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THE CONSTRUCTION AND DEMOLITION WASTES IN KLANG VALLEY, MALAYSIA

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Abstract

Numerous activities in construction and demolition (C&D) projects are generally considered as complex and distant that may affect surrounding environment and public health. Construction, remodelling, repairing, refurbishing or demotion works of buildings and other infrastructures such as roads generate huge amounts of hazardous and non-hazardous materials. In the present work, an attempt has been made to highlight a number of issues in C&D waste management in the Klang valley of Malaysia and which then discusses the current traditions of managing those materials in Malaysian perspectives. The paper concludes with a number of recommendations that can help to improve C&D waste management in Malaysia national perspectives.

Keywords: Construction and demolition wastes, Waste management, Solid waste, Klang valley of Malaysia, national perspectives.

INTRODUCTION

Generally, waste is defined as a substance or object which is disposed of or is intended for disposal or is required to be disposed of by the provisions of laws. Wastes are generated in solid, liquid, sludge or gaseous form during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and many other human activities (Wang, 2010). Due to rapid urbanization and industrialization coupled

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with ever increasing population growth have led to an increase in solid wastes in most developing countries. The wastes generated from various human activities, both industrial and domestic, can result in health hazards and have a negative impact on the environment. In Peninsular Malaysia, the amount of solid waste generated per day increased from an estimated 23, 000 tonnes in 2010 to 25, 000 tonnes in 2012, averaging about 0.9 kilograms per person per day. Solid waste in Malaysia on average consists of 45.0 per cent food waste, 24.0 per cent plastic, 7.0 per cent paper, 6.0 per cent iron, and 3.0 per cent glass and others (Ahmed, 2010).

Waste management is defined as the discipline associated with the control of generation, recovering, processing and disposal of wastes in a manner that is in concordance with the best principles of human health, economic, engineering, aesthetics, and other environmental considerations (Tchobanoglous, 1993/ 2003). It is an important part of the urban infrastructure, as it ensures and provides protection of the environment and human health. In order to ensure proper management of waste, it is vital that the types of waste are identified. Different wastes need different handling treatment and disposal. According to Wolley (2000), reducing, reusing and recycling appear to be profitable alternatives that will increase the lifetime of landfills and reduce exploration of natural resources. In addition to that, some European countries' waste management practices are based on prevention (minimization), recovery and restriction (reusing and recycling). Though construction is one of the vital issues for national economic growth, however, the activities pertaining to construction pose various kinds of hazards to the environment and public health (CIDB, 2009). Proper management of construction and demolition (C&D) wastes is a burning issue (European Commission, 2000). There is an urgent need to look for improvements to the present C&D waste management practices so as to ensure good public health in an atmosphere that is environment friendly. All professionals have important roles in better management of C&D waste materials. The present research is conducted with reference to Malaysian perspectives through a case study on Klang Valley in peninsular Malaysia. The main objectives of the present research are as follows:

i) To identify the common types of waste materials generated at the construction sites and find out the common causes of generation;
ii) To identify the most common methods applied in managing C&D wastes at construction sites;
iii) To recommend the ways through which the present C&D management practices can be improved in Malaysia.

BACKGROUND OF KLANG VALLEY

Klang valley which is generally considered as a showcase of Malaysia consists of an area comprising Kuala Lumpur and its suburbs attached with adjoining cities and towns in the state of Selangor. Geographically, it is delineated by the Titiwangsa Mountains to the north and east and the Strait of Malacca to the west. The conurbation of Klang Valley is known as the heartland of Malaysia's industry and commerce and has a total population of about 6.6 million as of 2010 (Wikipedia, 2011) with 1.7% average growth rate. Klang valley is comprised of the following district areas: Federal Territory of Kuala Lumpur; Federal Territory of Putrajaya; Selangor District of Petaling, Klang, Gombak, Hulu Langat, Sepang, Kuala Langat, Kuala Selangor, Sebak Bernam and Hulu Selangor. Principal cities/ towns in the Klang Valley are shown in Figure 1.

Source: Wikipedia (2011).

Figure 1: Principal cities/towns in Klang Valley and the borders of state of Selangor and Kuala Lumpur

AN OVERVIEW OF MALAYSIAN POLICIES AND LEGISLATIONS IN SOLID WASTE MANAGEMENT

The construction industry in Malaysia has experienced a wide range of expansions during the past 20 years. Today, most of the construction projects undertaken are complex in nature, demand greater skills and superior technologies, fast track and concurrent work practices, and are very competitive in terms of price. In order to promote environmentally sound and sustainable development, combined with the aims of continued robust economy, the Malaysian government has established a legal and institutional framework for environmental protection regarding solid wastes. If the construction solid waste is not properly managed then it will affect the neighbourhood and consequently, it will have negative impact on all kinds of planning activities. The Environmental Quality Act (EQA) was enacted in 1974 for the prevention, abatement and control of environmental pollution and to enhance the general quality of the environment. The amendments were deemed necessary to incorporate new developments and issues in the control of the environment.

The Local Government Act was adopted in 1976. This Act has provided a better institutional and legal framework for local authorities to carry out their duties. The Act prohibits the deposition of waste in any stream, channel, drain and river. The Act also provides power to local authorities to maintain cleanliness in towns and put up sanitary measures for the removal of waste in their respective operational area. Further, Malaysia has developed a comprehensive set of legal provisions related to the management of waste. The regulation is based on the "cradle to the grave" principle. A facility which generates, stores, transports, treats or disposes scheduled waste is subject to the following regulations:

- Environmental Quality (Prescribed Premises) (Schedule Waste Treatment and Disposal Facilities) Order 1989;
- Environmental Quality (Prescribed Premises) (Schedule Waste Treatment and Disposal Facilities) Regulations 1989;
- Environmental Quality (Prescribed Conveyance) Order 2005;
- Environmental Quality (Scheduled Waste) Regulations 2005.

