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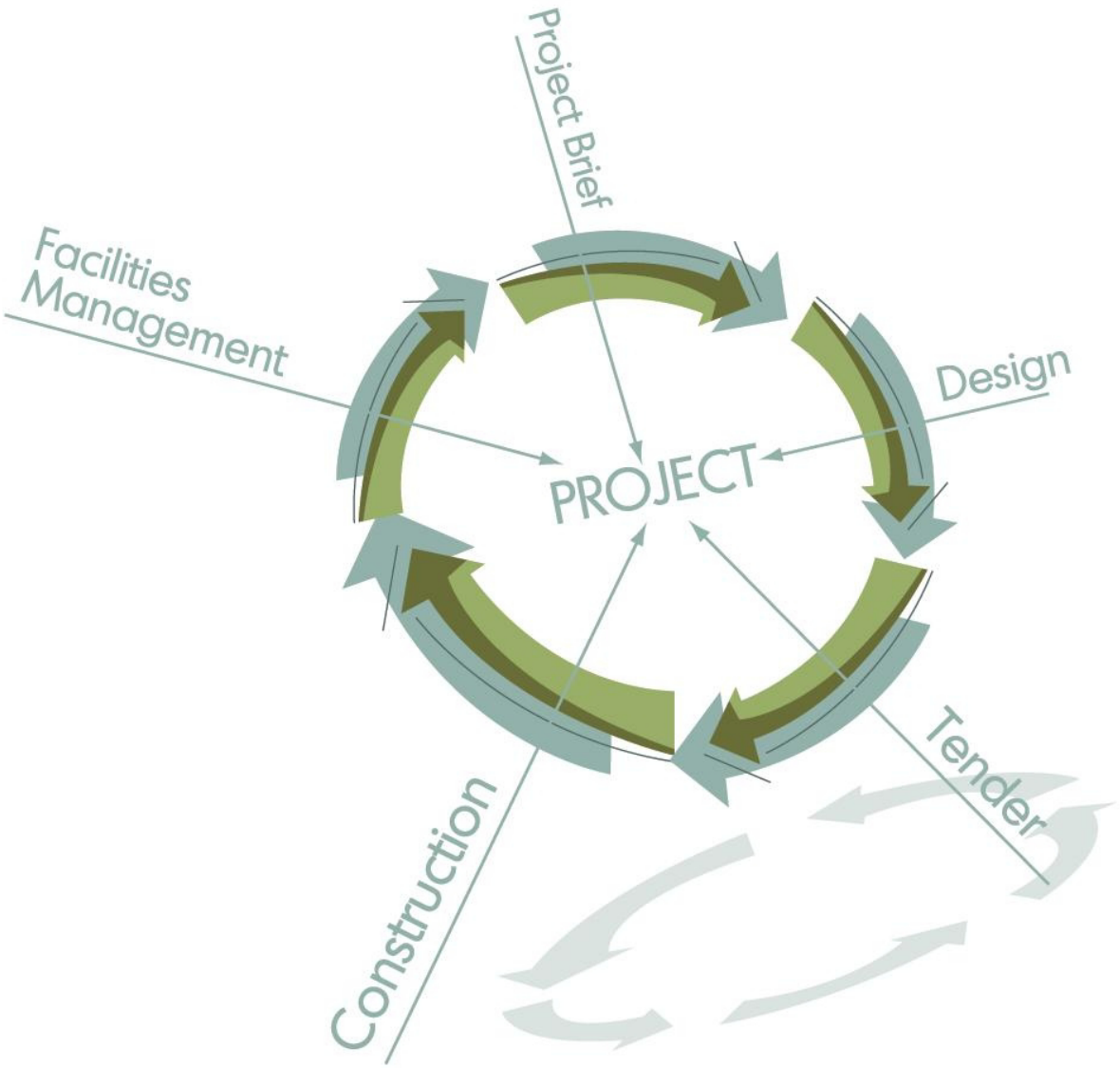

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Contents

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Editorial

Welcome from the Editors

Welcome to the seventh issue of Malaysian Construction Research Journal (MCRJ). We would like to take this opportunity to extend our special thanks to all authors involved and also to express special acknowledgement to all reviewers for the outstanding support. This issue will look into six selected papers emphasizing the concept of Sustainable Development (SD) in construction industry.

Firstly, **Aulia and Matori** with the aid of Geographical Information Scale (GIS) explore the suitability location assessment of the existing petrol filling stations on a macro urban scale. A suitable petrol filling station site must have environmental low impact criteria and attributes that will enable them to be located in safe location with no unacceptable risk to surrounding people or the environment. With Surabaya metropolitan as a case study, the suitability sites for petrol filling station is created by single ranked map that is combined from all data maps using weighted overlay sum method.

Ramanathan et. al in second paper argues that sustainability in infrastructure projects is a mandatory issue to assure a long term ecosystem functions, as well as enhancing the quality of life in urban and rural communities. These values will be achieved through the systematic management of multiple projects development, i.e. the Design and Build infrastructure projects in Sabah of East Malaysia. By considering established systems for design, contract, contract administration, construction execution and supervision; the paper provides solutions for the sustainable management and investigate continuous quality improvement in managing multiple D&B projects.

Any disourse in the construction industry will not be completed without addressing the Health, Safety and Environment (HSE) issue. **Ahmed et. al**, in the third paper, evaluates the past and present trends of behavior based safety in the industry. Most behavioral studies conducted showed that reduction in injuries occur if safe behavior becomes more prevalent than unsafe behavior. Modern methods of construction and new ways of performing tasks expedite the progress of work but also introduce new hazards. At-Risk Behavior Analysis and Improvement System (ARBAIS) concept is one of the methods that could address this issue in particular to reduce the injuries and fatalities due to worker's unsafe action.

Construction industry is widely known as one of the biggest culprits in the depletion of natural resources all over the world. And construction is so synonymous with the high consumption of cement and concrete. Environmental issues resulted from cement production have brought world's concern into a novel concrete technology that is more environmentally friendly. Hence in the fourth paper, **Nuruddin et. al** introduces geopolymer as an alternative binder to cement to develop a greener technology in concrete industry. The research and experiments conducted show that optimum condition to the geopolymer concrete strength is achievable and can be conducted with cast in situ requirements.

The fifth paper brings us to the building maintenance issue. **Khamidi et. al** argues that by looking at the complete building life cycle, building maintenance is one of the many paths that construction industry stake-holders need to consider towards advocating sustainability. In the first part, the paper rigorously carried out a critical literature review to relate building maintenance and sustainability. Meanwhile on the second part, building defects in the Malaysian university campuses are analysed. This defect analysis is significant if universities wished to be seen as a role-model in sustainable maintenance management for their buildings and engineering services.

Last but not least, we bring your interest to the sixth paper where bio-briquettes technology in power and heat generation is being utilised as a sustainable source of energy. Although this is not directly related to the construction industry, however, knowing that 40% and more of world natural resources are used to generate energy; and building and construction are responsible for almost 50% of global energy consumption, the paper is relevant and timely. As a contribution to mankind, **Liew et. al** shows how bio-briquettes are developed from waste which is renewable and sustainable and at the same time provide a source of energy in our quest for alternative energy.

In a conclusion, all six papers may have reflected the R&D potentials in the construction industry in advocating sustainability as a mainstream theme. It is also very important to note that efforts in advocating sustainability in the construction industry cannot be addressed effectively by a single discipline. The six research works presented in this issue, show some variances in disciplines and approaches (though not all) that with continuous funding can make a substantial impact in the construction industry. In a true spirit of SD, we urge everyone out there to **use less**, **save more** and **advocate always**.

Editorial Committee

SUITABILITY ANALYSIS OF PETROL FILLING STATION SITE USING GIS

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Abstract
Petrol Filling Stations (PFS) are amongst those that have high potential of fire hazard due to their dangerous storage, hence their siting should be carried out properly. Their improper siting could lead to disastrous consequences during fire and causing pollution to surrounding soil and underground water should leakage occur to their under storage tanks. In Surabaya metropolitan, the growth of motor cycle is around 12% per year and the total number of car and motor cycle is up to 1.6 million, hence the need to establish new Petrol Filling Stations is always there to add to the 90 stations that have already existed. This study integrates Geographic Information System (GIS) and Analytic Hierarchy Process (AHP) to assist proper siting of PFS in Surabaya. The GIS with spatial analysis provides an opportunity to identify suitable site by computing various criteria based on environmental consideration. In another hand, AHP is applied to quantify the priority ranking of each criteria based on stakeholders preference. This integration called as spatial multicriteria decision support system will help to find suitable site based priority preference. At the end of this study, Petrol Filling Stations sites in Surabaya have been identified which could be classified as high suitable area, medium suitable area, and low suitable area. It therefore could be concluded that GIS and AHP are proven as an essential tool to assist correct siting of PFS.

