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A Study on Construction Waste Management of a Refurbishment Project in Kuala Lumpur

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ABSTRACT Construction waste management is an important environmental issue. The huge volume and various compositions of construction waste have made its disposal a serious problem because it leads to environmental impacts such as landfill space and resource depletion. Greater concerns must be given to construction waste generation and management to reduce its burden to the environment. A refurbishment project site situated in Kuala Lumpur was selected for the study by regular site visits and initial environmental review (IER) was conducted to gather information on site activities and waste management practice. Environmental aspects and impacts caused by construction waste management were identified and their significance was assessed quantitatively and qualitatively. Four on-site sorting schemes were proposed and their practicality was discussed. The most significant environmental aspect was disposal of paper-based packaging waste followed by disposal of inert waste and plastic-based packaging waste, and recycling of steel containers off-site. The most preferred sorting scheme was to sort at specific work area for different types of work tasks. On-site sorting should be encouraged to facilitate construction waste reuse and recycling. Specific guidelines for construction waste management should be formulated and enforced to ensure sustainable construction.

ABSTRAK Pengurusan sisa pembinaan merupakan suatu isu alam persekitaraan yang penting. Kuantiti sisa-sisa pembinaan dan kepelbagaiannya telah menjadikan pelupusan satu masalah yang serius kerana pelupusannya membawa beberapa kesan kepada alam sekitar, seperti kekurangan ruangan tapak pelupusan sisa pepejal dan sumber-sumber semulajadi. Lebih perhatian harus ditumpukan terhadap penjanaan dan pengurusan sisa-sisa pembinaan demi meringankan beban sisa-sisa pembinaan kepada alam sekitar. Satu tapak projek pengubahsuaian di Kuala Lumpur telah dipilih untuk kajian ini. Beberapa lawatan tapak pembinaan dan peninjauan awal alam sekitar (IER) telah dijalankan untuk mengumpul maklumat tentang aktiviti-aktiviti tapak pembinaan serta pengurusan sisa-sisa pembinaan. Aspek-aspek dan impak-impak alam sekitar yang disebabkan oleh pengurusan sisa pembinaan telah dikenalpasti dan signifikasi mereka telah dinilai secara kuantitatif dan kualitatif. Empat skim untuk menjalankan pengasingan sisa-sisa pembinaan di tapak telah dicadangkan dan kesesuaiannya telah dibincangkan. Aspek-aspek alam sekitar yang paling signifikan ialah pelupusan bungkusan berasaskan kertas. Ini diikuti dengan sisa lengai dan bungkusan berasaskan plastik serta kitar semula bekas besi di luar tapak. Skim pengasingan yang paling sesuai digunakan ialah mengadakan kawasan kerja yang berlainan untuk kerja-kerja yang berlainan. Pengasingan sisa pembinaan di tapak harus dilaksanakan untuk memudahkan usaha kitar semula. Garis panduan untuk pengurusan sisa pembinaan harus dirangkakan dan dikuatkuasakan untuk merealisasikan hasrat pembinaan mampan.

(Construction waste management; Environmental aspects and impact)

INTRODUCTION

The construction industry plays a major role in Malaysia's development. New townships, high-rise buildings, highway, light-rail transport (LRT), monorail and shopping malls of various futuristic architectural designs celebrate the modern construction advancement. Construction industry is both growth initiating and growth dependent as it establishes infrastructures required for socio-economic development, which contribute to overall economic growth, and eventually leads to increase in income that generate demands for additional construction activity [1]. Construction industry is one of the largest industries in developed and developing countries in terms of investment, employment and Gross Domestic Products (GDP) contribution [2]. In Malaysia, construction industry has contributed about 4.5 percent to 4.7 percent (4.5% – 4.7%) in terms of GDP for the years from 1997 to 1999 [3]. Between 1965 and 2001, the industry's share of GDP fluctuated between 3.2 percent and 5.4 percent (3.2% - 5.4%) [1]. Countries with more dynamic national economies are largely bunched at the upper end of this range. Construction industry also creates physical assets which are the bases of virtually every aspect of development and the creation of much of the world's man-made capital [4].

Construction industry is part of the economic sector that constructs, alters, repairs and demolishes buildings, civil engineering works and other similar structures. It also includes the assembly and installation of prefabricated components and building engineering services [1]. The construction industry in Malaysia is governed by regulations under the Construction Industry Development Board (CIDB) Malaysia, the National Institute of Occupational Safety and Health (NIOSH) Malaysia and by local authorities such as the Ministry of Housing and Local Government, Local Government Department, Fire Services Department, Sewerage Services Department and Department of Town and Country Planning, where the construction projects take place.

However, construction industry also brings adverse environmental impacts. For example, forest clearing for development projects can lead to local environmental impacts, such as landslide, flash flood, global warming and natural destruction phenomenon such as rise of sea water level. Therefore, reducing the environmental impacts of construction is a continuous professional and social concern in promoting sustainable development [5]. It is important to incorporate the concept of sustainable development in the construction industry because the industry is not by nature an environmentally friendly industry [6]. Its environmental impacts span a few aspects, namely: air, water, natural resources, and social and aesthetic. It is important to first identify the elements in the construction industry that cause adverse environmental impacts by means of Initial Environmental Review (IER) so that proper mitigating measures can be formulated.