Overall, the government's policy is to ensure:

- the clean, safe, healthy and productive environment for present and future generations;

- the conservation of the country's unique, diverse cultural and natural heritage with effective participation by all sectors of the society; and
- a sustainable lifestyle and pattern of consumption and production.

A BRIEF LITERATURE REVIEW ON C&D WASTE

Increased Generation of C&D Waste

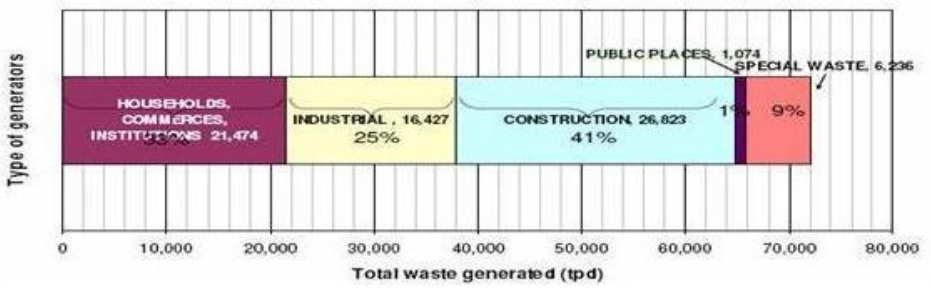
The materials generated from C & D waste activities are quite different, the reason is related with construction activities make use of presently available industrialized processes and materials while demolition activities often remove existing unusable or abandoned structures form the proposed construction site, and consequence of different waste stream (Colin Jeffrey, 2011). Fishbein (1998) stated that construction waste is one of the main contributors to serious environmental problems in many developing countries. According to statistical data, Construction and Demolition debris (C&D) recurrently makes up to 10-30 % of the wastes received at any landfill sites all over the world. For example, in Hong Kong an average of 7030 tonnes of C&D waste were disposed of at landfills every day in 1998, representing about 42% of the total wastes (Environment Protection Department, 1999/ 2000). Approximately, 136 million tonnes of C&D wastes were generated in the United States in 1996 (refer to Table 1), of which 53% accounts from residential areas (Franklin Associates, 1998).

Table 1: Summary of C&D Debris Generation in USA in 1996.

Sources	Residential		Non- residential		Total	
	Tonnes	*%*	*Tonnes*	*%*	*Tonnes*	*%*
Construction	6, 560	11	4,270	06	10,830	08
Renovation	31,900	55	28,000	36	59,900	44
Demolition	19,700	34	45,100	58	64,800	48
Totals (%)	*58,160 (43)*	*100*	*77,370 (57)*	*100*	*135,530 (100)*	*100*

Sources: Franklin Associates, EPA530-R-98-010, 1998

Figure 2 shows the classifications of solid wastes generators in Peninsular Malaysia: 1) Households, commerce, institutions (33%); 2) Industrial (25%); 3) Construction sector (41%); 4) Public places (1%); and 5) Special waste (9%). We observed that the construction industry has contributed the highest percentage (41%) due to rapid development followed by households, commerce and institutions (33%) and 25% generated from Industrial process.



Source: *MHLG/ Danida*

Figure 2: Solid Waste Generation in Peninsular Malaysia year 2007

Form above description it obvious that due to increase the C&D waste quantity, dearth of enough landfills and then long-term unpleasant environmental, economic and social impacts of the disposal of C&D waste, where effective C&D waste management is indispensable to protect neighbourhood environment (Muluken *et. al*, 2012).

Types and Components of C&D Wastes

Generally, wastes are divided into a number of different categories according to their physical, chemical and biological properties. Another classification is made by their composition. Solid wastes are waste materials that contain less than 70% of water which includes materials such as household garbage, some industrial wastes, some mining wastes, and oilfield wastes, e.g., drill cuttings (Chen and Li, 2006). Hurley (2003) affirmed that the main solid wastes present in the construction are gravel, concrete, asphalt, bricks, tiles, plaster, masonry, wood, metal, paper and plastics. Franklin Associates (1998) explained that construction debris from building sites typically consists of trim scraps of construction materials, such as wood, sheetrock, masonry, and roofing materials.

Concrete: Concrete is a material that consists of cement, aggregate, water and a number of other chemical admixtures. Generally, concrete is the most commonly used component for both substructure and superstructure of buildings and other infrastructures. Poon (2004) found that the material wastage in construction is mainly due to the disparity between the quantity of concrete ordered and that required, mostly in the case of ready mix concrete supply. It is also due to poor planning by the contractors on the amount of concrete required for the construction. Further, project delays and inefficient material handling processes also create wastes on site.

Reinforcement: Reinforcement bars are regarded as an essential component of reinforced concrete and reinforced masonry structures in construction. It provides better frictional strength to the concrete. The main causes of its wastage are careless cutting by the labourers and inaccuracy in estimated dimension. Poon (2004) confirmed that damages during storage and rusting also contribute to the volume of wastes.

Wood: According to the California Integrated Waste Management Board (2008), the primary constituents of wood waste are used lumber, trim, shipping pallets, and other kinds of wood debris from construction and demolition activities. Wood waste is, by far, the largest portion of the waste stream generated from construction and demolition activities. The main cause of wood wastes is natural deterioration (Poon, 2004), especially in the demolition activities.

Bricks and blocks: Bricks and blocks are mostly used to form the internal walls, fixtures and partitions of a building. Study conducted by Poon (2004) shows that the generation of bricks or blocks during construction process begins from the transportation to the site until its point of use.

