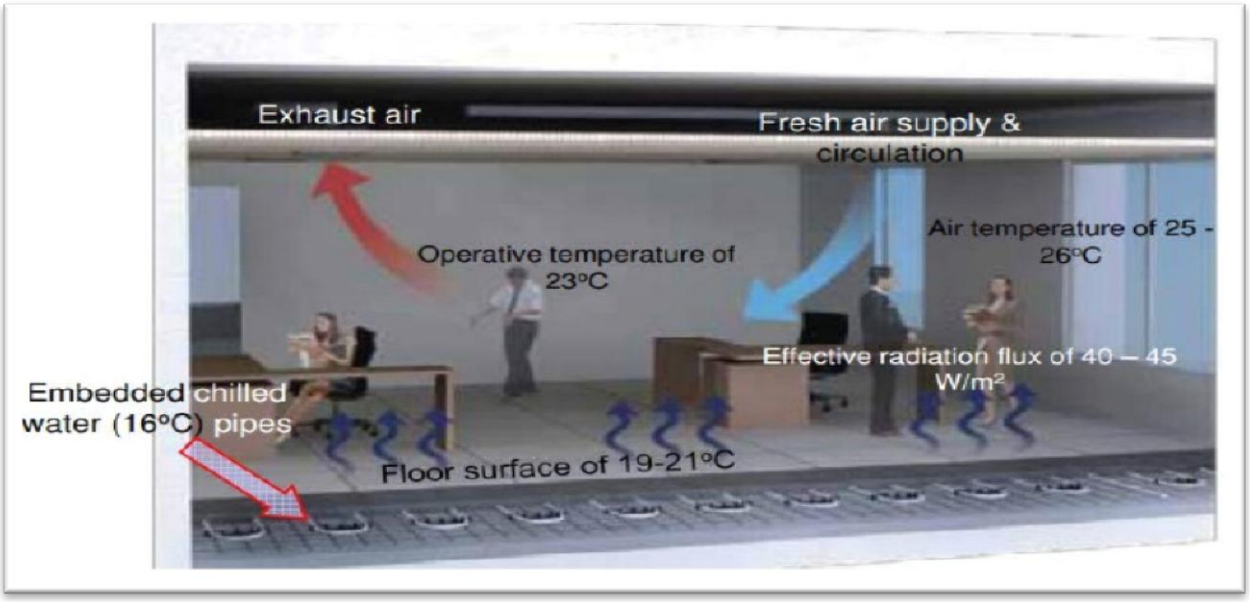


Figure 2: Concept application of radiant floor cooling system (2) (Holcim Indonesia 2011)

In basic physical phenomena, where there is a temperature difference between two objects, both objects will make an effort to equalize the temperature. In a radiant system the equalizing temperature occurs through radiation. Radiation is an approach where energy is transferred through an empty space or air, without heating or cooling the space itself. In other words, if an object is warmer than another, the cooler object will absorb heat radiated from the warmer body, resulting in cooling one and heating the other. This is how the Sun transfers heat to the Earth, the radiant heat wave travels from millions of miles away through the cold space until it hits a surface and warms it, no air is involved (Timmons Design Engineers 2012).

According to REHAU Group (2012), there are four modes of heat transfer from the human body. Heat from the human body can be transferred not only by radiation and convection, but also through conduction and evaporation. Conduction is heat transfer through direct contact simply like the hand feeling warm or burning on a hot plate whereas evaporation is heat transfer with vapour loss for example occurring in breathing and in perspiration in warm conditions. The level of heat emission from the human body occurring through these four modes of transfer is shown in Figure 3.