The importance of construction waste management can be seen in the European Union definition of sustainable construction where the terms are defined as the use and or promotion of: environmentally friendly materials, energy efficiency in buildings, and management of construction and demolition waste [7]. Construction and demolition (C & D) wastes are a type of the solid wastes such as wood, steel, concrete and dirt generated within a community, which arise from new construction sites, road construction and maintenance, total or partial demolition of buildings and civil infrastructure, land levelling, foundation and civil works, and broken pavement, for example, wood, steel, concrete and dirt [8, 9]. Usually, C & D wastes consist of eight to twenty percent of municipal solid wastes where the typical value is 14 percent [8]. The nature and volume of C & D wastes are also influenced by the age of a building, for example, many older houses are built with reinforced concrete while modern houses have been based on steel frames [9]. Demolition waste usually consists of high percentages of inert materials like bricks, sand and concrete but the actual characteristics of the waste may vary depending on the types of structures demolished and the demolition techniques used [10].

C & D wastes usually consist of large volume with bulky items such as timber formwork and fine debris such as sand. Therefore, its disposal method could pose a large issue within the process of construction, if it has to be an environmental friendly one. C & D wastes management should flow from waste prevention, waste minimization, reuse and recycling to the ultimate disposal. Although C & D waste streams are generally disordered, contaminated, heavily mixed and sometimes physically altered to a point where reuse and recycling is difficult, 80 percent of the C & D wastes is reusable or recyclable especially for construction waste, as new construction waste is usually clean [9, 11]. The reuse and recycling opportunities for C & D wastes depend on the markets for the individual materials and the technology for segregating and processing the wastes. Recycling of C & D wastes is most effective if the wastes are properly separated on site according to their nature or level of mixture and less money would be required for material separation [11].

Currently, there are no specific policies and guidelines for the disposal of construction waste in Malaysia. However, dumping of waste at an unauthorized area is illegal. The construction waste disposal contractor either disposes the construction waste in a landfill which accepts construction waste or arranges for the waste to be dumped in an area requiring land levelling, for example, old mining ponds to be converted into recreational areas. With the ever increasing volume of solid waste in Malaysia and scarcity of land in the urban area where majority of the construction and demolition activities take place, waste disposal problem is becoming serious. Furthermore, C & D wastes are generated in large quantities and their recycling is uncommon. The aim of this study is to investigate the construction waste management practice at a selected site and to identify environmental aspects and impacts caused by construction waste and to recommend mitigating actions to mitigate the significant adverse impacts.

METHODOLOGY

A site of refurbishment project situated in urban and sophisticated Kuala Lumpur City Centre was chosen for the study. An Initial Environmental Review (IER), which constitutes of checklists compiled from Initial Environmental Review Protocol from EMS Training Resource Kit by United Nations Environmental Programme, International Chamber of Commerce and International Federation of Consulting Engineers [12] and literature review, was conducted through site visits in order to obtain the on site activities and current construction waste management practice. Environmental aspects and impacts caused by construction waste management were derived from the IER.

The methods used for assessing the significance of the environmental aspects and impacts identified were adapted from Wang [13]. The assessment was carried out qualitatively (Method A) and quantitatively (Method C). Wang had identified three methods to assess the environmental impacts i.e. Method A, which is qualitative, Method B and Method C, which are quantitative. However, the author had adopted Method C because it classifies the range of significance level. The environmental aspects and impacts were judged qualitatively by considering the factors of severity and probability which will result in priority rating while the quantitative method was carried out by considering pre-determined key criteria of environmental and business concerns where each criterion was assigned a score.

RESULTS AND DISCUSSION

The Site

The site is situated amidst downtown KLCC and adjacent to high-rise commercial buildings. The project studied was a refurbishment and addition of an existing 14-storey hotel project. The area for the site was 6250 m^2. Upon completion, the original 14-storey hotel guestroom will have additional two floors with a new 16-storey guestroom block and a four-storey parking block adjoining the existing block. The project was started in March 2004 and was expected to complete in June 2005. There were approximately 20 officers and 280 workers working on site. Figure 1 shows the flow of operations on site.

Construction Waste Generated From On Site Activities

Table 1 shows the main wastes generated from the activities from the finishing and furnishing/ renovation stage. It can be noted that the types of wastes generated from the activities onsite were a mixture of inert and non-inert wastes. Literature review showed various classifications of C & D wastes. Some classified C & D waste into construction waste and demolition waste [8, 14]. Wong and Yip classified C & D waste into inert and non-inert wastes [15] while Poon *et al.* [16] classified it into structural and finishing wastes. The wastes generated on the site studied were easily classified as finishing wastes not only due to the wastes were caused by activities in the finishing and furnishing/ renovation stage, but also due to the types of wastes generated, for instance, surplus cement mortar for plastering and screeding; broken raw material such as brick, tile and granite; paints; and packaging waste for furniture.