Various Causes of C&D Wastes

There are two kinds of C&D wastes – direct and indirect. Direct waste is defined as a loss of value of those materials due to damage and normally these cannot be repaired/ used again (Mahanim *et al*., 2007). Some of the causes of direct wastes are: Transportation, delivery and internal site movements (Formoso *et al*., 1999); poor storage of materials (Skoyles, 1987); Problem in fabrication (Mahanim *et al*., 2007); poor attitudes of construction workers (Udayangani *et al*., 2006); design change/variation (Graham and Smither, 1996). On the other hand, indirect wastes occur principally from replacement of materials.

INTEGRATED C&D WASTE MANAGEMENT

C&D Waste Management is a part of a growing movement towards developing a sustainable world. Sustainable or "green" management techniques are designed to protect the environment, save resources, and conserve energy.

Proper use of construction waste management techniques has proven to have economic benefits for the construction industry (Simpson, 2006). No matter what the scale or complexity of the project be, from large new building offices to manufacturing facilities, waste management best practice strategies save construction costs and dramatically reduce the impact on the environment. Integrated Waste Management (IWM) is defined as the selection and application of suitable techniques, technologies and management programs to achieve specific waste management objectives and goals (Tchobanoglous, 2003). At the same time, the process takes into consideration of technical, legislative, economic, socio-cultural, institutional and environmental aspects of waste management. The authors of this study have identified four basic management options for IWM: 1) source reduction; 2) recycling and composting; 3) combustion; and 4) landfills.

The waste management process consists of material reduction in the design and planning stages, reducing scrap and waste at building site, reusing materials on site, and recycling materials which cannot be reused. All the processes involved are to be carried out within existing legal, social and environmental guidelines that protect the public health and the environment and are economically acceptable. For a successful integrated C&D waste management plan, it is essential that all the disciplines including administrative, legal, construction professional and workers, etc. communicate and interact with each other and maintain a positive interdisciplinary relationship.

Reduction of C&D Wastes

Chadravanthani (2006) asserts that in Malaysia, wastes are being generated at an alarming rate. Despite the widespread acceptance of recycling as a formal waste management method, however, in Malaysian national domestic recycling rate still stay close around a mere five per cent. According to Kibert and Languell (2000), the first priority of C&D waste management should go to reducing the amount of waste generated. Next priorities should go to reusing, recycling, composting, burning and land filling.

Pichtel (2005) maintains that waste minimization must be given high priority in order to limit any unfavourable environmental impacts, to hold down disposal costs as well as minimizing future liability. He also asserts that reducing C&D waste requires commitment and attention from all parties involved.

Reuse of C&D Wastes

Many materials extracted from demolition or deconstruction can be reused or stored for future potential use (Mahanim _et al_., 2007). Tchobanoglous and Keith (2002) underlined that, in any construction or demolition project, a broad variety of reusable and unused items should be found which include lumber of different sizes, plywood, asphalt shingles, insulation, heating ducts, etc. Furthermore, wastes such as broken concrete, blocks and bricks can be used in a number of applications.

In addition to the above, functional building or architectural components can often be reused for the next construction job. According to Pun _et al._ (2006), demolition waste reuse and recycling play important roles in value transformation for building material lifecycle, local economics, sustainable environment and natural resource conservation.

Recycling of C&D Wastes

Recycling is the process of collection, separation, clean-up and processing of waste materials to produce a marketable material or product and therefore contributes to the economy, both in providing jobs and business opportunities (William, 1998; Sherman, 1996). In 1996, it was estimated that an average of 20 to 30 per cent of the C&D debris generated were recycled (Southeast Regional Environmental Finance Center, 1996).

The waste materials to be recycled are determined on the basis of a number of factors that include their market value, their access to potential markets, and the quantities in which they are available (Dolan _et al_., 1999). Tchobanoglous and Keith (2002) have shown that the principal materials that are now recovered from C&D waste for recycling include concrete, wood, asphalt shingles, drywall, metal and soil.

Composting of C&D Wastes

The present researchers assert that composting, which is an element of an integrated solid waste management strategy, can be applied to mix up municipal solid waste as well as it can contribute to the reduction of the amount of waste produced. Accordingly, construction and demolition debris, tree limbs, and other fibrous organic materials may be grounded to produce wood chips, mulches, and feedstock for composting. If the site layout provides an area to store the compost, it may be kept and used for landscaping. The compost may be marketed to landscaping firms for commercial use. Compost can be used as a soil treatment, artificial topsoil, or growing medium amendment.

Combustion and Land-filling of C&D Wastes

It is also emphasized that burning should be one of the last alternatives for C&D waste with the permission from necessary authorities. Caution must be taken when burning takes place in order to prevent and avoid adverse health effects as well as uncontrolled burns. A landfill, also known as a dump, is a site for the disposal of waste materials by burial and is the oldest form of waste treatment. Historically, landfills have been the most common methods of organized waste disposal and remain so until the modern era in many places around the world.

RESEARCH METHOD

To fulfil the objectives of the present research, a survey method was adopted. The prospective respondents are decided to be mainly contractors, engineers and quantity surveys. The present survey is self-administered and the sample size is 32. After collecting all the responses from the respondents, SPSS version 19.0 has been used to analyse the data. In particular descriptive statistics, analysis of variance (ANOVA), multi-variate analysis of variance (MANOVA) components have been used. To conduct the present research, a questionnaire covering all the salient aspects of C&D wastes was formed that consisted of the following sections:

Section A - Background of the Respondents: The respondents were asked to provide information on position/profession, gender, age, and working experience.

Section B - Generation of C&D Waste: In the first two questions, the respondents were asked to articulate whether they are aware about construction and demolition wastes and their level of agreement on the statement “Construction industry now-a-days generates the C&D waste which creates substantial impacts on the environment and human health”. Further, on a set of factors pertaining to C&D waste, the respondents were asked to state their level of knowledge ranging from very poor to excellent. Next, from among construction, renovation, refurbish, remodel, repair and demolition, the respondents were asked to tick the item(s) that contribute(s) largest amount of wastes.