Keywords: *Geographic Information System; Petrol Filling Station Site; Site Suitability Analysis*

INTRODUCTION

Petrol Filling Station has potential hazards to the site and environment. Among the hazard from Petrol Filling Station are the leaking of Underground Storage Tank (UST) that will contaminate groundwater (Fogg et al. 2005), fire hazard evoked by open flame (Hassanain et al. 2006), static electricity (Nabours, 2004), air pollution evoked by aromatic compound concentrations (Lin et al. 2005), and the traffic jam due to vehicle queue to access Petrol Filling Station (Iman et al. 2008).

A study by the U.S. Geological Survey, the petrol additive MtBE (Methyl-tertiary-Butyl Ether) has been detected in at least 40 percent of public wells. It is randomly sampled from 225 water supply wells in Rockingham County in 2003. They also found a correlation between Methyl-tertiary-Butyl Ether concentration and proximity to USTs (Ayotte et al. 2005).

Because of Petrol Filling Station potential hazards to the environment, therefore a more study concerning the suitability analysis of Petrol Filling Station site is highly required.

Surabaya Metropolitan as a Case Study

Now days, the growth of Petrol Filling Station in Surabaya is very rapid. There are 90 already-existing Petrol Filling Station sites that can be found. The Vice Mayor of Surabaya municipality, Arif Affandi said that this Petrol Filling Station number still could not cope with the number of vehicle. The growth of motor cycle is up to 12% per year and the total number of car and motor cycle is almost 1.6 million (Surabaya, 2009).

Furthermore the Surabaya municipality does not have regulation of Petrol Filling Station siting that concerns about its hazards. That is why many Petrol Filling Stations established in a location that close to each other without concern on the hazardous impact that could emerge should any mishap happen. There should be suitable regulation for Petrol Filling Station siting which amongst other states the maximum number of Petrol Filling Station within the areas, safety and circulation inside Petrol Filling Station site.

The improper siting of PFS in Surabaya City could lead to disastrous consequences, since environmental safety was not given due consideration. Hence, the criteria for Petrol Filling Station site that focus to the environmental hazards risk of Petrol Filling Station should be determined. The utilization of Geographical Information System (GIS) can provide an opportunity to select of suitable Petrol Filling Station sites.

Problem Statement and Research Objective

The main objective of this study is to develop an approach of GIS-based suitability analysis to identify suitable sites for Petrol Filling Stations in Surabaya city. More specific tasks to reach this objective are:

1. To investigate considered factors for suitability analysis of Petrol Filling Station based on hazardous environmental risk of Petrol Filling Station.
2. To assess suitable Petrol Filling Station sites using spatial analysis (GIS).

Research Scope of the Study

The scope area taken for real simulation for this research is Surabaya metropolitan as the second largest city in Indonesia. And the scope study of this research is limited to environmental concern which is focused to the hazards identification of Petrol Filling Station.

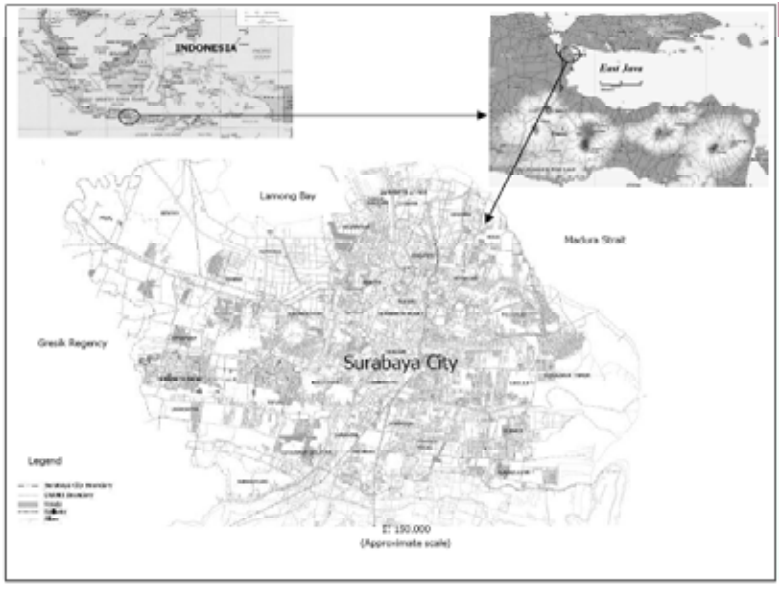

Figure 1. Surabaya Metropolitan, East Java, Indonesia.

BACKGROUND

A Petrol Filling Station is where petrol or other vehicle fuels are sold and where maintenance and minor automobile repair services may be conducted. A Petrol Filling Station consists of a petrol bar with petrol outlets and typically with other associated facilities such as car washes, automotive services, convenience stores and food services (Ottawa, 2006).

Environmental, Health, and Safety Risk/Liability Issues of Petrol Filling Station

By reviewing the type and condition of equipment on site and putting it in a site specific context (both in terms of surrounding neighbours and environment of Petrol Filling Station), it is possible to judge relative risks of pollution. As mentioned in table 1, there are several sources, pathways, and receptors that perceive as pollutant linkage that might be occurred in Petrol Filling Station.

Table 1. Pollutant linkage

Source	Pathway	Receptor
Leaking UST's	Permeable strata above water table	Groundwater in aquifer
Poorly maintained oil/water separator	Surface water sewer	Surface watercourse
Faulty pressure/vacuum vent on tank vapour manifold	Prevailing wind direction	Air quality in local residential area

(Source: Institute of Petroleum, 2002)

Based on *Guidelines for soil, groundwater and surface water protection, and vapour emission control at Petrol Filling Station* there are several identified source of risks which are (Institute of Petroleum, 2002):

- Tank and pipe age, soil chemistry conditions, oil/water separator design, leak and spill history as potential sources;
- Drainage lay out, geology, and underground services as potential pathways;
- Proximity of houses, cellars, rivers, aquifers, water abstraction as Potential receptors.

Petrol is a mixture of many organic substances and has properties that can give rise to fire, explosion, health and environmental hazards (Commission, 2002). These hazards can also arise if petrol is misused off site and for this reason it is important that petrol is only dispensed into properly designed and labelled containers.

Fire/Explosion Risk

Vehicle fuels are highly flammable and if stored or handled incorrectly severe fire or explosion may result, with potential for severe injury, loss of life and damage or destruction of the site and locality. Petrol Filling Stations are usually located within the context of urban neighbourhoods and near public and residential properties. Hospital, school, and parks are also public facility that included as sensitive area and need to be protected from Petrol Filling Station hazards. This makes the provision of fire protection systems and the establishment of fire prevention measures critically essential for the protection of human life and properties.

An incident of fire at a Petrol Filling Station facility should be controlled immediately at its early stages to prevent the growth and the spread of fire and the chance of explosion to occur (Hassanain et al. 2006).

Fuel Leaks and Spills

Released fuel will enter the soil directly beneath the site or around its perimeter. Petroleum floats on water surfaces and can be transported over long distances via drainage channels and other watercourses. Petroleum (and its associated additives) is toxic to flora and fauna and can pollute significant volumes of water. Liquid product can flow downwards through soil towards the water table, where it can either float or dissolve. A large percentage of drinking water comes from groundwater resources (aquifers). How petrol can contaminate soil and groundwater is illustrated by figure 2. Between five and six million underground storage tanks in the U.S. are used to store a variety of materials, including petrol, fuel oil, and numerous chemicals. The average life span of these tanks is 18 years; and over time, exposure to the elements causes them to corrode. In 1990 it was estimated that hundreds of thousands of these tanks were leaking (Environmental hand book, 2002).

VOC Emissions

The main emissions to air are Volatile Organic Compounds (VOCs) i.e. fuel that evaporates, particularly during delivery and dispensing operations (Brimblecombe, 1996). VOCs can cause dizziness, asphyxiation and are potentially carcinogenic. VOCs are also a primary component of smog, with major health impacts in urban areas. VOC emissions can be reduced with the use of special fuel filter nozzles incorporating vapour recovery systems.

Static Electricity

Conditions that cause static electricity to be generated are present on Petrol Filling Stations from (USAID, 2008):

- The road tanker, which can become electrically ‘charged’ during the journey to the filling station;
- The flow of petrol through the delivery hose to the storage tanks; and
- Personnel involved in the delivery process becoming charged with static electricity.

Collision and Traffic Jam

There is a risk of collision between vehicles using the fuel station and pedestrian traffic both on the site and passing by its entrance and exit points (European bank, 2009). The layout of the site should be designed to provide clear lines of sight wherever possible and to minimize the need for vehicles and pedestrians routes to cross. Access and egress into the site need to be carefully considered to avoid issues of queuing and congestion. A Petrol Filling Station could possibly cause traffic obstructions if it is located near to intersection, in a high traffic flow road, or near to grade crossing.