Raw Materials Stored On Site

Due to congested site space and for safety purposes, most of the raw materials used on site were scheduled for delivery according to the various phases of the operation. This method is called "Just-In-Time Delivery". The "Just-In-Time Delivery" strategy reduces the time that materials would be stored on site and thus reduces the potential for damage from poor handling and storage. Furthermore, it eliminates the need for long-term site storage and the danger of over-ordering [17]. Thus, extra space and cost for constructing storage area for raw materials and security system can be saved. Generally, materials for the finishing and furnishing/ renovation stage were stored in a cool, well-ventilated and dry place, away from direct sunlight. All materials were under the responsibility of the Material Controller and supervisor on duty at each floor level. There are procedures for onsite materials handling which not only prevent unnecessary waste and loss of money due to replacement, but also take care of health and safety issues [11]. For instance, spillage of diesel will cause fire hazard.

Waste Handling and Waste Disposal

Rubbish chute installed at the existing building was used to channel the construction waste to the waste pit. The construction waste collected at the waste pit was disposed off site by the licensed subcontractor using 3-tonne lorry daily from three to six loads. The cost of hauling service was RM250 per day. However, the contractor needed to pay an extra disposal fee of RM20 per trip. Special wastes such as used engine oil, pesticide containers, and paint containers were not disposed directly to the waste pit. Engine oil was stored in drums and sent back to workshop where the personnel in the workshop would seek proper disposal. The paint containers were recollected and recycled off-site by subcontractors doing the trade. For water proofing containers, the subcontractors washed the containers prior to disposal at the waste pit as construction waste. There should be proper disposal procedures for different types of waste arising from different activities [18]. For instance, environmentally threatening items such as anti-termite treatment, waterproofing substances (some waterproofing substances are not biodegradable and some have the tendency to bioaccumulate) and paint require special handling and disposal procedures due to their hazard potential.

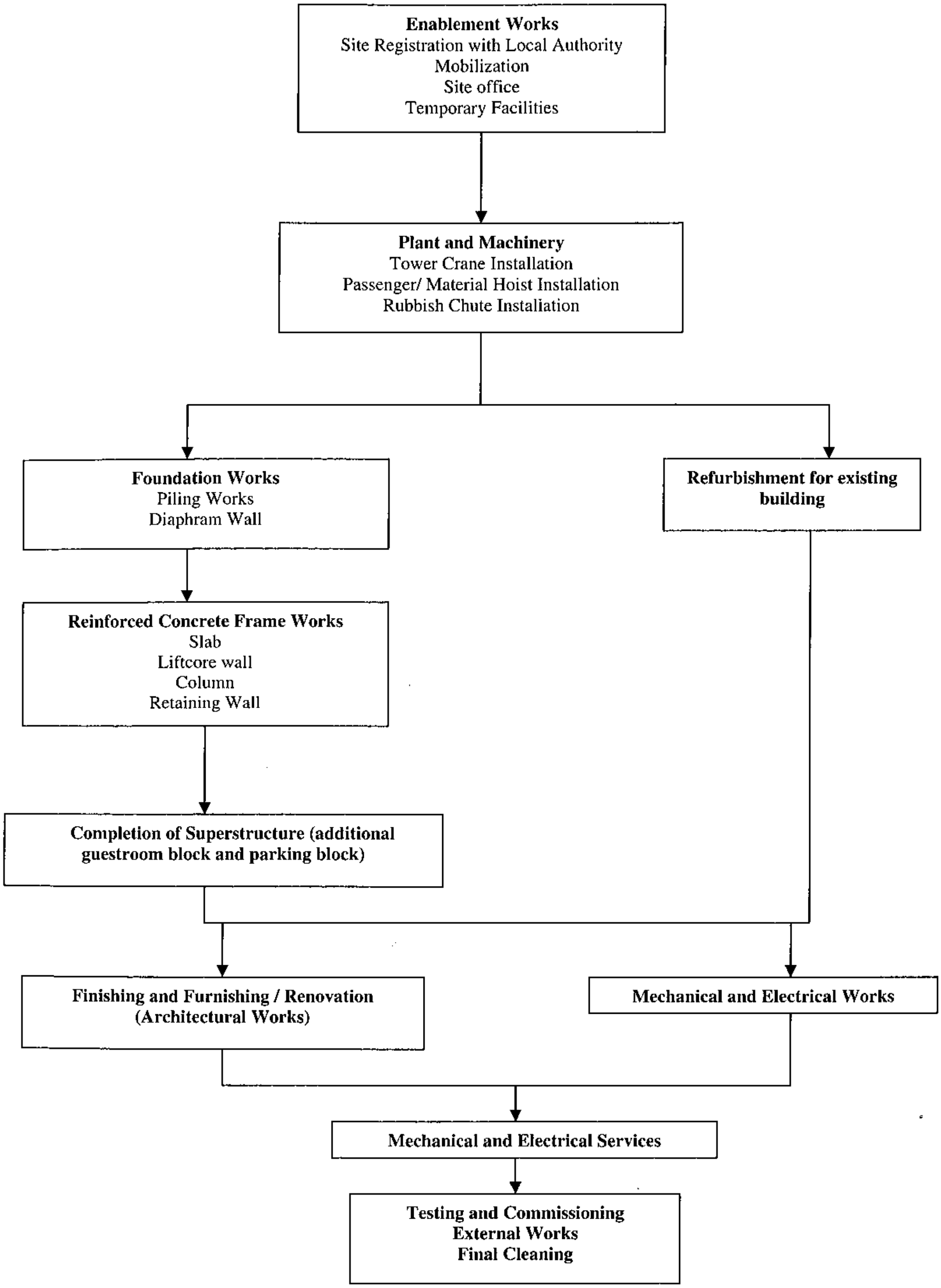

Figure 1. The Flow Diagram of Operations on the Construction Site

Table 1. Waste Generated from Different Activities during the Finishing and Furnishing/renovation Work