Section C - Practice on C&D Waste Management: In this section, the respondents were asked to articulate their level of awareness on C&D waste management and rating of its practice in his/her Construction Company. They were also asked to specify the waste management method (Reduce, Reuse, Recycle, Composting, Burning, Land filling) that has been in use in his/her company in reference to a variety of waste materials.

Section D - Minimizing C&D Waste: Using the 1-5 Likert scale (where 1 = minimally potential and 5 = maximally potential), the respondents were asked to rate several strategies in order to minimize the C&D waste materials.
Altogether 50 questionnaires were distributed to the respondents that include mainly contractors, engineers, and quantity surveyors in Klang valley area. All the respondents were contacted personally. The questionnaire was pilot tested through one quantity surveyor. He recommended rewording some of the questions which was done before communicating to the survey respondents.

DATA ANALYSIS

Thirty two completed questionnaires were analysed. Table 2 provided the category of respondents who completed the questionnaires. The profile of the respondents is shown in Table 3.

Table 2: Category of respondents.

Respondents	Distributed	Responded	Percentage of return
Contractors	20	12	60%
Engineers	12	8	67%
Quantity Surveyors	12	9	75%
Others	6	3	50%
Total	50	32	64%

On the question of awareness, 88% of the respondents (28 in number) mentioned that they were aware on C&D wastes and the rest 12% were not aware about that. Figure 3 represents respondents' agreement/disagreement on the impacts of C&D wastes on environment and public health. As we observe, 72% of the respondents agree that C&D waste affects environment and public health, with 12% of them strongly agreeing or remaining neutral on the issue. Only 4% disagreed.

Table 3: Respondents' demographic information

Personal Information	Frequency	Percent
Gender		
• Male	25	78.12
• Female	7	21.88
Age group		
• Less than 25 years	7	21.88
• 25-34 years	9	28.12
• 35-44 years	8	25.00
• 45-54 years	6	18.75
• 55 years or more	2	6.25
Working experience		
• Less than 5 years	11	34.37
• 5 -14 years	11	34.37
• More than 15 years	10	31.25

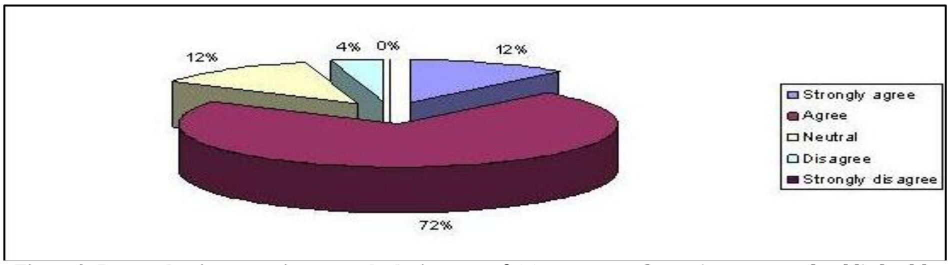


Figure 3: Respondent's perception towards the impacts of C&D waste to the environment and public health

Table 4 presents the respondents' level of knowledge on various aspects of C&D waste and its management. Last column shows the mean values of the level of understanding. We observe that the respondents' level of understanding below average on the following matters: Current percentage of C&D waste products; Waste management hierarchy; Malaysian policies and legislation in C&D waste. Apart from the above three matters, the respondents possess above average knowledge in all other aspects. In fact they are most knowledgeable in the following four matters (refer to Table 4): Definition of C&D waste; Types of C&D waste; Factors contributing to C&D waste; Benefits of C&D waste management.

Table 4: Level of knowledge on various aspects of C&D waste

Matter	Level of knowledge					Mean
	Very Poor (1)	Poor (2)	Average (3)	Good (4)	Excellent (5)	

Definition of C&D waste	0 (0)*	2 (6)	17 (53)	9 (28)	4 (13)	3.47
Types of C&D waste	0 (0)	4 (13)	17 (53)	9 (28)	2 (6)	3.28
Factors contributing to C&D waste	0 (0)	5 (16)	17 (53)	9 (28)	1 (3)	3.19
Benefits of C&D waste management	0 (0)	4 (13)	19 (59)	8 (25)	1 (3)	3.19
Roles of construction of people in managing and reducing C&D waste	1 (3)	5 (16)	16 (50)	10 (31)	0 (0)	3.09
Integrated waste management	0 (0)	8 (25)	17 (53)	6 (19)	1 (3)	3.00
Malaysian policies and legislation in C&D waste	3 (9)	9 (28)	16 (50)	2 (6)	2 (6)	2.72
Waste management hierarchy	1 (3)	11 (34)	17 (53)	3 (9)	0 (0)	2.69
Current percentage of C&D waste products	3 (9)	10 (31)	16 (50)	3 (9)	0 (0)	2.59

* The first and second numbers show the number of respondents and percentage, respectively. The same mode has been adopted in many of the subsequent tables. It is noted here that the total sample size is 32.