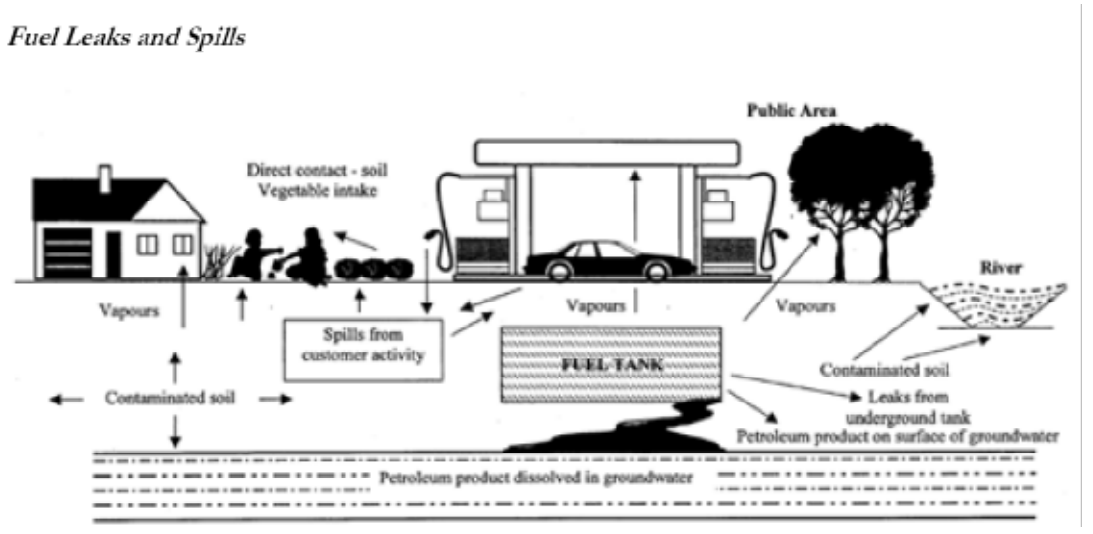

Figure 2. Fuel Leaks and Spills possibly Contaminate Soil dan Grounwater

Figure 2, illustrates about potential hazards that might be occurred in PFS. It shows that oil spill due to the leaking of underground storage tank or any human activity can lead into groundwater contamination, surface water contamination, and soil contamination.

Criteria for Site Selection

Petrol Filling Station siting needs to consider many factors. A list of criteria for Petrol Filling Station consistent with environmental risk and requirement site are summarised as follows (NEPA, 1999; BAD, 2003). In pursuance of the research objective, criteria are seen in table 2.

In accordance with the objective of research which put the environmental issue as the main concerned, so here are several sub objectives that made as platform for criteria. They are water system protection from UST's leaking, vicinity area protection from Petrol Filling Station's fire and explosion hazard, proper land use selection, and access road due to in-out activity. Each of this sub objectives are break down into several criteria, subsequently all criteria also break down into several indicators.

As mentioned in Table 2, take for instance the sub objective to water system protection from UST's leaking is considered water system linkage as the criteria. They are groundwater, private well, river, lake, and sea water. It might be explained, when the UST's leaking and the petrol spills out contaminates groundwater. In another hand, when it dissolves and migrates to private well or more over river and lake, so it might be possible to contaminate city drinking water resources.

Table 2. Suitability criteria

Objective	Criteria	Indicator
Water system protection from UST's leaking	Safe the groundwater	At least 300 ft from groundwater
	Safe the seawater	At least 3.250 ft from saline water
	Safe the river and lake	At least 500 ft from river and lake
	Safe the private well	At least 250 ft from artesis well
Vicinity area protection from Petrol Filling Station's fire and explosion hazard	Minimizing impact for the residential properties	At least 500 ft from residential properties
	Minimizing impact for the nearest hospital and school	A least 100 ft from hospital and school
	Avoiding electro static environment	At least 150 ft from High Voltage Area
Proper land use selection	Land availability	At least 12.000 ft^2 on vacant land
	Safety UST's construction	Less than 35% steep
	Land use	Located in commercial/industrial zone
Minimizing disturbance to acess road selection due to in-out activity	Distance to Intersection	At least 250 ft from intersection
	Distance to road	At least 40 ft. from road property boundaries
	Distance to grade crossing	At least 820 ft from grade crossing

(Source: NEPA, 1999; BAD, 2003)

METHODOLOGY

A Geographical Information System is a computerised system for input, storage, management, display and analysis of data that can be precisely linked to a geographic location. GIS helps the user determine what locations are most/least suitable for development. In this way, the results of GIS analysis can provide support for decision-making (Chang, 2008).

The eight steps in Spatial Analysis include:

1. Define criteria for the analysis
2. Define data needed
3. Determine what GIS analysis operations should be performed
4. Prepare the data
5. Create a model builder
6. Run the model builder
7. Analyze results
8. Refine the model as needed

Data

The following input data area required to compute optimized location:

1. Land use map
2. River and lake map
3. High voltage electricity network map

4. Slope map
5. Road network map
6. Road class information
7. Railway network map
8. Coastal area information
9. Hospital, school, and fire station map
10. Groundwater map
11. Private well map

Data source is provided by Department of Housing and Urban Planning, Surabaya Municipality, 2005. In addition, the projection used for this model simulation is WGS 1984 UTM Zone 49S. Unfortunately, several data such as groundwater and private well map are unavailable due to unavoidable circumstances.

Spatial Analysis

Spatial Analyst enables desktop GIS users to create, query, and analyze cell-based raster maps; derive new information from existing data; query information across multiple data layers; fully integrate cell-based raster data with traditional vector data sources; and create sophisticated spatial models using *Model Builder*. Model builder is a tool for creating and managing automated and self documenting spatial models. Model builder enables users to create process flow diagrams and scenarios to automate the modelling process.

In model builder process to convert these themes to grid themes using the vector conversion process was carried out. Models are represented as sets of spatial processes, such as buffer, classification, and reclassification and overlay techniques. Each of the input themes is assigned a weight influence based on its importance, then the result successively multiplying the results by each of the constraints. This process is often used in site suitability studies where several factors affect the suitability of a site (Mitchell et al. 2001). Then the GIS overlay process can be used to combine the factors and constraints in the form of a weighting sum process.

Designing spatial analysis model is required to create backbone of GIS operations for this research (McCoy, 2001). The process for determining the suitable parcel for Petrol Filling Station in this study is performed by a GIS Spatial analysis using ArcGIS Model Builder. It is seen briefly in Figure 3.