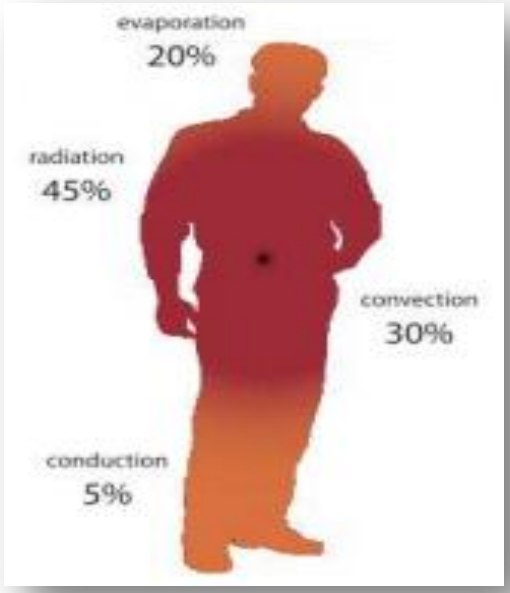


*Figure 3: Four modes of heat emission from human body (REHAU 2011)*

More heat can be drawn out from the human body by radiation than by any other means. Human bodies radiate heat to any surface which is cooler than the bodies' surface temperature of 29°C to 32°C. People will feel most comfortable where at least 45% of heat emission from the body is by radiation.

The reason for a radiant cooling system instead of an air-conditioning system is shown in Figure 4. The figure shows that a 100 per cent air-conditioning system installation will have a higher average air temperature inside a room due to solar heat gains and casual heat gains from office equipment like computers, lighting, photocopying machines, etc. On the other hand, with an air-based system operating in a combination with a radiant cooling system, air temperatures inside the room will be lowered, with the heat emitted from the occupant and equipment transferred to temperature controlled surfaces via radiation

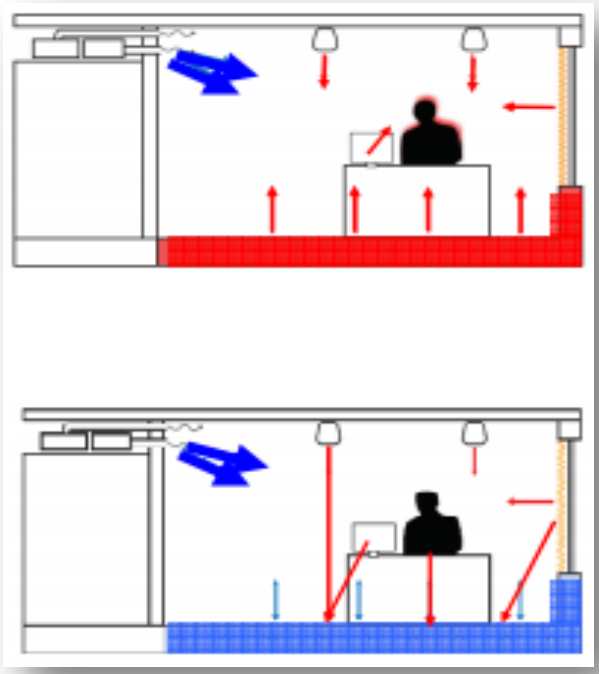

*Figure 4: Surface temperature variations for different cooling systems applied (REHAU 2011)*

**Opportunities with Radiant Cooling System**

In terms of government policy, The Report: Malaysia 2010 gives a clear indication that in recent years Malaysia has a greener mindset, aiming to become the latest green construction zone in the South-East Asian region. Nowadays people everywhere are encouraged and introduced to the use of green and environmental friendly technologies and resources. Such technology for sustainable building has been going through a phase of rapid growth, becoming the main thrust of the construction sector in many countries. The Report also noted that in the 2010 budget speech, the present Prime Minister of Malaysia, Dato Najib Tun Abdul Razak announced the intention of promoting the use of eco-friendly technology and resources in construction, including the setting of a RM1.5 billion fund for soft loans to companies that use and supply green technology (Oxford Business Group Malaysia 2010).

Buildings today are more sustainable and thermally efficient in providing acceptable and predictable comfort. In today's built environment, sustainable buildings do not merely minimize total energy use and greenhouse gas emissions that cause global warming, but also significantly satisfy the building occupants thermal comfort requirements (Edwards 1999).

HVAC systems, most of which are all-air systems, circulate air not only for ventilation, but also as a heat transfer device. These systems are designed to control the temperature, humidity, and air movement inside a building to create a comfortable

environment for building occupants with better thermal comfort and indoor air quality. Nevertheless, some negative factors are noted. Apart from energy waste, the capability to supply high velocity cold-draft can bring about air temperature differences between the human head and feet, creating discomfort (Feustel and Stetiu 1995).