Does the respondents' demography (particularly, profession and extent of experience in work) have any effect on their knowledge on various aspects of C&D waste? One-way ANOVA has been performed for all the items shown in Table 4 for both profession and number of years of working experience. In this ANOVA analysis (also subsequent MANOVA analysis), independent variables are 'profession' and number of years of working experience and dependent variables are various aspects of C & D waste. Minimum p-values were found to be 0.143 (F=2.094) and 0.122 (F=2.266) for profession and working experience, respectively. Hence, respondents' profession and years of working experience do not have significant impact on the results. In other words, contractors, engineers, and quantity surveyors do not differ significantly in their opinion on the knowledge of CDW and its management. Same is the case for people having different amount of working experience. Two-way ANOVA (profession versus working experience) also confirms the findings. No interaction was found to be significant for any item (minimum p-value = 0.168 was observed for 'benefits of CDWM'). Since ANOVA considers only one dependent variable at a time, both 1-way (profession and working experience, separately) and 2-way (profession and working experience together) MANOVA were performed and the results are shown in Table 5. None of the p-values was found to be significant. Therefore, considering all the items together, the respondents' opinions do not differ significantly across various types profession and the number of years of working experience.[1]

Table 5: 1-way and 2-way MANOVA tests results on the level of knowledge on various aspects CDW.

Type of MANOVA	Independent variable	Wilk's λ	F	p	Partial η^2	Observed power
1-way	Profession	0.567	0.655	0.830	0.247	0.351
	Experience	0.412	1.238	0.279	0.358	0.683
2-way	Profession	0.245	1.358	0.239	0.505	0.638
	Experience	0.222	1.496	0.176	0.529	0.693
	Profession * Experience	0.108	1.050	0.434	0.426	0.711

Figure 4 shows the respondents' opinion towards the types of projects that contribute largest generation of C&D wastes. It is found that 75% of the respondents' view is that residential construction projects generate maximum amount of wastes and this is followed by non-residential demolition projects (69%).

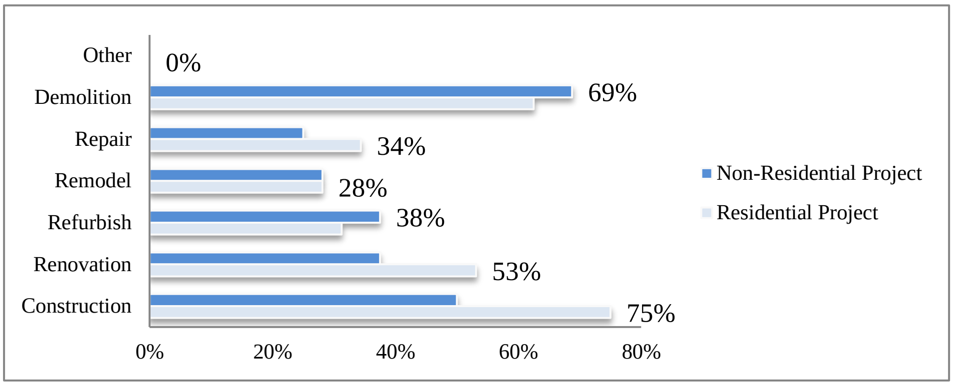


Figure 4: Respondents' opinion on types of projects which causes the biggest generation of C&D waste

According to the data obtained, 75% of the respondents' view is that residential construction projects generate maximum amount of wastes and this is followed by non-residential demolition projects (69%). One of our objectives was to identify the components of construction materials that contribute to the C&D wastes. The respondents were asked to rank the components provided from the least contributor (1) to the most contributor (5). Table 6 provides the results.

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[1] For all the ANOVA and MANOVA tests of the present study, 'Others' and 'No experience' categories under Profession and Working experience, respectively were omitted owing to smaller sample size.

Table 6: Respondents' opinion on the composition of C&D wastes.

Component	Level of contribution					Mean
	Least contributor (1)	Less contributor (2)	Moderate contributor (3)	More contributor (4)	Most contributor (5)	
Wood	0 (0)	0 (0)	16 (32)	8 (25)	8 (25)	3.75
Concrete	0 (0)	5 (16)	6 (19)	14 (44)	7 (22)	3.72
Bricks	0 (0)	5 (16)	11 (34)	8 (25)	8 (25)	3.59
Plastics	0 (0)	3 (9)	16 (50)	9 (28)	4 (13)	3.44
Others	0 (0)	1 (3)	6 (19)	1 (3)	2 (6)	3.40
Reinforced Concrete	0 (0)	5 (16)	17 (53)	8 (25)	3 (9)	3.38
Paper/ Cardboards	3 (9)	4 (13)	10 (31)	10 (31)	5 (16)	3.31
Rubble	1 (3)	8 (25)	12 (38)	5 (16)	6 (19)	3.22
Metals	2 (6)	3 (9)	17 (53)	8 (25)	2 (6)	3.16
Reinforcement	2 (6)	4 (13)	11 (34)	13 (41)	1 (3)	3.13
Drywall	1 (3)	2 (6)	22 (69)	6 (19)	1 (3)	3.13
Roofing	1 (3)	8 (25)	13 (41)	8 (25)	2 (6)	3.06
Rubber	2 (6)	7 (22)	18 (56)	2 (6)	3 (9)	2.91
Glass	3 (9)	8 (25)	12 (38)	8 (25)	1 (3)	2.88

*It is noted here that the total sample size is 32

It is clear that wood, concrete, bricks, and plastics constitute the bulk of C&D waste materials. From the whole table, the single highest percentage (69) of respondents said that drywalls constitute moderately to C&D wastes. Generally speaking, most of the respondents held the view that the components either constitute moderately or more than moderately to the C&D wastes (this is evident from the columns "Moderate contributor" and "More contributor"). We also observe that rubber and glass comprise the least amount to C&D wastes. From the mean values, we can also conclude that moderate contributors are reinforced concrete, drywall, metals, rubble, and paper/cardboards. In addition to the above findings, with one way ANOVA, one & two way MANOVA has also been performed. In this regard, the independent variables are profession and working experience and dependent variables are various composition of C & D waste. One-way ANOVA test shows that respondents' profession does not have significant impact on their opinion except the component 'Roofing'. On this component, quantity surveyors (M=3.778) and contractors (M=2.417) differ significantly (F=8.559, p=0.001). With regards to working experience, 1-way ANOVA reveals that 'less than 5 years' (M=3.000) differ significantly from the '5-14 years' (M= 3.636) (F=3.815, p=0.034). However, they do not differ on the remaining components. One-way as well as two-way MANOVA tests confirm the findings as shown in Table 7.