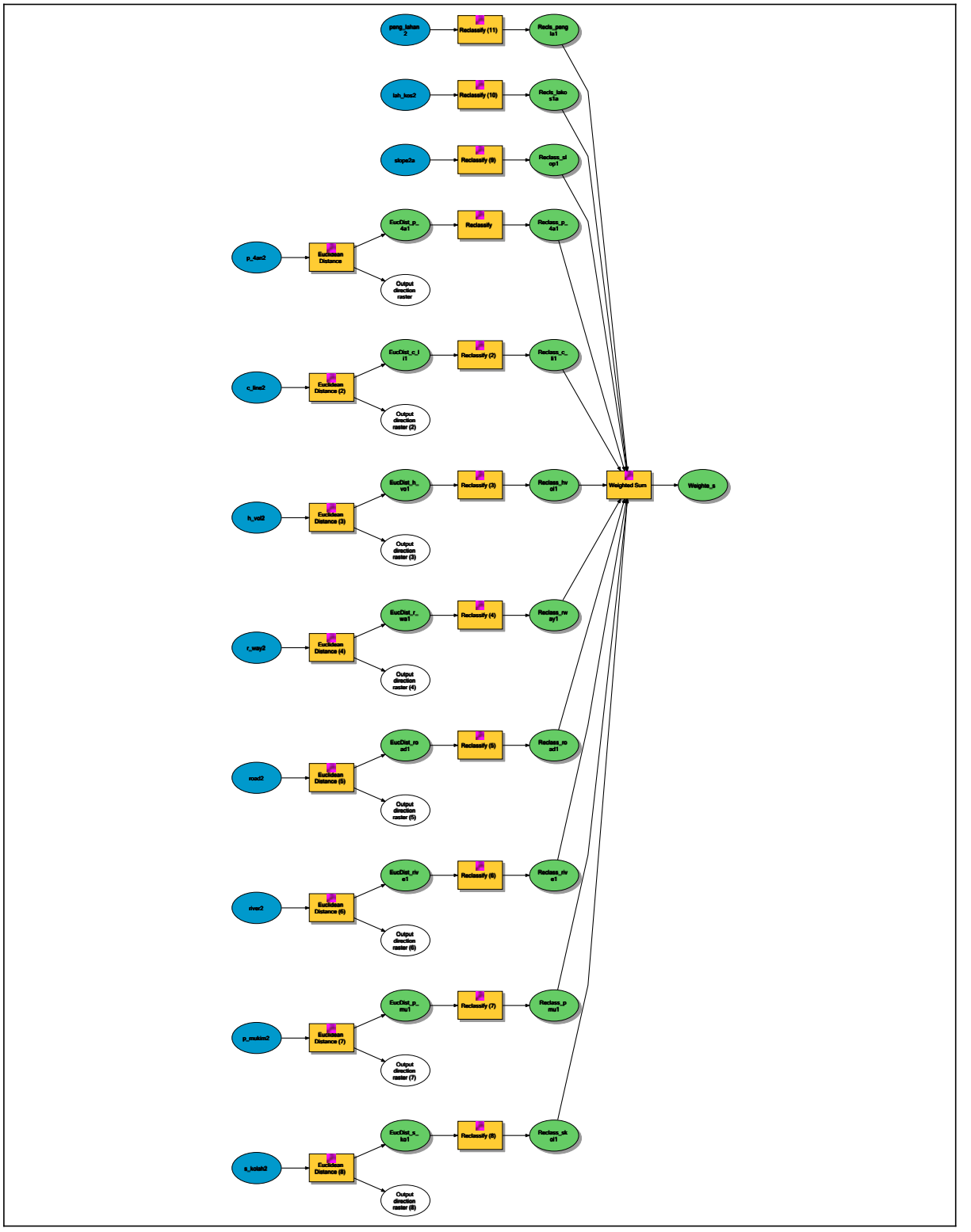

Figure 3. Spatial Model Builder

Figure 4. Weighted Overlay Sum Steps for Spatial Analysis

Several steps taken for spatial analysis is summarised in Figure 4. First of all, all data map layers should be converted from vector form to raster form. A raster consists of a matrix of cells (or pixels) organised into rows and columns (or a grid) where each cell contains a value representing information. For several data map layers, this first step proceed further with euclidean distance analysis to apply the safety distance between Petrol Filling Station to several criteria that has been set up as what indicator mentioned in suitability criteria. The Euclidean distance output raster contains the measured distance from every cell to the nearest source. When all data map layers already set up in certain prerequisite for safety distance through euclidean distance analysis, we have to compare the values of classes between layers by assigning numeric values to classes within each map layer so they have equal importance in determining the most suitable location. Then finally, all data map layers is ready to be overlaid by using weighted sum method to create single rank map of suitability analysis.

RESULT & DISCUSSION

There are several steps inquired to obtain suitable site for Petrol Filling Station. Firstly, we have to convert all data map layers from vector to raster feature. Secondly, create Euclidean distance from any raster feature that is considered as constraint criteria. Other required criteria such as vacant land availability, land use, and slope are reclassified directly without applying any Euclidean distance to this raster feature.

Euclidean Distance Result

The Euclidean distance output raster contains the measured distance from every cell to the nearest source. The distances are measured as the crow flies (Euclidean distance) in the projection units of the raster, such as feet or meters and are computed from cell centre to cell centre. Every layer has different Euclidean distance, for an example coastal line has minimum requirement for safety UST's area in distance 3.250 ft from saline water, so along coastal line there is a kind of virtual barrier with width 3.250 ft as safety area for UST's from saline water intrusion that can cause leakage. It is seen briefly in figure 5.

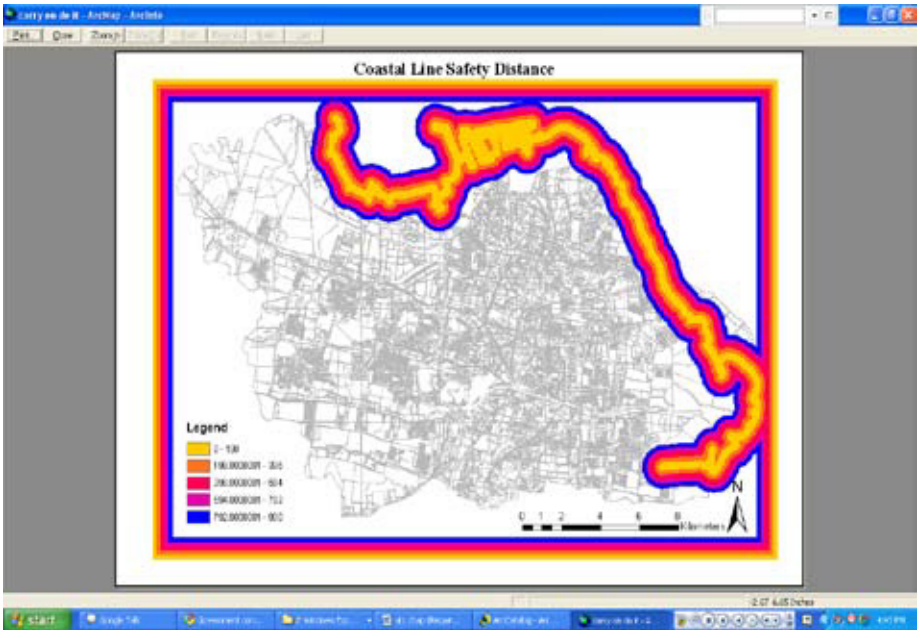

Figure 5. Euclidean Distance Analysis for Coastal Area Data Map Layer

Reclassification Result

To create a single ranked map of potential areas to site Petrol Filling Station we have to compare the values of classes between layers by assigning numeric values to classes within each map layer, it is called as reclassifying. Having all measures on the same numeric scale gives them equal importance in determining the most suitable locations, hence all data map layers will be reclassified into new numeric value or scoring as '3,2,1' (McCoy et al. 2001). The scores of '3,2,1' are used to identify the differences among high suitability, moderate suitability, and no suitability.

Table 4. Suitability class for criteria

Criteria	Classification of Criteria		
	Low Suitability	**Medium Suitability**	**High Suitability**
	1	**2**	**3**
Distance to Coastal Line	<3.250 ft	-	>3.250 ft
Distance to River and Lake	<500 ft	-	>500 ft
Distance to Residential Properties	<500 ft	-	>500 ft
Distance to Hospital and School	<100 ft	-	>100 ft
Distance to High Voltage Area	<150 ft	-	>150 ft
Distance to Intersection	<250 ft	-	>250 ft
Distance to Road Property Boundaries	<40 ft	-	>40 ft
Distance to Grade Crossing	<820 ft	-	>820 ft
Land Use	Fish pond Green open space	Residential School	Industrial Commercial
Slope	1-40%	1-15%	1- 10%
Land availability	Non vacant land	-	Vacant land

(Source: Analysis Result, 2009)

Suitability class of each criteria is divided into three classification which are low suitability, medium suitability, and high suitability. Low suitability area is assigned by 1, medium suitability area is assigned by 2, and high suitability area is assigned by 3, respectively (Carolina, 2005). Distance to groundwater and private well criteria were not included due to unavailability of data.

Explanation of suitability class of criteria, reclassified of land use criteria is used as example which is seen briefly in Figure 7. In Figure 7, area which is seen by light purple colour are fish pond and green open space area that considered as low suitable for Petrol Filling Station so classified by 1 value. Respectively, area which is seen by medium purple colour are residential and school area that considered as medium suitable for Petrol Filling Station so classified by 2 value. Area which is seen by dark purple colour are industrial and commercial area that considered as high suitable for Petrol Filling Station so assigned by 3 value.

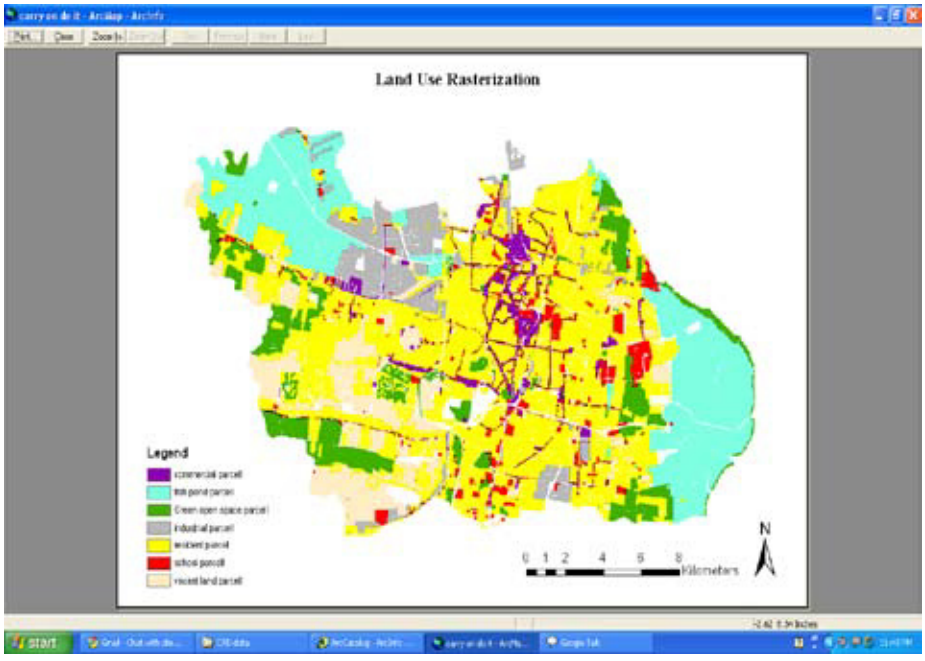

Figure 6. Land Use Data Map Layer

Figure 6 is depicting land use data map layers that will be reclassified into new numeric value so will have same importance with another data map layers.