NO.	ACTIVITIES	INPUT	OUTPUT MATERIAL
1	Wall Plastering	• Cement • Sand • Lime • Water	• Plaster mix • Cement paper packaging
2	Floor Screeding	• Cement • Sand • Water • Non-metallic floor hardener	• Screed mix • Screed mix contaminated with non-metallic floor harderner
3	Waterproofing	Waterproofing substances: • Axel Crystle 126 (powder form) • Axel Top 208 M Metalic Floor Hardener • Axel Quartzite 403 • Axel Aquashield 100 PT A • Axel Aquashield 100 PT B • Axel Insulguard 801 • Axel Latex 1001	• Waterproofing substances
4	Floor and Wall Tiling	• Cement/ adhesive cement • Polymer • Sand • Water • Lime • Grouting material	• Tiles • Cement mortar • PVC tile rim
5	Ceiling Fixing	• Gypsum pinhole board	• Cutting waste
6	Timber Flooring	• Plywood • Adhesive glue (Stauf) • Sand paper • Varnish • Sardolin Oil • Skirting material	• Plywood • Sand paper • Skirting and timber strip cut-off
7	Plaster ceiling work	• Plasterboard • Casting plaster • Grouting material • Stopping compound	• Plaster board scraps
8	Aluminium and Glazing Work	• Aluminium frames • Glass • Silicon and gasket • Tape	• Tape • Broken glass • Gasket
9	Granite and Marble Works	• Marble • Adhesive mortar (Marble mate + Hydroment) • Grouting cement • Magic Repellent Impregnator • Polyethylene sheet/ plywood	• Adhesive mortar • Magic Repellent Impregnator • Polyethylene sheet/ plywood • Broken marble and granite
10	Brick Work	• Brick • Cement • Sand • Water	• Broken Brick • Cement mortar • Wooden pallet
11	Anti-termite Treatment	• Chlorpyrifos	• Chlorpyrifos
12	Painting Works	• Variety of Paints	• Paint containers
13	Emulsion Coating to Internal Plaster Wall	• Axel Emulsion Primer White • Axwall 602 Emulsion • Axwall 602 top coat	• Paper packaging

Table 1. Waste Generated from Different Activities during the Finishing and Furnishing/renovation Work (continued)

NO.	ACTIVITIES	INPUT	OUTPUT MATERIAL
14	Skim Coating	• J-Plasta skim coat material	• Steel containers
15	Production and Positioning of Loose and Built-in Furniture	• Prefabricated furniture	• Bubble pack • Corrugated carton
17	Installation of Sanitary Fittings	• Sanitary fitting	• Sanitary fitting

On Site Waste Sorting Possibility

Four waste sorting schemes for future similar site condition were proposed and the practicability was judged against factors affecting the choice of sorting scheme [16]: Site space, Management effort, Labour, Cost, Interference with normal activities, and Waste sortability. A rating scale of 1 to 4 was used for each criterion. The indicator of the scale is shown below:

1 **2** **3** **4**

1st choice ⟶ Last choice

Lowest cost ⟶ Highest cost

Table 2 shows the four sorting schemes proposed and the judgement on the practicability of the schemes proposed.

Site Space

The manual sorting at rubbish chute will occupy the least site space as the sorting area will be at the waste pit and no extra space is required. The least favourable choice will be having two rubbish chutes because it will interfere with the renovation of the particular guestroom used for opening of rubbish chute.

Management Effort

All schemes required extra management effort in allocating space for extra rubbish chute and collection bins and setting special procedures for waste removal off-site except the fourth scheme which is similar to the current practice onsite and therefore requires little extra effort.

Labour and Cost

Scheme four will allow recyclables to be collected automatically when the wastes are to be cleared from the work place after the end of each phase of work by the workers doing the works and therefore will not incur much extra cost. The first scheme will incur the highest cost in terms of labour and raw material needed for installation of extra rubbish chute.

Table 2. The Proposed Waste-Sorting Schemes

NO.	SCHEME	SITE SPACE	MANAGEMENT EFFORT	LABOUR AND COST	INTERFERENCE WITH NORMAL ACTIVITIES	WASTE SORTABILITY
1	2 rubbish chutes: 1 for recyclable (e.g. steel/ wood) and 1 for other waste.	4	4	4	4	4
2	Separate bins for recyclable (e.g. Steel/ wood).	3	3	3	3	2
3	Manual sorting at rubbish chute.	1	2	2	2	3
4	Sort at specific work area for different types of work.	2	1	1	1	1

Interference with Normal Activity
Scheme four is similar to the current practice on the site studied and therefore will not interfere much with normal activity. The other schemes will acquire extra spaces for setting up the waste sorting areas and eventually will congest the site space, which will pose a threat to the safety on site.