Table 7: 1-way and 2-way MANOVA tests results on the composition of CDW.

Type of MANOVA	Independent Variable	Wilk's λ	F	p	Partial η^2	Observed power
1-way	Profession	0.001	2.576	0.318	0.973	0.167
	Experience	0.003	1.148	0.571	0.941	0.104
2-way	Profession	0.0.000	9.554	0.099	0.989	0.417
	Experience	0.000	5.989	0.152	0.982	0.301
	Profession * Experience	0.000	3.368	0.142	0.959	0.362

A 3 × 3 factorial ANOVA was employed to determine the effects of profession and working experience on the respondents' opinion on the ranking of construction materials. The main effect of profession F(2,20)=5.449, p=0.013, η^2= 0.353 and interaction F(4,20)=3.674, p=0.021, η^2=0.424 were found significant for 'Reinforced concrete'. Overall, quantity surveyors (M=3.667) consider that reinforced concrete contribute more to the production of CDW compared to contractors (M=2.917). No other significant difference was observed in this factorial design experiment. Respondents were also asked to provide their opinion on the extent they agree/ disagree on a number of factors that generate C&D wastes. Table 8 shows the summary results.

Table 8: Respondents' opinion on factors that generate C&D wastes.

	Level of agreement/disagreement					
Factor	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	Mean
Waste due to the nature of building demolition or renovation works	0 (0)	2 (6)	6 (19)	13 (41)	11 (34)	4.03
Poor storage of construction materials	0 (0)	0 (0)	7 (22)	18 (56)	7 (22)	4.00
Carelessness of workers in handling materials	1 (3)	1 (3)	9 (28)	14 (44)	7 (22)	3.78
Waste due to design changes/variations	1 (3)	2 (6)	8 (25)	14 (44)	7 (22)	3.75
Excessive handling	0 (0)	4 (13)	12 (38)	14 (44)	2 (6)	3.44
Problems during fabrication	2 (6)	1 (3)	14 (44)	12 (38)	3 (9)	3.41
Waste due to negligence	1 (3)	3 (9)	16 (50)	10 (31)	2 (6)	3.28
Waste due to poor design specifications	1 (3)	6 (19)	10 (31)	14 (44)	1 (3)	3.25
Carelessness during quantity analysis and measurement	2 (6)	4 (13)	14 (44)	8 (25)	4 (13)	3.25
Substitution (materials delivered to the site are used for other purposes)	2 (6)	12 (38)	8 (25)	10 (31)	0 (0)	2.81

*It is noted here that the total sample size is 32

Most of the respondents are of the opinion that wastes depend on the nature of demolition/renovation of buildings. They also concur that following are three major reasons for generation of waste:

- Poor storage of construction materials;
- Carelessness on the part of workers in handling materials;
- Waste due to design changes/variations

However, the following three items were not found as significant in terms of generation of C&D wastes:

- Waste due to poor design specifications;
- Carelessness during quantity analysis and measurement;
- Substitution (materials delivered to the site are used for other purposes)

One-way ANOVA results show that respondents on the basis of profession differ on their opinion about 'Substitution'. Quantity surveyors (M=3.333) opined that substitution generates more wastes compared to contractors (M=2.333) (F=4.205, p=0.026). Tukey HSD post hoc test also confirms the findings (p=0.041). With regrds to working experience, respondents having experience 'less than 5 years' (M=3.200) and '5-14 years' (M=3.273) consider that substitution generates more wastes compared to the respondents having experience '15 years or more' (M=2.000) (F=8.197, p=0.002). Tukey HSD homogeneous subsets are shown in Table 9.

Table 9: Tukey HSD homogeneous subsets for 'Substitution'.

Experience	N	Subset for alpha =0.05	
		1	2
Less than 5 years	10	2.000	
5-14 years	10		3.200
15 years or above	11		3.273
Sig.		1.000	0.977

When profession and experience were considered jointly, 2-way ANOVA experimental design test confirms that both (Profession: F(2,20)=3.926, p=0.036, η^2=0.282; Experience: F(2,20)=3.968, p=0.035, η^2=0.284) differ significantly on 'Problem during fabrication'. Contractors (M=3.583) and quantity surveyors (M=3.556) held the view that 'Problem during fabrication' contributes in generating CDW more than engineers (M=2.875). On the other hand, respondents having working experience '5 to 14 years' (M=3.818) consider that 'Problem during fabrication' contributes more towards CDW compared to 'less than 5 years' (M=3.200) and '15 years or more' (M=3.200). However, their interaction was not found significant ($F(4,20)=1.206$, $p=0.334$, $\eta^2=0.194$). One-way and two-way MANOVA tests results are presented in Table 10, which indicate that respondents do not differ significantly on the items when they are considered together.

Table 10: 1-way and 2-way MANOVA tests results on the factors that generate CDW.

Type of MANOVA	Independent Variable	Wilk's λ	F	p	Partial η^2	Observed power
1-way	Profession	0.351	1.169	0.335	0.408	0.645
	Experience	0.366	1.240	0.277	0.395	0.699
2-way	Profession	0.198	1.639	0.236	0.554	0.640
	Experience	0.188	1.434	0.205	0.566	0.666
	Profession * Experience	0.031	1.633	0.057	0.580	0.930

Next, the results of a number of Yes/ No type of questions are presented (refer to Table 11). It is surprising to find that more than 50% of the respondents are either not familiar or they are not sure about C&D waste management. Further, almost 50% of the respondents are either not familiar or not sure about 3R principles of waste management. Again less than 50% of the respondents' companies practice 'Reuse' to lessen the burden of C&D waste materials.