Radiant cooling is an alternative HVAC system which allows the enhancement of energy efficiency and thermal comfort. Yet, the radiant cooling system also falls into the green technology and innovation classification, given the advantage of energy savings as one of its benefits. Due to the opportunity to reduce energy use and the dissatisfaction with conventional HVAC systems, radiant cooling technology has becomes very popular in recent years, especially in Europe (De Carli *et al*. 2002).

The climate of Malaysia is generally tropical, hot and humid, throughout the year with temperature range from 20°C to 30°C. Moreover, Malaysia was aiming for 70 per cent of the total market share of green construction services, green materials, plus building management and solutions that promote environmental sustainability (TheGlobalOne.net 2012). This shows that opportunities for radiant cooling are immense.

**The Benefits of a Radiant Cooling System when compared to a Conventional HVAC System**

People choose radiant cooling because it has many benefits. According to Feustel (1994), water is a better heating and cooling transport agent than air; its heat absorption capacity is 4 times greater in comparison. There are also many benefits of radiant cooling systems when compared against those for traditional HVAC systems, including:

**a) Peak Power Demand & Energy Consumption**

According to Energy Design Resources (2000), there is a difference in the heat transfer mechanism of a radiant cooling system and an air-conditioning system – the hydronic radiant cooling system reduces peak power demand by pumping chilled water to provide radiant cooling, rather than by blowing chilled air. A hydronic system can transport a given amount of cooling with less than 5 percent of the energy required to deliver cool air with fans.

Figure 5 shows how radiant cooling systems achieve savings relative to conventional systems:

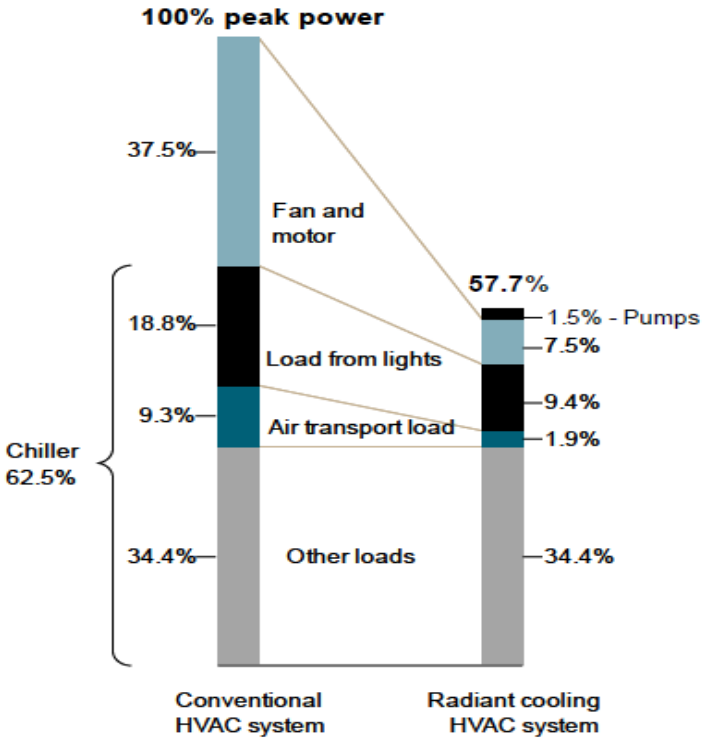


*Figure 5: Comparison of peak power demand of conventional HVAC system and radiant cooling system (Source: Energy Design Resources 2000)*

Figure 5 highlights the components of peak HVAC energy use in a building for a conventional system and for a water-based radiant cooling system. As shown in the graph, about 62.5 percent of the conventional HVAC system's energy use consists of cooling load that the chiller must remove. In fact, all of the remaining power demand is used for air transport which is not required for a radiant cooling system. The hydronic radiant cooling system is using chilled water as the transport medium. Due to the physical properties of water, hydronic radiant cooling systems can reduce peak power demand by pumping chilled water to provide radiant cooling, rather than by blowing chilled air.