Waste Sortability
The fourth scheme will result in highest waste sorting because the wastes in specific work place are not heavily mixed and can be sorted easily. The first scheme seems to result into the highest rate of waste sorting. However, there is a risk of workers dumping all kind of wastes into both rubbish chutes.

From all the schemes discussed above, the fourth scheme was the best option for the future construction site with similar site condition. A previous study showed that the best option to obtain high separation of non-inert materials from inert materials at the source of waste generation was the first scheme [16]. However, in this study, the scheme proposed is to separate recyclables and non-recyclables. Waste recycling would be more successful by proper source separation and providing separated bins for all recyclables [11].

Recycling and Reuse Possibility
Steel waste and steel scraps such as door stiffeners and aluminium scraps were collected and sold to scraps collectors. Substance such as excess waterproofing chemical was reused elsewhere on site for similar purpose. The formworks were reused until damaged. Reusable timbers were collected and sent to other sites for reuse. Furthermore, excess ready-mixed concrete was reused for non-structural applications such as containment area for petroleum product storage, generator set area, diesel tank area and surface improvement for access road.

It was observed that recycling could have been practised for wood pallet and paper or plastic packaging because the finishing and furnishing/ renovation stage acquired lots of raw materials which were well-packed in either corrugated containers, plastic containers or stacked wooden pallet. The amount of plastic and paper packaging waste in the waste pit was significant. Therefore, recycling of these wastes should be done. However, the attempt of recycling depends on a few factors: availability of market for the recyclables, sorting of C & D waste on site, collection and transport, and contamination [18]. For example, if the waste wood, which was recycled as fuel wood, was contaminated, then the recycled wood would lose its value [19]. Therefore, better planning before demolition and effective management is essential to increase the quantity and quality of recyclable and reusable materials obtained from site [10]. Although recycling is a good activity, the availability of technology and facility for recycling as well as the safety and health aspect of the recycling process should be considered as well. Generally, the market for recycled materials is a problem. However, by being proactive in recycling C & D waste, market for the recyclable and reusable waste would eventually be created [20].

Environmental Aspects and Impacts Identified
The environmental aspects and impacts of construction wastes identified in this study are shown in Table 3. The condition of environmental aspects is classified as either occurring in normal or abnormal situations. The environmental impacts are classified as either positive or negative impact. Positive impact is an aspect that brings beneficial change to the environment while negative impact is an aspect that brings adverse change to the environment.

Table 3. Environmental Aspects and Impacts Identified

NO.	ENVIRONMENTAL ASPECTS	CONDITION	ENVIRONMENTAL IMPACTS	NEGATIVE/POSITIVE IMPACT
	Wall Plastering			
1	Disposal of plaster left-over.	Normal	Landfill space depletion.	Negative
2	Consumption of water, sand and cement.	Normal	Natural resource depletion.	Negative
3	Run-off of sand.	Abnormal	Sedimentation in drainage system.	Negative
4	Disposal of plaster due to mixing error.	Abnormal	Landfill space depletion and natural resource depletion.	Negative
5	Disposal of cement paper packaging.	Normal	Landfill space depletion and renewable resource depletion.	Negative
	Floor Screeding			
6	Disposal of screed mix left-over.	Normal	Landfill space depletion.	Negative
7	Consumption of water, sand and cement.	Normal	Natural resource depletion.	Negative
8	Disposal of mixture of screed mix and non-metallic floor hardener.	Abnormal	Potential soil contamination.	Negative
9	Disposal of cement paper packaging.	Normal	Landfill space depletion and renewable resource depletion.	Negative
10	Disposal of screed mix due to mixing error.	Abnormal	Landfill space depletion and natural resource depletion.	Negative
	Waterproofing			
11	Washing and disposal of waterproofing containers.	Normal	Run-off of non-biodegradable waterproofing substances contaminate water courses.	Negative
12	Reuse mixture of ready-mix concrete and waterproofing substances for non-structural use.	Normal	Reduce landfill space depletion.	Positive
13	Disposal of packaging (plastic containers and bags).	Normal	Landfill space depletion.	Negative
14	Reuse of surplus waterproofing substances in other parts of site.	Normal	Reduce stress on water courses.	Positive
	Floor and Wall Tiling			
15	Disposal of broken tile.	Normal	Landfill space depletion.	Negative
16	Disposal of excessive adhesive mortar.	Normal	Landfill space depletion.	Negative
17	Consumption of water, sand and cement.	Normal	Natural resource depletion.	Negative
18	Disposal of carton box.	Normal	Landfill space depletion and renewable resource depletion.	Negative

Table 3. Environmental Aspects and Impacts Identified (Continued)