Table 11: Familiarity with C&D waste management

Question	Yes	No	Not Sure
Are you familiar with C & D waste management?	13(41)	5(16)	14(44)
Are you familiar with Reduce, Reuse and Recycle (3R), composting, burning and land filling options?	18 (56)	4 (13)	10 (31)
In order to prevent larger amount of generation of C&D wastes, does your construction company practice reusing of construction materials?	13 (41)	7 (22)	12 (38)

Figure 5 provides the results on ratings (1 = Very poor, 5 = Excellent) of C&D waste management in the respondents' companies construction sites. Clearly, in most of the companies, the level of C&D management is average.

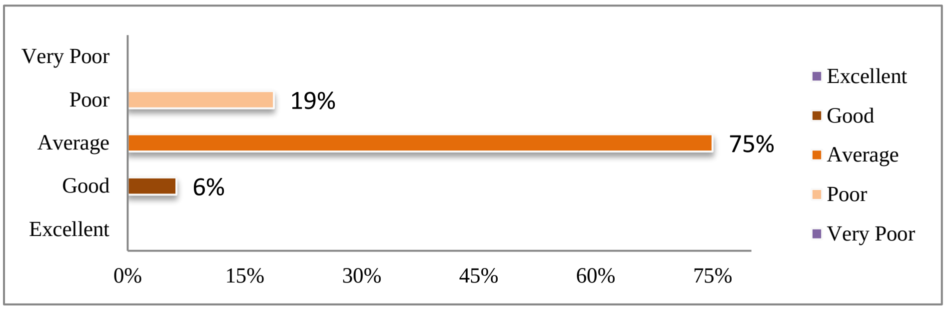

Figure 5: Rating Level of C&D waste management on construction site

C&D waste management is a part of a growing movement towards developing a sustainable world. It is important to identify the most common methods being used at the construction sites in order to protect the environment as well as to save resources, and conserve energy either directly or indirectly. Figure 6 shows the percentage of usage of various waste management methods that include reduce, reuse, recycle, composting, burning or land filling. The listing has been done for materials: wood, concrete products, reinforced concrete, reinforcement, drywall, metal products, plastics products, roofing, rubble, bricks, glass products, rubber, paper or cardboards and others.

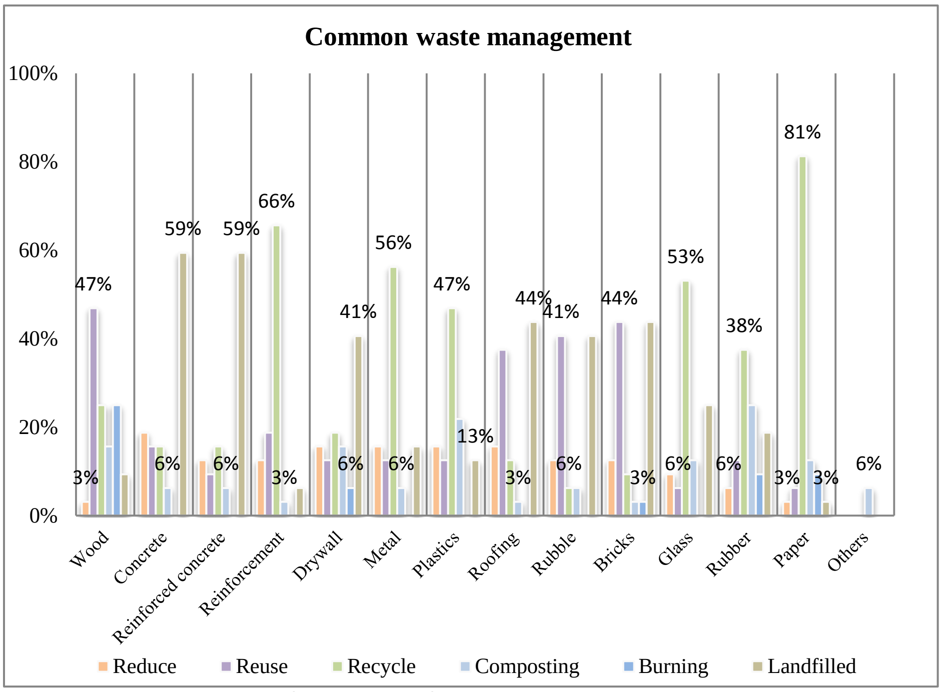

Figure 6: Extent of applications of various C&D waste management methods

From the figure, we note the following points:

- According to 47% of the respondents, reuse is the most common method to handle wood waste
- The most common method for dealing with concrete, reinforced concrete, drywall, rubble waste, roofing, and bricks is land filling; the reason could be that land filling is a cheaper option.
- Metals, plastics, papers/ cardboards are mainly recycled
- Rubbers are recycled.

Table 11 provides the summary of the most commonly used methods to deal with varieties of C&D waste materials.

Table 11: Application of C&D waste management methods

Types of C&D waste	Waste management method					
	Reduce	Reuse	Recycle	Composting	Burning	Land fill
Wood		■				
Concrete						■
Reinforced Concrete						■
Reinforcement			■			
Drywall						■
Metals			■			
Plastics			■			
Roofing						■
Rubble						■
Bricks						■
Glass			■			
Rubber			■			
Paper/ Cardboards			■			
Others				■		

All possible measures need to be taken to minimize the construction wastes. Respondents were asked to provide their opinion on the effectiveness of a number of wastes minimization strategies. Table 12 provides the summary results.