Moreover, loads from lights can be reduced because the radiant system can directly release half of the lights' heat to outside the building if it is ventilated with 100 percent outside air. In conventional buildings, most of that heat stays in the building with re-circulating supply air. As a result, the energy saving is greater than 42 percent

**b) Indoor Air Quality**

Conventional HVAC systems are all-air systems designed to remove sensible heat, maintain a comfortable indoor air and to provide fresh, filtered air to building occupants by re-circulated air inside a space. Radiant cooling can utilize 100% outside air supply, so there is less circulation of stale air, keeping a constant or easily controllable volume of fresh air coming in. Due to ventilation, air is not re-circulated

and there are no wet surface cooling coils, thereby reducing the likelihood of bacterial growth. Radiant cooling can positively help the environment by limiting the chlorofluorocarbons (CFCs) use. CFCs were widely used as air-conditioning and refrigerator coolants, known as an environmental hazard, a greenhouse gas that contributes to global warming and may cause fatal effects such as skin cancer and damage to crops (Stetiu 1997).

**c) Thermal Comfort**

The human body is continuously generating heat. To perform normal functions, the body has to maintain a balance between heat generation and heat loss. Radiation has the highest heat transfer coefficient. It is perceived as the most comfortable method of heat transfer, and is followed in order by convection and conduction. The possibilities of increasing heat loss through evaporation are very limited. The principle of a radiant cooling system leads to better thermal comfort than conventional HVAC which cool a person via convection only. By using a combination of radiation and convection modes of radiant cooling system, the surfaces are cooled evenly, and the temperature is more evenly distributed. Overall, it may cool the floor, room, contents and people more efficiently than other systems.

**d) Cost Savings**

Like a refrigerator, an air-conditioner works by piping a chemical refrigerant through cycles of compression and expansion. The refrigerant absorbs heat from the cool interior air and releases it to the hot air of the outdoor living environment. In doing so, the temperatures tend to even out, meaning heat naturally flows from a hot to a cold area. So an air-conditioner has to mechanically compress the gaseous refrigerant into a much hotter liquid form and pump it through outdoor coils from which it can release the heat it has absorbed. To do this requires a lot of energy (Cox 2006). Radiant cooling systems have the potential to reduce electricity cost in district zones with the timely use of off peak electricity rates. With regard to the peak energy demand and energy savings, a radiant cooling system needs low maintenance as there are fewer electrical devices compared to an all-air system, making it the less expensive option in the long run.

**e) Space Saving**

The need for individual air conditioning units in outside walls can be eliminated, and a common central air system can serve both interior and perimeter zones. Decreased ducting, conditioning units and fans between floors, can bring about an extra, on average, a 2 vertical feet of usable room space with more freedom to design and innovate or building cost savings with a lower floor-floor height. The reduction in duct shaft areas can be as much as 70%.

**Limitations of Radiant Cooling System and Solutions**

Most of the early cooling ceiling systems developed in the 1930s failed because of the real threat of condensation that often occurred in cooling mode. The problem was deemed too difficult to deal with, and the consequences too great (Stetiu 1997). Subsequent studies showed that the key to successful radiant cooling is to control the supply water temperature by the dew-point of the air, not by air temperature. To avoid this problem, the surface temperature must always be above the dew-point.

Dew-point is the temperature at which water condenses out of the air. A perfect example to illustrate condensation is the dew on the lawn in the morning. When the temperature of the grass falls below the dew-point of the air, the grass gets wet. Hereby, the more moisture in the air, the higher is the dew-point. In humid climates, simply opening a door or window could allow enough humidity into the building to allow condensation to occur (Fey 2011).

*Figure 6: Condensation on grass*

*Figure 7: Defect on carpet caused by condensation on concrete slab*

Since the latter part of the 20th century, the building industry has developed a better understanding of the controls needed for a radiant cooling system. When using a surface system for cooling, the surface temperature or air temperature must be controlled to prevent condensation on the structure's surface. This may be done by simultaneously dehumidifying the ventilation air to a certain level and maintaining the cooling surface temperature above the dew-point temperature. The condensation could be avoided if the radiant system operates in conjunction with a small ventilation system that function as a regulator designed to lower the dew-point of the indoor air or to maintain the cooling system temperature above the dew-point. If the dew-point is further reduced through dehumidification of the supply air, the temperature of the radiant surface can also be reduced, and higher sensible loads can be removed by radiation (Bean *et al*. 2010). Today, moisture control problems can be mitigated by recent advancements in sensor and control technology. The risk of condensation can be mitigated by switching off the supply of cold water as soon as the relative humidity reaches dew point levels. Or, this can be done by installing a two-way valve that is used to control the permitted amount of water to circulate through the piping. The