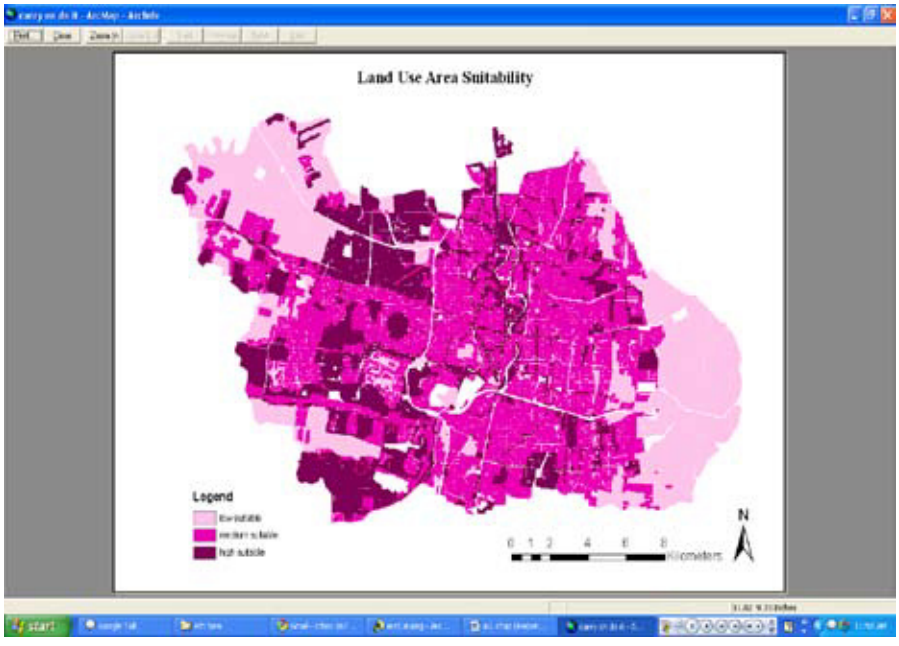

Figure 7. Land Use Data Map Layer after Reclassification Analysis

Figure 7 is land use data map layers that has been reclassified into new numeric value so can be identified which area considered as low suitable, medium suitable, and high suitable area.

Weighted Sum Result

Weighted overlay sum is a method that overlay several raster multiplying each by their given weight and summing them together. One major difference between the weighted overlay tool and the weighted sum tool is the weighted sum tool allows for floating point values whereas the weighted overlay tool only accepts integer raster as inputs (McCoy et al. 2001).

The final suitability map for locating Petrol Filling Station sites is seen briefly in Figure 8. Eleven raster layers are ranked for development suitability on a scale of 1 to 3. And for the weighted overlay sum result, the layers are added each cell is ranked on a scale of 11 to 33. The highest suitable area is represented by the darkest purple colour. The least suitable area is represented by the brightest purple colour.

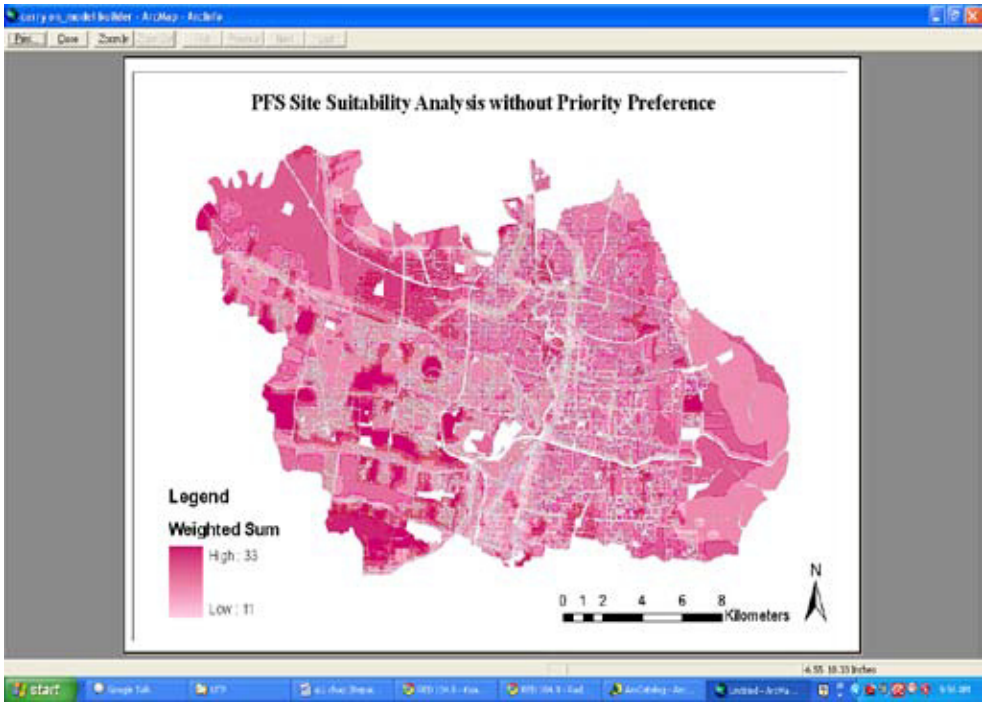

Figure 8. Suitability Map for Petrol Filling Station

CONCLUSION

In this research, GIS is developed for site suitability assessment. The set of criteria for Petrol Filling Station siting had been developed through an examination of the relevant literature review that focuses on environmental and liability issues which are water system protection from UST's leaking, vicinity area protection from Petrol Filling Station's fire and explosion hazard, proper land use selection, and access road selection due to access-egress activity. The suitability sites for existing Petrol Filling Station is seen by single ranked map which is combined from all data maps using weighted overlay sum method. In conclusion, single ranked map shows that the darkest purple colour as most suitable sites and the brightest purple colour as least suitable sites for Petrol Filling Station.

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SUSTAINABLE CONSTRUCTION OF MULTIPLE D&B BRIDGE PROJECTS IN SABAH

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Abstract

In recent years, the "sustainability" in infrastructure projects is a mandatory issue to assure long-term ecosystem functions, as well as enhancing the quality of life in urban / rural communities. These values will be achieved through the systematic management of multiple projects developed in rural areas. Selected infrastructure projects are being implemented by Design and Build (D&B) procurement system in Sabah (East Malaysia). In these development projects, 45 Bridges in bridge replacement projects are being executed simultaneously by the author's Design and Build firm. The former were awarded in 5 packages in the first phase of Bridge replacement project for PWD. The latter are constructed for Ministry of Rural development. The company manages such projects by using established systems for design, contract, contract administration, construction execution and supervision. Engineers from qualified engineering bodies are selected and appointed for In-house design team / supervision team. Discussion and inputs in selecting critical bridge components including (i) Methods of pile foundation, (2) Selection of suitable beam technologies, (3) No. of spans, etc are explained. Majority of the construction works are executed directly by the main contractor with appointed specialist contractors for piling works and beam production. The objectives of this paper are to give solutions for the sustainable management and investigate for improvement in management of multiple D&B projects.

Keywords: *Sustainable construction, Multiple projects, Design and Build and Specialist works.*

INTRODUCTION

Construction is probably the largest industry in the developed world. All construction activities have a major effect on the environment. Construction activities consume more energy than any other activity, and consequently lifetime efficiency of project is a major determinant of total energy demand. The manufacturing, construction machineries and transportation of construction materials requires considerable use of energy. Therefore, the construction industry has a unique role to play in sustainable development. Sustainability can be achieved by the use of D&B method for handling multiple projects to overcome the excess use of energy and the limited resources on sharing basis from the same resource pool.

Multiple projects have an advantage of using resources on sharing basis from the common resource pool. This will comparative reduce the number of machineries used. In the projects which are awarded individually each and every project will require minimum number of the construction machineries and resources involving energy and fuel. However when all the projects (of similar scope of works) are awarded collectively under single roof as multiple projects the usage of construction machineries and resources will be optimised. In which the resources are used from one single resource pool on sharing basis. Better control and planning will help to cut down the energy usage to considerable level.

The Rural development projects are significant for the local community and have to be delivered in time. Any delay in completion of the projects due to failures of improper management and construction systems are often unbearable causing inconvenience to the public. Further the delayed delivery is not going to facilitate the full purpose for which the projects are implemented under development plans. Thus, development projects for rural agencies has been focused with great premium on management of project durations.

Increased usage of calendar day type contracts and the introduction of accelerated construction provisions with high amount of liquidated damages into many construction contracts serve as an evidence of concern for the schedule (O'Connor and Huh 2006). However such efforts have limited effect if construction contract estimates too lengthy time. Factors affecting overall construction progress from the experience are weather and seasonal effects, location of the projects, traffic impacts, relocation of construction utilities, type of projects, special items, material delivery time, conflicting construction operation, access to site, logistics, budget, land / property acquisitions, legal aspects. The effective project management system's reliance on important factors like proper planning analysis, design management; construction control and supervision in order to avoid complications in multiple projects are reported in this paper.

LITERATURE REVIEW

The term "sustainable development" became popularized with the publication of "Our Common Future" in the Brundtland Report (1987) which defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The interpretation of this definition has, however, since 1987 broadened and matured.