Table 12: Opinion on waste minimization strategies

Potential waste minimization strategies	Level of agreement/disagreement					Mean
	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	
Appropriate location for storage	0 (0)	1 (3)	7 (22)	17 (53)	7 (22)	3.94
Fabrication: Handling and cutting of materials appropriately	0 (0)	1 (3)	9 (28)	14 (44)	8 (25)	3.91
Standardization and flexibility in designs	1 (3)	1 (3)	7 (22)	16 (50)	7 (22)	3.84
Ensure appropriate dimensions and quality of materials	0 (0)	2 (6)	9 (28)	14 (44)	7 (22)	3.81
Proper implementation of materials management plan	0 (0)	2 (6)	7 (22)	18 (56)	5 (16)	3.81
Early plans for purchases and deliveries	0 (0)	1 (3)	11 (34)	15 (47)	5 (16)	3.75
Return ability of unused containers and pallets	0 (0)	1 (3)	11 (34)	16 (50)	4 (13)	3.72
Accuracy in take-off quantities	0 (0)	1 (3)	14 (44)	12 (38)	5 (16)	3.66
Provide convenient containers for materials storage and retrieval	0 (0)	2 (6)	15 (47)	8 (25)	7 (22)	3.63

*It is noted here that the total sample size is 32

According to the respondents, the most preferred strategies are the following:

- Appropriate location for storage
- Appropriate cutting and handling of materials
- Design standardization and flexibility in design
- Ensure appropriate dimensions and quality of materials
- Proper implementation of materials management plan

Surprisingly, respondents' profession and extent of working experience do not have significant effect on the findings on the waste minimization strategies. In the relevant 1-way ANOVA, the minimum p-value and the corresponding F-value were found to be 0.166 and 1.926, respectively (profession); the corresponding values for working experience are 0.083 and 2.722, respectively. Same is the observation even considering all the strategies together as it is noted from Table 13.

Table 13: 1-way and 2-way MANOVA tests results on the waste minimization strategies.

Type of MANOVA	Independent Variable	Wilk's λ	F	p	Partial η^2	Observed power
1-way	Profession	0.461	0.947	0.534	0.321	0.518
	Experience	0.413	1.237	0.280	0.358	0.683
2-way	Profession	0.473	0.606	0.861	0.312	0.280
	Experience	0.358	0.894	0.591	0.401	0.423
	Profession * Experience	0.116	1.009	0.483	0.417	0.688

However, the 3 × 3 ANOVA experimental results show significant interaction on two strategies, namely, 'Standardization' ($F(4,20)=4.892$, $p=0.006$, $\eta^2=0.495$) and 'Unused containers' ($F(4,20)=3.151$, $p=0.037$, $\eta^2=0.387$). With regards to main effect, experience ($F(2,20)=4.773$, $p=0.020$, $\eta^2=0.323$) has significant impact on 'Purchase plan'. Contractors (M=4.000) consider that this strategy has more potential to minimize CDW at construction sites compared to quantity surveyors (M=3.300). At the end of the questionnaire, the respondents were asked to provide more recommendations which they feel appropriate in order to reduce C&D waste materials and improving efficiency of waste management at the construction sites. The following recommendations are provided herewith that possess higher frequencies:

- Implement the Industrialized Building System (IBS);
- Control the purchasing activities systematically in order to prevent surplus materials;

- Plan appropriately at the early stage for the whole construction project;
- Use recycled materials for the future construction in order to reduce the amount of wastes generated;
- Enforce rules and regulations on proper site management and control with strict monitoring and supervision.

Since the sample size of the present research (i.e. 32) is rather small caution should be exercised to generalize the forgoing findings.

Table 14: Differences in respondent's opinion across profession, and experiences

No	Independent variables	Dependent Variables	Differences
1	Profession	Various aspect of C & D Waste	No significant difference
	Working Experiences		No significant difference
2	Profession	Composition of C & D waste	On 'roofing' component, quantity surveyors and contractors differ significantly.
	Profession and working experiences	Composition of C & D waste	Quantity surveyors consider that reinforced concrete contributes more to the production of CDW compared to contractors when working experience is considered.
3	Profession	Factors that generate C&D wastes.	Quantity surveyors are of the opinion that substitution generates more waste compared to contractors.
	Profession and working experiences	Factors that generate C&D wastes.	Contractors and quantity surveyors contend that 'Problem during fabrication' contributes in generating CDW more than engineers, when working experience is considered.
4	Profession	Waste minimization strategies	Contractors (M=4.000) consider that 'purchase plan' has more potential to minimize CDW at construction sites compared to quantity surveyors.

The summary of the significant differences in opinion between professional experiences are provided in Table 14.

CONCLUSIONS AND RECOMMENDATIONS

Over the years, SWM has attracted considerable attentions from the researchers. Since solid wastes are being generated at an increasingly higher rate all over the world, improvements in SWM techniques are in genuine need. In the present work, an attempt has been made to highlight a number of issues in SWM, particularly C&D waste management in the Klang Valley of Malaysia. First, we have observed that the main wastes generated are: wood, concrete, bricks, plastics, and reinforced concrete. The two main causes of the generation of excessive amount of wastes are poor storage of construction materials and carelessness in handling and cutting of materials. Therefore, in order to reduce waste, appropriate actions are to look for better storage and in the provision of an adequate amount of training of the construction workers, especially how to reduce the amount of wastes. We anticipate high return on investment of training to the ground level construction workers.

The following recommendations are also put forward towards improving C&D waste management in Klang Valley:

- The utilization of Industrialized Building System (IBS) to reduce waste, as suggested by some respondents;
- In order to minimize C & D wastes, awareness among various parties involved is absolutely essential;
- Hire personnel with higher professional skills and those who have greater sense of responsibility and accountability at the grass root level of construction sites.

Caution needs to be exercised to generalize the findings as the sample size of the present study was rather small. Especially, the respondents' demographic effects on the findings could be different sample size is increased.

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