NO.	ENVIRONMENTAL ASPECTS	CONDITION	ENVIRONMENTAL IMPACTS	NEGATIVE/POSITIVE IMPACT
	Ceiling Fixing			
19	Disposal of damaged galvanized wire hanger.	Normal	Landfill space depletion and non-renewable resource depletion.	Negative
20	Disposal of gypsum board scraps.	Normal	Landfill space depletion.	Negative
	Timber Flooring			
21	Disposal of damaged plywood and plywood cut-off.	Normal	Landfill space depletion and renewable resource depletion.	Negative
22	Disposal of timber flooring and skirting cut-off.	Normal	Landfill space depletion and renewable resource depletion.	Negative
	Plaster Ceiling			
23	Disposal of plaster board scraps.	Normal	Landfill space depletion.	Negative
24	Disposal of damaged galvanized wire hanger.	Normal	Landfill space depletion and non-renewable resource depletion.	Negative
	Aluminium and Glazing			
25	Recycle damaged Aluminium frames.	Abnormal	Reduce landfill space depletion and non-renewable resource depletion.	Positive
26	Disposal of broken glass.	Abnormal	Landfill space depletion.	Negative
27	Disposal of plastic packaging.	Normal	Landfill space depletion.	Negative
28	Disposal of paper packaging.	Normal	Landfill space depletion and renewable resource depletion.	Negative
	Granite and Marble Works			
29	Disposal of broken marble and granite.	Normal	Landfill space depletion and non-renewable resource depletion.	Negative
30	Disposal of polyethylene sheet cover.	Normal	Landfill space depletion.	Negative
31	Disposal of plywood cover.	Normal	Landfill space depletion and renewable resource depletion.	Negative
32	Disposal of excessive adhesive mortar.	Normal	Landfill space depletion.	Negative
33	Consumption of water, sand and cement.	Normal	Natural resource depletion.	Negative
34	Disposal of carton box	Normal	Landfill space depletion and renewable resource depletion.	Negative
	Brick Work			
35	Disposal of broken brick.	Normal	Landfill space depletion and resource depletion.	Negative
36	Disposal of excessive cement mortar.	Normal	Landfill space depletion.	Negative
37	Consumption of water, sand and cement.	Normal	Natural resource depletion.	Negative
38	Disposal of plastic packaging.	Normal	Landfill space depletion.	Negative
39	Disposal of wooden pallet.	Normal	Landfill space depletion and renewable resource depletion.	Negative

Table 3. Environmental Aspects and Impacts Identified (Continued)

NO.	ENVIRONMENTAL ASPECTS	CONDITION	ENVIRONMENTAL IMPACTS	NEGATIVE/POSITIVE IMPACT
	Anti-Termite Treatment			
40	Spillage of chlorpyrifos onto the ground.	Abnormal	Soil contamination.	Negative
41	Seepage of chlorpyrifos into the soil.	Abnormal	Soil contamination.	Negative
	Painting Work			
42	Recycling of steel containers off-site.	Normal	Reduce non-renewable resource depletion.	Positive
43	Spillage of thinner/ paint.	Abnormal	Soil contamination.	Negative
44	Disposal of brush.	Abnormal	Landfill space depletion.	Negative
	Emulsion Coating to Internal Plaster Wall			
45	Recycling of steel containers off-site.	Normal	Reduce non-renewable resource depletion.	Positive
46	Disposal of brush.	Abnormal	Landfill space depletion.	Negative
	Skim Coating			
47	Disposal of surplus skim coating lump.	Abnormal	Landfill space depletion.	Negative
48	Disposal of paper packaging.	Normal	Landfill space depletion and renewable resource depletion.	Negative
	Installation of Ready-made Furniture			
49	Disposal of bubble pack packaging protector.	Normal	Landfill space depletion.	Negative
50	Disposal of corrugated carton packaging.	Normal	Landfill space depletion and renewable resource depletion.	Negative
	Installation of Sanitary Fittings			
51	Disposal of broken sanitary ware.	Normal	Landfill space depletion.	Negative

Significant Environmental Aspects and Impacts Identified

Table 4 shows the comparison of significant assessment by method A (qualitative method) and method C (quantitative method). Only selected environmental aspects and impacts were being assessed because some environmental aspects and impacts identified were of similar nature, characteristics and 'frequency'.

There were four environmental aspects and impacts identified as the most significant in both method A and method C: Disposal of cement paper packaging; Disposal of carton boxes; Disposal of paper packaging for aluminium glazing; and Disposal of corrugated carton packaging for ready-made furniture, which were of paper based packaging wastes. The environmental impacts of these wastes are landfill space depletion and renewable resource depletion, which is forest resource. Forest resource is widely utilized for making wood product such as wood furniture, packaging and construction materials such as plywood and timber flooring. The loss of forest resource causes environmental problems such as landslide, flash flood, impact on biological diversity and global carbon cycle. Therefore, the paper-based packaging wastes disposal will not only shorten the lifespan of the landfill but also cause adverse environmental problem. A previous study showed that packaging waste was one of the five most significant sources of construction waste [21]. Furthermore, the depletion of forest resources would cause disruption of construction process or increase in construction cost due to construction industry being heavily reliant on the raw materials from natural resources [22].