supply valve will close automatically as soon as the temperature reaches the dew point level measured by a humidity sensor. For instance, a variation of this control scheme consists of window contacts that switch off the water supply if the windows are opened (Timmons Design Engineers 2012).

The installation cost of a radiant cooling system can be higher than an air system because of the cost of the piping and plumbing. Moreover, the slab radiant cooling system needs to be supplemented with significantly downsized force-air system to ensure that the indoor environment is kept dry to prevent condensation on the chilled slab surface and also to provide adequate fresh air to the building occupants. This is compensated by the reduced running costs and the reduced costs of downsized air components such as fans and ductwork resulting in a more economical life cycle cost (Energy Expert 2011).

From another viewpoint, there is also a limited availability of professionals experienced in radiant cooling – either design, installation, maintenance or repair of the system. Even though hydronics and radiant cooling is not a new technology, it is still a small market, leading to a lack of familiarity and limited experience by architects, engineers and other related professionals. This limitation will probably diminish as information becomes more widely available about its successful application in Europe, Asia and hopefully in Malaysia.

## RESEARCH METHODOLOGY

The research study utilized several methods to complete the paper as follows:

**Primary Data Sources:**

**I. Semi-Structured Interview**

Interviews were scheduled with participants that fit the background requirements. The criterion of analysis for this data collection is the radiant cooling application, so experience from radiant cooling installation and adoption is required. The interviewees were the construction industry professionals – the Engineer, Developer and the Diamond Building Owner and Users of the building. The set of research questions were prepared based on their different standpoints and expertise. Not every question was asked of each participant, but each question asked will be interpreted in the same way for each participant to minimize bias. Allowance was encouraged within the interviews for participants to reflect and pursue their own interpretations from their experience for deeper exploration of data.

**II. Focus Group Interview**

The second type of interview technique is group interview or focus group study. This technique was performed particularly for interview with a group of building Users from Diamond Building instead of a one to one interview asking the same

set of research question. In this study, 4 interviewees were asked for their direct views and opinions on the radiant cooling performance.

### III. Case Study

A case study was conducted to justify the research problem of the study. It was carried out on one of the buildings in Malaysia integrated with a radiant cooling system, which is the Diamond Building, headquarters of the Energy Commission of Malaysia located at Putrajaya. A site visit to the Diamond Building was conducted.

**Secondary Data Source:**

**Literature Review**

Literature review is the secondary research method for this study. It was an excellent aid to understand the topic and to learn from the experience of other researchers. An extensive literature review was carried out on related internet resources, books, articles, magazines, news on the theories, facts and recent developments in radiant cooling.

## FINDINGS AND DATA ANALYSIS

### A Case Study on Diamond Building, Putrajaya

*Figure 8: Diamond Building in Putrajaya*

By referring to GreenPagesMalaysia (2012), the Diamond Building, the Headquarters of the Energy Commission of Malaysia (EC) in Putrajaya, is an energy efficient and sustainable eight-storey high Corporate Office with two levels of basement parking. It is the first Green Building in Malaysia to achieve both Green Mark Platinum and GBI (Green Building Index) Platinum Green Building Certifications. The building also

won two CIDB Malaysian Construction Industry Excellence Awards (MCIEA) in 2010 for the Contractor Award G7 and Innovation Special Award categories. Recently it also received two other awards – the Asian Energy Award 2012 (New and Existing Building Category) and the Green Apple Award 2013 for Built Environment and Architectural Heritage.