The protection of the environment is today recognized as but one element of sustainable development; others include social and economic factors. In the UK Government's Sustainable Development Strategy, Sustainable development is defined as enabling "all people throughout the world to satisfy their basic needs and enjoy a better quality of life, without compromising the quality of life of future generations", thereby accentuating the importance of the social element. Today, it is widely accepted that sustainable development has three foundations: environmental, social and economic. If this is accepted, the link between sustainable development and construction becomes clear; construction is of high economic significance and has strong environmental and social impacts.

Philip et.al (2008) mentions that Construction is probably the largest industry in the developed world. It accounts for approximately 10% of UK Gross Domestic Product. However, all construction activities have a major effect on the environment. The operation of buildings consumes more energy than any other activity, and consequently Lifetime efficiency of buildings is a major determinant of total energy demand. The manufacturing and transportation of building materials accounts approximately 25% of energy used by UK industry. Buildings also have a major effect over a long period on several generations. Therefore, the construction industry has a unique role to play in sustainable development.

Sustainable roadway construction can be defined as the optimal use of natural and man-made resources during the roadway lifecycle causing negligible damage to the environment. Two means of improving the sustainability of roadways are to minimise the amount of energy consumed for their construction and to efficiently use roadway materials to reduce waste (Gambatese and Rajendran 2006).

Burgan and Sansom (2006) have discussed the importance of construction to the three elements of sustainable development, namely economic growth, social progress and effective protection of the environment. The paper identifies the issues facing construction in meeting the sustainable development agenda; these include efficient use of natural resources, reducing energy consumption, reducing emissions, minimising waste, more efficient land use, reducing the impact on construction sites and creating better employment conditions. The ways in which steel construction addresses these issues are discussed. In the context of new buildings, steel's impact on the construction process-namely speed, prefabrication, safety, waste minimisation and factory and site conditions are described. Ways in which construction can contribute to reducing the energy consumption in buildings, particularly during the "in-use" part of the building's lifecycle, are outlined. The role of steel in extending the life of existing building stock is examined and design features for enabling re-use of steel components are highlighted. The paper concludes with remarks on the extent to which constructional steel is recovered and recycled at the end of life of buildings.

Research studies starting from 1987 have identified three elements of sustainable development, namely economic growth, social progress and effective protection of the environment. Construction needs efficient use of natural resources, reducing energy consumption, reducing emissions and minimizing waste. The multiple infrastructure projects in Sabah have utilised sustainable construction methods. The following case study of D&B approach describes this.

REAL TIME PROJECT CASE STUDY

Design and Build (D&B) has become significant procurement method for implementing various development projects in the country. D&B combines the design and construction functions and vests the responsibility of such functions with one entity: the design-builder. The D&B enables owner to employ one contractor that takes sole responsibility for delivering the assigned project with defined requirement standards. Several Public work development projects in Sabah (East Malaysia) are implemented under Design and Build (D&B) procurement methods. The multiple design and build projects namely (1) Proposed Bridge replacement projects (Project I to V) in various districts of Sabah and (2) Two proposed Road projects constructed for Ministry of rural works were managed efficiently and delivered for public usage in stages. The proper management system both in design and construction team has helped to complete in accordance to the master schedule and the construction quality has met the designers' requirements.

Sabah situated on the northern tip of the island of Borneo (Figure 1) is the second largest state in Malaysia. Over 70% of population lives in rural area and the majority depends directly or indirectly on agriculture. The state has several development projects procured by D&B

Method for upgrading rural roads and replacement of bridges for the benefit of rural sectors contributing to the national economy. Five contract packages comprising 45 bridges located in 12 districts in the state having 76,115 Sq. Km coverage area [9] and two road projects in one district were awarded. As summarised in Table 1, in addition to the Bridge projects, two road projects were also handled simultaneously.

The projects started at different times having simultaneous construction period at various stages of completion. Many of these projects have been completed successfully and delivered to client for public usage. The remaining bridges are at various stages of completion, progressing in accordance to the master schedule.

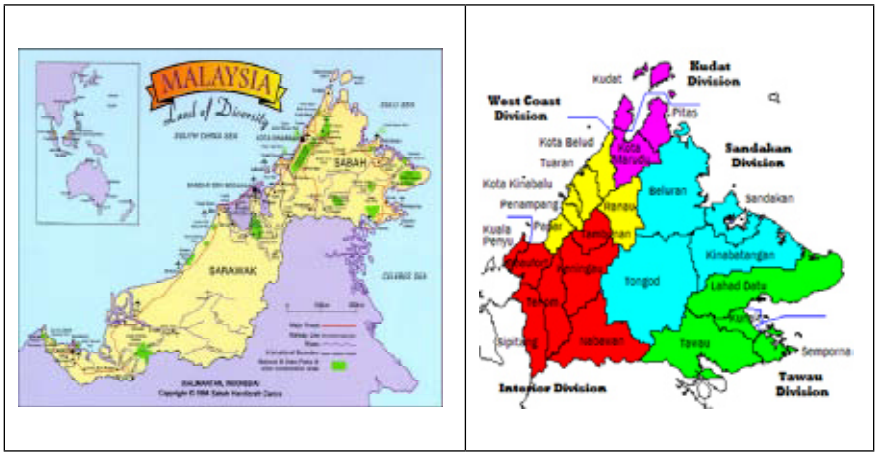

Figure 1. Map of Sabah in Borneo Island (left); and Sabah districts (right)

For the success of all the projects in multiple environments there are many issues to be carefully considered right from pre design stage till commencement of construction works and close out. Particularly the projects are spread throughout the state at various locations raised many complexities in project commencement, equipment mobilization, work coordination, resources transfer, material supply, logistics, etc. Any failure in management system will have heavy cost implications namely over spending and exceeding of estimated budget.

Table 1. Schedule of multiple contracts handled in Sabah

Project Number	No. of Bridges	District Locations (given No.)	Project Duration	
			Months	Period
1	12	3	18	Jul 03 – Jan 05
2	5	3	18	Jan 05 – Jul 06
3	8	3	18	Jul 05 – Jan 07
4	13	3	20	Oct 05 – Jun 07
5	7	3	20	Oct 05 – Jun 07
Total	**47**	**12**	**48**	**Jul 03 – Jun 07**

PROCEDURES FOR D&B PROJECT

The procedures adopted for effective management in the D&B project are explained in Figure 2 (in Appendix) "Process flow chart of Design and Build Project". It covers the activities at various stage of the project and the end output of those stages (at RHS) including the team of personnel involved (to the Left) to progress from one stage to another. The important aspects of the mandatory activities of Pre-design stage, Conceptual design stage, Tender and Contract, Construction stage and Maintenance are given below.

CONSTRUCTION PHASE

The above procedures are repeated for every D&B project simultaneously. In multi-project setting every project will be at different level of procedures based on the progress of interdependent activities at pre design stage. Important aspects of the construction phase are discussed below:

Design Management

Many design consultants were appointed in a project by the D&B contractor. This method gives better results to perform the design procedures and providing conceptual designs in specified time frame. Even though the conceptual drawings are prepared earlier in the design stage, the designs are reviewed by the construction team both at pre and post commencement of physical works. This enabled the D&B contractor to assess in the presence of the design consultant the required resources and decide the critical bridge activities namely (i) Method of pile foundation, (2) Selection of suitable beam technologies and (iii) No. of spans. Based on this approach for the Multiple D&B bridge projects the resources required are shown in Table 2. The aim of this review is to have various combinations of construction methods and technologies to avoid the dependency on a single method, single specialist entity and to suit the site condition that minimise temporary works. This has the expected benefits on the project execution with minimum dependency on any one expert or consultant.

Construction Supervision

Even though many designers were involved in the multiple projects, one qualified engineering body was selected for supervision of all the projects. This will enhance smooth execution of all the projects by having everyone reporting to one supervising consultant.