The second most significant environmental aspect were: Disposal of plaster and screed mix left-over; Disposal of plastic packaging; Disposal of gypsum board and plaster board scraps; and Disposal of bubble pack packaging protector. Plaster and screed mix left-over, and gypsum board and plaster board scraps are inert waste. Furthermore, gypsum board is non-biodegradable. Therefore, disposal of these inert wastes would definitely take up much of the landfill space and decrease the landfill lifespan. Plastic packaging is non-biodegradable and therefore, recycling of plastic is a considerable option. Studies have shown environmental benefit of recycling and reuse of plastic-based packaging. The benefits include reducing the amount of waste disposed in landfills, conservation of raw petrochemical products, energy saving and reduction in greenhouse gas emissions [23, 24].

The third high ranking was a positive impact, recycling of steel containers off-site. Steel is a non-renewable resource and therefore its recycling would prolong its sustainable use. The main reason the steel containers were not disposed off to landfill was due to its market price. This reason also leads to the recycling of damaged aluminium frames (aspect no. 25). Ready-mix concrete (aspect no. 12) was also recycled for the same reason, mainly for non-structural uses such as containment area for petroleum product storage, generator set area, diesel tank area and surface improvement for access road. The three lowest ranking aspects were all from abnormal situations: Run-off of sand; Disposal of plaster due to mixing error; and Spillage of Chlorpyrifos onto the ground. Abnormal situations have lower rank in both method A and method C. The classification of method A and method C are affected by the condition of environmental aspects, for example, if the aspects happened only under abnormal situation or unlikely to happen, then the significance will be lesser.

Construction waste management issue is a very significant one. This issue is also significant in other countries [14, 27, 21, 25]. Most of the aspects showed high significant levels. This is similar to Wang [13] where most environmental aspects and impacts under the waste management issue had high significant levels. Disposal of C & D waste has great impact on the environment [26] particularly landfill space depletion and natural resource depletion [4]. This is due to the vast quantity of C & D waste and mixture of waste characteristics found in the usually heavily mixed C & D waste. The C & D materials mostly comprise of natural resources: renewable and non-renewable, e.g. sand, metal, cement, brick, steel and plywood. Furthermore, Cole [11] had included human health issues as one of the impacts due to the usage of materials and substances in construction sites, for example, paints, solvents, wood preservatives, pesticides, adhesive and sealants.

Table 4. Comparison of Significant Assessment by Method A and Method C (Qualitative and Quantitative Method)

NO.	ENVIRONMENTAL ASPECTS	ENVIRONMENTAL IMPACTS	METHOD A SIGNIFICANCE LEVEL	PRIORITY RANKING	METHOD C SIGNIFICANCE LEVEL	PRIORITY RANKING
	Wall Plastering					
1	Disposal of plaster left-over.	Landfill space depletion.	Top	1	Very Significant	2
2	Consumption of water, sand and cement.	Natural resource depletion.	Top	1	Very Significant	6
3	Run-off of sand.	Sedimentation in drainage system.	Low	4	Non-Significant	16
4	Disposal of plaster due to mixing error.	Landfill space depletion and natural resource depletion.	Low	4	Non-Signficant	17
5	Disposal of cement paper packaging.	Landfill space depletion and renewable resource depletion.	Top	1	Very Significant	1
	Floor Screeding					
6	Disposal of screed mix left-over.	Landfill space depletion.	Top	1	Very Significant	2
8	Disposal of mixture of screed mix and non-metallic floor hardener.	Potential soil contamination.	Low	4	Very Significant	12
	Waterproofing					
11	Washing and disposal of waterproofing containers.	Run-off of non-biodegradable waterproofing substances contaminate water courses.	Medium	3	Very Significant	8
12	Reuse mixture of ready-mix concrete and waterproofing substances for non-structural use.	Reduce landfill space depletion.	Top	1	Very Significant	4
13	Disposal of packaging (plastic containers and bags).	Landfill space depletion.	Top	1	Very Significant	2
14	Reuse of surplus waterproofing substances in other parts of site.	Reduce stress on water courses.	High	2	Very Significant	11
	Floor and Wall Tiling					
15	Disposal of broken tile.	Landfill space depletion.	High	2	Very Significant	7
16	Disposal of excessive adhesive mortar.	Landfill space depletion.	Medium	3	Very Significant	10
18	Disposal of carton box.	Landfill space depletion and renewable resource depletion.	Top	1	Very Significant	1
	Ceiling Fixing					
19	Disposal of damaged galvanized wire hanger.	Landfill space depletion and non-renewable resource depletion.	Medium	3	Very Significant	9
20	Disposal of gypsum board scraps.	Landfill space depletion.	Top	1	Very Significant	2

Table 4. Comparison of Significant Assessment by Method A and Method C (Qualitative and Quantitative Method) (Continued)