As a sustainable project, the Diamond Building developed by Senandung Budiman Sdn. Bhd. (a subsidiary of Putra Perdana Berhad) fully utilizes current technology in saving natural resources, such as including photovoltaic cells to harvest solar power and convert it into electricity, rainwater harvesting systems for irrigation and toilet flushing, grey water recycling systems, water and energy-saving devices (light and $CO_2$ sensors), and floor slab cooling system to minimize wastage and reduce peak load demand. This building is expected to have an energy intensity of 85 kWh/$m^2$/year, in contrast with the standard intensity of 250 kWh/$m^2$/year in Malaysia.

Air-conditioning for the Diamond Building is provided by two separate systems, the conventional cold air supply system and radiant cooling slab system. This technology makes the building structure function as a thermal storage system by embedding flexible 22mm PERT (polyethylene pipes of increased temperatures resistance) pipes in the reinforced concrete slabs during construction. 40% of the cooling comes from the chilled water slabs. The radiant cooling slabs have chilled water pipes embedded in the concrete slab itself. At night, 18°C cold water is circulated in the slabs to cool them down to about 20°C. During the daytime, the system is shut off, and the floor slab passively absorbs heat from people, computers and solar heat gains. The advantages of the Floor Slab Cooling System applied in Diamond Building include reducing cooling transport energy by 64%; shifting much of the cooling to the slabs so that the Air Handling Unit (AHU) System can be downsized by about 30%; and moving 30-40% of the cooling to night time so that the building can enjoy lower off-peak energy rates. The radiant cooling slab system needs to be complemented with a significantly downsized conventional cold air supply system to ensure that the environment is kept dry to prevent condensation on the chilled slab and also to provide adequate fresh air to the building occupants. As the air ventilation rate is reduced significantly with this air-conditioning system, the noise caused by the ducts also reduces significantly, improving the acoustic comfort..

*Fig 9: Cooling pipes laid before concrete pour*

*Fig 10: Manifold riser for slab cooling pipes*

*Fig 11: No suspended ceiling*

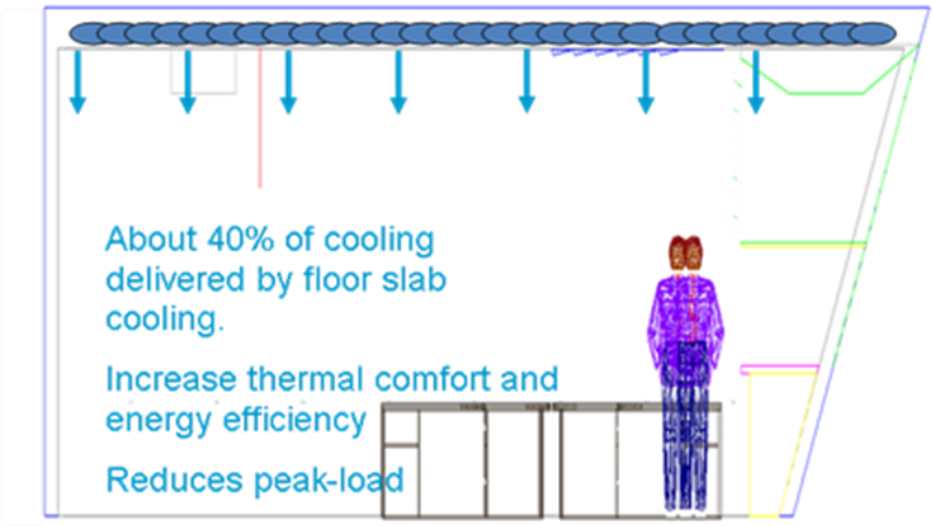


*Fig 12: Suspended ceiling omitted to enhance slab cooling*

According to IEN Consultant Reimann (ca.2012 cited ChyNaluri 2012), the Diamond Building has 57% electricity savings ($CO_2$ emission savings corresponding to taking 324 cars off the road); 71.4 kWh solar PV plant ($CO_2$ emission savings corresponding to taking 30 cars off the road), water-efficient fittings, rainwater harvesting and grey water recycling (water saved corresponds to consumption of 12 households); conducive working environment (50% daylighting, good air quality and passive slab cooling). Most of the electricity consumption of the Diamond Building is due to the cooling system. By radiant cooling, 47% of electricity energy from air-conditioning system can be saved. Additional savings come from the 35% savings on the district cooling consumption for the building..