Table 2. Summary of specialist works

Sl No.	Project	No. of Bridges	Pile foundation (m)		No. of Span	Beam: Concrete beam (No.)		Beam: Steel girder
1	Project 1	12	H Piles (356x368x133 kg/m)- Micro piles 300m Diameter- Pad Footing	6 Bridges 3 Bridges 3 Bridges	1 span - 12 Bridges	I-16 x 20.5m I-16 x 21.9m I-16 x 22.0m I-16 x 26.2m I-16 x 27.9m I-16 x 30.9m I-20 x 33.8m	10 10 5 18 7 10 17 77	 0
2	Project 2	5	Micro piles 300m Diameter- 500mm dia. Spun Pile	3 Bridges 2 Bridges	4 Bridges - 1 Span 1 Bridge - 4 Spans	I-16 x 16.7m I-16 x 35.8m M6 x 23.2m M6 x 21.8m M6 x 22.05m UM6 x 23.2m UM6 x 21.8m UM6 x 22.05m	10 14 16 8 8 4 2 2 64	 0
3	Project 3	8	Micro piles 300m Diameter- Bored piles 600mm dia. - Concrete spun piles - Pad Footing	2 Bridges 3 Bridges 1 Bridge 2 Bridges	4 Bridges - 1 Span 1 Bridge - 2 Spans 3 Bridges - 3 Spans	I-16 x 26.4m I-16 x 24.6m I-16 x 34.6m I-16 x 20.5m M2 x 15.3m M4 x 19.8m UM2 x 15.3m UM4 x 19.8m	6 10 7 5 16 32 4 8 88	 0
4	Project 4	14	Micro piles 300m Diameter- 500mm dia. Spun Pile Pad footing	9 Bridges 3 Bridges 1 Bridge	12 Bridges - 1 Span 1 Bridge - 3 Spans	T11 - 16.75m UM4 - 16.75m M6 - 23.20m UM6 - 23.20m I-20 - 29.67m I-20 - 29.755m I-20 - 29.770m I-20 - 29.63m M6 - 19.74m	32 4 32 8 12 12 6 6 8 120	 0
5	Project 5	7	Micro piles 300m Diameter- 500mm dia. Spun Pile	7 Bridges 1 Bridge	6 Bridges - 1 Span 1 Bridge - 3 Spans	I-16 x 26.60m	6	6 Bridges

Physical Works

Few challenges and issues met during the construction are discussed very briefly in this section. The major work quantities for the principal structure are listed in Table 3. To complete the project as scheduled within the contract period the critical issues need proper attention and clarity in actions which will ensure the smooth progress of balance works. The critical issues in this multiple projects are the temporary works and the logistic plan which are very uncertain.

Temporary works are classified into two sections: (1) Temporary diversion and (2) Temporary works for construction of foundation and substructure. Figure 3 provides an example for each type.

Logistic Plan for the projects spread all over the state are linked and are derived from the project works program and schedule. Any revision in works program required revision in Logistic plan and the resource management team has to be informed. Periodic feedback, monitoring and control meetings are held to improve the logistic strategies and resource management in multi-project sharing settings. The distance map shown in Figure 4 is to understand the importance of planning in transportation of resources. Herbsman and Ellis (1995) has emphasized that the transportation agencies have great control on construction duration.

Figure 3(a). Temporary works for foundation

Figure 3(b). Temporary bridge diversion

Table 3. Quantity breakdown of works of D&B Bridge Projects

Project	No of Bridge	Pile Foundation (m)	Concrete (m^3)	Formwork (m^2)	Reinforcement (MT)	Beam		Bridge Bearing (No.)	River Lining (m^2)
						Prestressed (No)	Steel Girder (Kg)		
Project 1	12	Steel H pile - 1140m 300mm dia Micro pile - 1530m	3466.80	9497.30	602.92	77	-	Rubber bearing - 144	3359.48
Project 2	5	500mm dia Spun Pile - 1080m 300mm dia Micro pile - 2862m	6727.60	16490.30	1155.20	64	-	Rubber bearing - 128	3025
Project 3	8	300mm dia Micro pile - 1348m 500mm dia Spun Pile - 432m 600mm Bored pile - 1204m	4308.80	9988.00	700.51	88	-	Rubber bearing - 210	7134
Project 4	13	300 mm dia. Micro Piles - 4292 m 500mm dia. Concrete Spun Pile - 2,016 m	4195.00	10431.90	760.80	120	-	Rubber bearing - 220	3963.00
Project 5	7	300 mm dia. Micro Piles - 4,302 m 500mm dia Spun Pile - 560 m	3111.32	8158.24	562.60	6	1632.90	Rubber bearing - 66 Mechanic Pot Bearing - 4	4339.00
Total	45		21809.52	54565.74	3782.03	355.00	1632.90		21820.48

DISTANCE
...
Kilometres
(Estimated)

	District 1	District 2	District 3	District 4	District 5	District 6	District 7	District 8	District 9	District 10	District 11	District 12
District 1												
District 2	75											
District 3	151	75										
District 4	447	372	296									
District 5	558	483	407	111								
District 6	673	598	522	226	115							
District 7	326	251	175	227	338	453						
District 8	654	579	503	207	96	119	434					
District 9	614	539	463	167	56	79	394	40				
District 10	682	607	531	235	202	317	462	298	258			
District 11	555	480	404	108	75	190	335	171	131	131		
District 12	601	526	450	154	121	236	381	217	177	175	50	

Figure 4. Distance map

OVERALL FINDINGS

Pre Design Stage

Failures of design consultants to consider the builder's problems in implementing the design can result in scheduling problems, delays, and complicated disputes during the construction process. The D&B contactor needs to pay more attention in selecting the design and supervision professionals who have ample experience in working with projects under D&B method.

Construction Phase

As many contractors have gained experience in D&B method, the minor negligence in process and output of Pre Design Stage, Conceptual Design stages, Tender contract stages can be rectified and overcome without serious effect on the project completion date. To achieve the anticipated completion dates Design-builders need to focus early on the solutions and methods to determine the Resource plan and Logistic method in multiple projects.

Benefits of D&B Method to Public sectors

Certain special construction projects require the expertise and specialist contractors known to have experience in similar kind of projects to undertake the D&B projects. Especially the present studies on the multiple bridge projects undertaken at various parts of the state to benefit the public sectors in rural background are considered unique and special in nature. As these bridges are situated at many locations and crossing rivers having different origins, catchments, profiles, sources, terrains, discharge, upstream, soil conditions, width, purposes, etc. careful

study and expertise are required to complete the project successfully. These projects of special characteristics cannot be undertaken by traditional design-bid-build method.

Thus the special projects in development plans are undertaken by D&B method to ensure the timely completion in order to achieve the anticipated completion date and also fulfill the commitments to the benefit the public. D&B methods have shortened the procedures of project implementation time from the date of decision. Further all the responsibilities are vested with the single Design-Builder, shortening the completion time. Adding to D&B concept PAC chairman Samid, S.A has said "The private initiative was far more efficient and giving the private contractor total control without any government oversight would see the projects completed much faster" (Bernama, 2006).

CONCLUSIONS

This paper describes how sustainability can be achieved in multiple D&B bridge projects on social, economic and environment aspects. The social sustainability was achieved by delivering the projects in time through efficient management. Economic aspects were achieved through efficient use of limited resources and environmental aspects through lesser use of energy and resources. Further, long term projects were executed to benefit public in large number of rural sectors still in semi primitive state. The delivery of projects in time with quality was considered important for the sustainable growth to the nation. These were achieved by implementing a significant procurement method with the established DB Project management system. The conclusions based on the study are:

1. When the projects (of similar scope of works) are awarded collectively under single roof as multiple projects the usage of construction machineries and resources will be optimized by sharing from single resource pool. Better control and planning will help to cut down the energy usage to considerable level.
2. The attempt to utilise sustainable management practices in multiple design and build projects in the Pre design stage and construction phase are reported.
3. D&B method is a sustainable method for development projects benefiting public.
4. There is a need to train the D&B concepts to the team involved in the project including client representative, consultants and local authorities.
5. General understanding about the industrial practice of project management is to start from the construction phase. Project management system in D&B method has to start right from the first day of project implementation (even before pre design stage) to ensure the project success with better results.

The construction of Multiple D&B bridge projects and two road projects in Sabah were executed smoothly. The two road projects were completed ahead of the scheduled completion date and are being used by public and are in the last quarter of its maintenance period. All the 45 bridges in five construction packages were handed over to the public works as per schedule and opened for public use. The benefits from the project are being realized and sustainable development through D&B project was gained.