NO.	ENVIRONMENTAL ASPECTS	ENVIRONMENTAL IMPACTS	METHOD A SIGNIFICANCE LEVEL	PRIORITY RANKING	METHOD C SIGNIFICANCE LEVEL	PRIORITY RANKING
	Timber Flooring					
21	Disposal of damaged plywood and plywood cut-off.	Landfill space depletion and renewable resource depletion.	High	2	Very Significant	5
	Plaster Ceiling					
23	Disposal of plaster board scraps.	Landfill space depletion.	Top	1	Very Significant	2
	Aluminium and Glazing					
25	Recycle damaged Aluminium frames.	Reduce landfill space depletion and non-renewable resource depletion.	Medium	3	Very Significant	11
26	Disposal of broken glass.	Landfill space depletion.	Low	4	Very Significant	10
27	Disposal of plastic packaging.	Landfill space depletion.	Top	1	Very Significant	2
28	Disposal of paper packaging.	Landfill space depletion and renewable resource depletion.	Top	1	Very Significant	1
	Granite and Marble Works					
29	Disposal of broken marble and granite.	Landfill space depletion and non-renewable resource depletion.	High	2	Very Significant	9
	Brick Work					
35	Disposal of broken brick.	Landfill space depletion and resource depletion.	High	2	Very Significant	7
39	Disposal of wooden pallet.	Landfill space depletion and renewable resource depletion.	Top	1	Very Significant	5
	Anti-Termite Treatment					
40	Spillage of chlorpyrifos onto the ground.	Soil contamination.	Low	4	Significant	15
41	Seepage of chlorpyrifos into the soil.	Soil contamination.	Low	4	Very Significant	13
	Painting Work					
42	Recycling of steel containers off-site.	Reduce non-renewable resource depletion.	Top	1	Very Significant	3
43	Spillage of thinner/ paint.	Soil contamination.	Low	4	Significant	14
44	Disposal of brush.	Landfill space depletion.	Low	4	Very Significant	10

Table 4. Comparison of Significant Assessment by Method A and Method C (Qualitative and Quantitative Method) (Continued)

NO.	ENVIRONMENTAL ASPECTS	ENVIRONMENTAL IMPACTS	METHOD A SIGNIFICANCE LEVEL	PRIORITY RANKING	METHOD C SIGNIFICANCE LEVEL	PRIORITY RANKING
	Installation of Ready-made Furniture					
49	Disposal of bubble pack packaging protector.	Landfill space depletion.	Top	1	Very Significant	2
50	Disposal of corrugated carton packaging.	Landfill space depletion and renewable resource depletion.	Top	1	Very Significant	1
51	Disposal of broken sanitary ware.	Landfill space depletion.	Medium	3	Very Significant	10

RECOMMENDATIONS FOR THE MITIGATING MEASURES FOR SELECTED SIGNIFICANT ENVIRONMENTAL ASPECTS AND IMPACTS

The impact(s) of environmental aspects identified from the construction waste management of the site studied could have both short term and long-term effects towards the environment. In this study, the most significant environmental aspects identified consisted of paper based packaging waste. Therefore, the paper based packaging waste should be separated from waste stream, collected and recycled. The contractor may reuse the carton boxes and corrugated cartons for on-site storage purpose, for example, waste paper storage. When the waste paper is sold, the collector can collect the whole carton off-site. This makes disposal and recycling occur at the same time. On the other hand, the contractor may use the corrugated carton as protective cover for floor tiling or granite and marble work.

The plastic based packaging waste can be collected and sent back to the supplier for reuse while the plaster and screed mix left-over, and gypsum board and plaster board scraps can be reduced through improved work efficiency. The damaged plywood and plywood cut-off from timber flooring and wooden pellet from brick packaging should be salvaged and reused or recycled. Waste wood can be recycled for use in erosion control and groundcover, organic soil amendment in agriculture, chipboard, export as fuelwood and as animal bedding [18]. Inert waste such as plaster and gypsum board and screed mix leftover should be separated from waste stream, collected and used for land reclamation; or by reducing the quantity through improved work efficiency.

CONCLUSIONS

Waste management is a very significant issue. Most of the aspects showed high significant levels. Disposal of construction and demolition (C & D) waste has great impact on the environment particularly landfill space depletion and natural resource depletion. This is due to the vast quantity of C & D waste and mixture of waste characteristics found in the usually heavily mixed C & D waste. Furthermore, human health issues could have arisen from the usage of materials and substances in construction sites.

Currently, there are no specific guidelines for C & D waste management and disposal. The CIDB Malaysia should play a leading role in formulating specific guidelines for the C & D waste management and disposal to help the construction industry manage its C & D waste. In addition, specific and clear classification of C & D waste should be determined to ease the management of C & D waste. Most of the current regulations governing the construction industry are for safety, welfare, pollution prevention and town planning. Specific regulations concerning the C & D waste management and disposal such as reuse, recycling, sorting and disposal should be formulated.

C & D waste management will become a great issue in the future due to landfill and resource depletion. Both issues will cause increased cost to the construction industry because there is a possibility that high hauling fee and landfill tax will be imposed on the disposal of C & D waste. Hence, on-site waste sorting and recycling should be implemented. The simplest and most practical waste sorting method is by implementing on-site specific area waste sorting, which had been shown to have the highest rate of waste sorting in this study. Construction industry should prepare to face the changes in business legislations and also the challenge of sustainable development due to C & D waste issue. Furthermore, various advantages accrue by being prepared and proactive in tackling environmental issues.

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