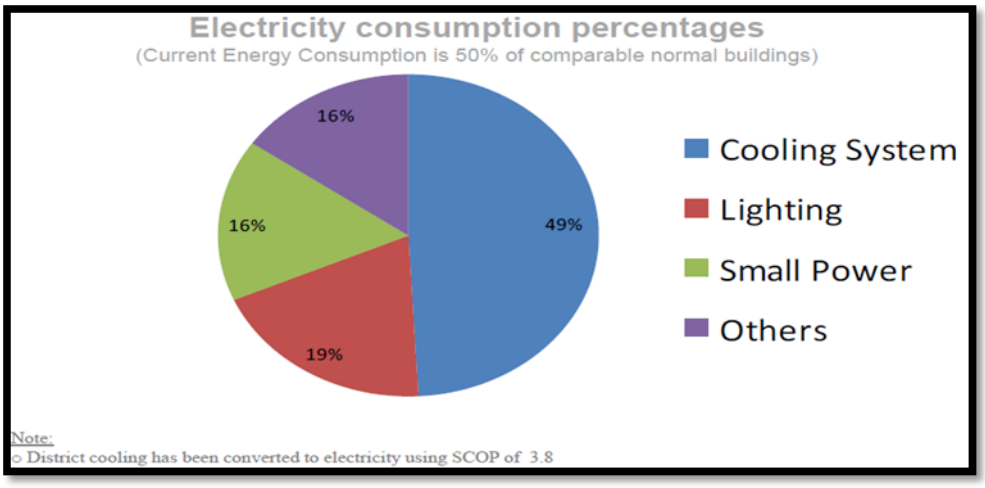


*Figure 13: Breakdown of Energy Consumption of Diamond Building*

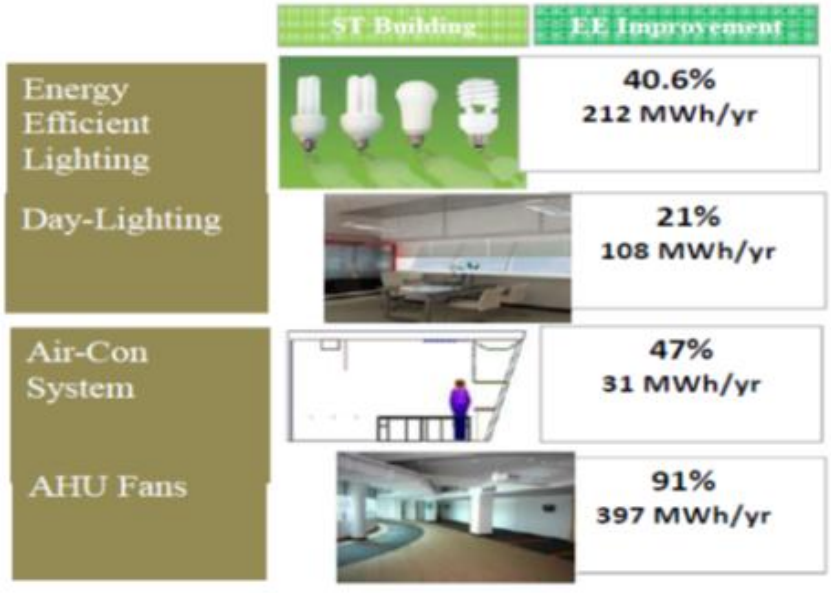


Figure 14: Energy Savings of Diamond Building

**Information collected from Interviews**

The 14 questions asked during the conducted interviews are:

1. In your opinion, what was the intention in choosing radiant system for cooling?
2. Does radiant cooling system improve the working environment in the building?
3. Based on your experience with air-conditioning and radiant cooling systems, are you satisfied with the radiant cooling performance? Are there any improvements to be considered?
4. The use of a proper control together with a ventilation system may be required to avoid condensation. A downsized air-conditioning system still needs to be installed in the building. Do you still think is it worthwhile to choose radiant technology?
5. How much is the installation cost of radiant cooling system? As compare with air-conditioning system, is it worthwhile?
6. What are the advantages of radiant cooling system compared with the conventional air-conditioning system?
7. Are there any disadvantages for adopting this system?
8. What skill level is required to install radiant cooling system?
9. What type of maintenance is required and how much is the cost involved?
10. Do you agree that the radiant cooling system is more comfortable and healthy than systems that circulate air?
11. Can radiant cooling supply all the cooling needs of a building?
12. Do you support the incentive to promote this system in the country nowadays?
13. If radiant cooling is so energy efficient, why isn't it widely adopted in Malaysia? What are the important barriers encountered in its entry into the market?
14. Is radiant cooling right for your next project? In future, if you are a building owner, will you opt for radiant cooling system for your own building?

According to the interviewees, the principal intention of a radiant cooling system application is in the interest of cost savings, reducing cooling energy consumption for the long term and increasing thermal comfort. Long term cost savings is the main reason for the radiant cooling's application. However, the installation cost of radiant cooling itself is quite expensive. The cost includes the design works, installation works and maintenance and monitoring works. Each part of the system is important and unique. The cost will escalate when any part of the system breaks down and requires replacement. From the developer's perspective, the installation of this system is aimed at long term cost savings and energy efficiency.

The intention of a radiant cooling system is not to substitute the air-conditioning system, but to downsize the latter system, contributing to more area space for the building layout and the floor levels of the building. It is acknowledged that it is worthwhile to install a radiant cooling system together with a smaller sized air-conditioning system. The reason for installing another cooling system is to reduce the probability of condensation. Taking into account the principal intention of a radiant cooling system which is to contribute towards long term energy and cost savings,

green technology features and thermal comfort, the decision to pursue radiant cooling is definitely worthwhile.

In short, the advantages of Radiant Cooling Systems are:

- long term energy and cost savings
- high thermal comfort/enhancement of thermal comfort
- energy efficiency
- one of the green technologies
- improved indoor air quality
- improved working performance and working environment
- downsized air handling unit and air-conditioning system
- contribution to additional space and reduction of height of suspended ceiling of each floor
- additional floor levels can be allowed for the same building height
- reduced cooling load of Cooling Tower, which lead to less pollution
- noise reduction.

The Government has provided incentives to promote the development of Radiant Cooling System in Malaysia. Nevertheless, the lack of professionals in the construction industry who are familiar, experienced and knowledgeable in this green technology for its implementation and maintenance is the main barrier to the viability of Radiant Cooling System use in the construction market of Malaysia. Besides the high installation cost, care must be taken to ensure that the radiant cooling pipes embedded in the reinforced concrete slabs during construction are not damaged during building occupancy by subsequent drilling or any intrusive works. Furthermore, Radiant Cooling System is not well known by the masses including the Developers or Clients.

## CONCLUSION

The concept behind radiant cooling is very similar to that of radiant heating. The most notable difference is that instead of emitting heat, the system absorbs it. A radiant cooling system works by circulating chilled water through pipes embedded within the floor, which cools the slab by absorbing the heat radiated from the rest of the room. The advantage of such a system is that it will lower energy consumption, as water has a higher heat transfer rate than air, while the pump is typically more efficient than the fan, therefore reducing the energy used to transport cooling around the building.

The radiant cooling slab system needs to be complemented with a significantly downsized conventional cold air supply system. This is to ensure that the environment is kept dry to prevent condensation on the chilled slab and also to provide adequate fresh air to the building occupants. As the air ventilation rate is reduced significantly with this air-conditioning system, the noise caused by the ducts also reduces significantly, improving the acoustic comfort of the occupants.

There is a strong political and market drive toward low energy buildings in Malaysia. Consequently, there is a strong will to develop sustainable low energy cooling

solutions. Radiant cooling technology is deemed to have a high market and growth potential similar to Europe and countries in Asia. Malaysia is one of the countries in Asia that guarantees a classical tropical climate throughout the year, thus, the market need is ever present. There are many advantages of applying a radiant cooling system; the cost savings and reduction of energy consumption are the main features. However, the lack of the related professionals is the major barrier to Radiant Cooling System development in Malaysia currently.

It is hoped that this study will be beneficial to all relevant parties involved in the built environment, ranging from the practitioners in the construction industry, the masses, academic researchers and students.

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