ACKNOWLEDGEMENTS

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APPENDIX

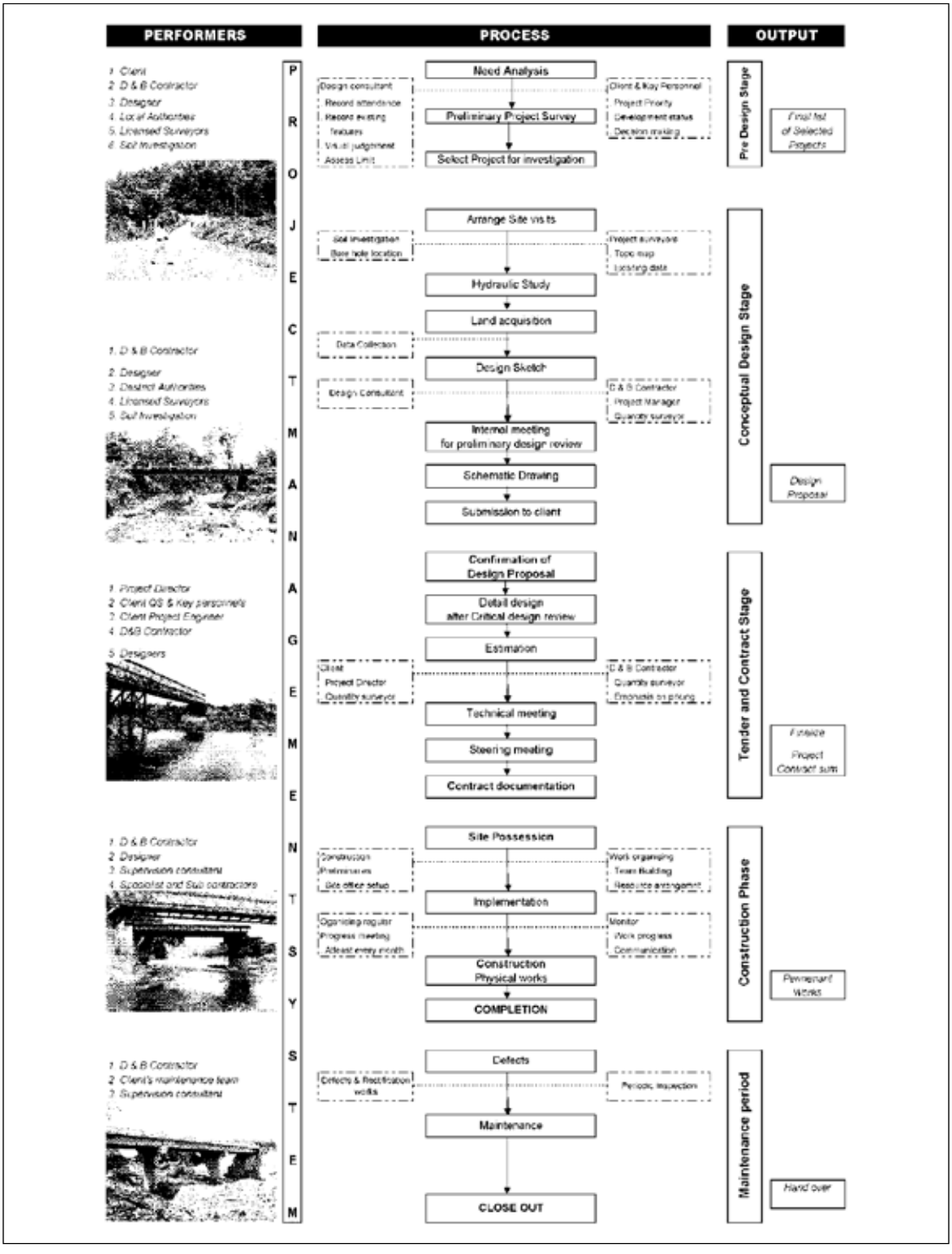

Figure 2. Process flow chart of design and build project

APPLICATION OF AT-RISK BEHAVIOUR ANALYSIS AND IMPROVEMENT SYSTEM (ARBAIS) MODEL IN CONSTRUCTION INDUSTRY

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Abstract
This study evaluates the past and present trends of Behaviour Based Safety in Construction Industry. The application of BBS in construction industry is very common around the world. Industries are focusing on reducing costs associated with accidents and injuries of workers. Most behavioural studies conducted showed that reduction in injuries occur if safe behaviour becomes more prevalent than unsafe behaviour. Track record showed that 88% accidents in industries occur due to worker's unsafe actions. Modern methods of construction and new ways of performing tasks expedite the progress of work but on the other hand introduce new hazards. Hazards and risks due to involvement of various specialty groups at different stages of construction phases are different. Various specialty groups such as Geo-tech, plumbing, electrical, transportation and etc impose unique hazards to the workers. The required approach to these hazards is not same. It is highly notice that traditional ways to handle these risks may not work appropriately. Therefore, a new systematic approach should be introduced to increase safe behaviours, reduce risky behaviours and prevent accident injuries and fatalities at work. One of the promising methods that could address this issue is using At-Risk Behaviour Analysis and Improvement System (ARBAIS) concept. The ARBAIS is a new concept that is currently gaining the popularity in process industries. ARBAIS is workable and practical since it is easy to implement, collect data and correct unsafe behaviour. In this work, the ARBAIS concept will be enhanced in order to accommodate the nature of construction industry. This method once implemented perhaps could reduce the injuries and fatalities due to worker's unsafe action.

Keywords*: ARBAIS, Construction Industry, Hazards and Risks, Site Accidents*

INTRODUCTION

Behaviour-based safety (BBS) is a program that has been implemented in many organisations to identify at-risk behaviour and to reduce the injury rate of their workers. The effectiveness of the BBS was proven with many companies recording a high percentage of reduction of injury rate, especially during the first year of implementation. However, the BBS process could be very labour intensive. It requires many observers to make the process effective. (Shariff and Keng, 2008) found that much effort was required to train the employees to become the observers. Many organisations that attempted to obtain the benefits of BBS did not sustain comprehensive participation required in BBS-related activities. With this drawback, it calls for a simplified process that could achieve the same result as BBS.

Safety measures in Construction Industry have been considered as an important issue. Construction Industry is now becoming one of the most dangerous industries. The main reason behind it the involvement of practices and processes of unique nature. In addition, the construction industry has relatively high fatality and injury rates, and traditional practices for construction safety are no longer sufficient to meet new challenges. Innovative strategies to reduce safety hazards and accidents are required to substantially improve safety in construction.

An analysis of the qualitative answers revealed that the main cause of accident or injuries among construction workers was due to the unwillingness of workers to comply with safety rules and regulations.

Construction workers attitudes towards safety are influenced by their perception of risk, management, safety rules and procedures. In Singapore, the construction industry had implemented safety management system (SMS) and SMS auditing for about 10 years now, but the improvement in safety standard is not significant (Teo and Ling 2006). Past studies have discovered that the successful implementation of the SMS on construction sites can help to prevent accidents. Therefore, it is essential to provide a comprehensive checklist of attributes that may affect the safety performance of worksites.

Henrich (1959) reported through Figure 1 that roughly 88% of all accidents are caused by the unsafe acts of people, 10% by unsafe conditions, and 2% by the act of God.

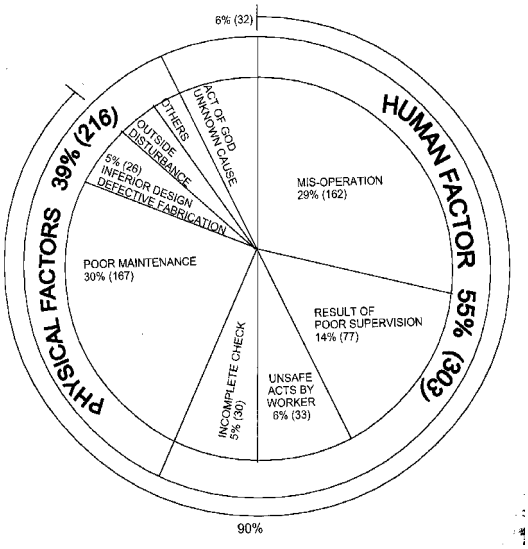

Figure 1. Accident-cause classification (total Number of accidents = 531) Figure in brackets denotes number of accidents (Henrich, 1959)

Hoffmann and Stetzer (1998) hypothesized that workers' perception of safety climate would be related to their reports of psychological strains (psychological distress or job dissatisfaction) in a negative fashion, and workers under strains would be more prone to accidents or injuries. In other words, workers who perceive a negative safety climate in the workplace would feel dissatisfied or distressed, which, in turn, increase their chance of involving accidents or injuries. Since the Asian financial crisis in 1997, many workers in Hong Kong perceive work stress due to job insecurity. (Mearns et al. 2001) suggested when construction workers in Hong Kong perceive a positive safety climate at work, because they face the threats of layoffs they then perceive pressure for good Performance (quality production), they would focus their attention on completing the work and less on the safety procedures. This, in turn, may make them violate more safety rules leading to a higher accident and injury rate. As a result, it was hypothesized that psychological strains are mediators between safety climate and safety performance.

In this study, the past and present trends of Behaviour Based Safety (BBS) in Construction Industry are evaluated. It will assist in examining the behaviour of people towards the latest technologies in BBS. It will also explore benefits and difficulties arising during the application of BBS Process. It provides new methods and strategies for observations and data analysis.

BACKGROUND

Different Methodologies Used for Implementation of Behaviour Based Safety

Bayesian Network (BN) Based Model

A Bayesian network (BN) based model was proposed by (Zhou et al. 2008). It establishes a probabilistic relational network among causal factors, including safety climate factors and personal experience factors that have influences on human behaviour pertinent to construction safety. It provides a methodology to identify potential strategies for safety improvement. A survey involving more than 4700 employees at a large construction firm in China was applied to establish a BN. BN-based analysis demonstrated that the safety climate factors may have a more significant influence on an employee's safety behaviour than personal experience factors. A method to find a strategy by controlling one individual factor (or simple strategy) to improve safety behaviour was then investigated. It was found that the simple strategy could be more effective when safety climate factors were properly controlled. In addition, a strategy via controlling multiple factors (or joint strategies) may even better improve the safety behaviour. The analysis suggested that a joint control of both safety climate factors and personal experience factors worked most effectively. Finally, the prediction of human safety behaviour under a specific climate was tested with the BN.

A structural equation model examined by (Mohamed, 2002). He studied the relationships between safety climate and safe work behaviour in construction site environments, which proved that safe work behaviour was a consequence of safety climate. The results demonstrated the importance of management commitments, communication, workers' involvement, attitudes, and competence, as well as supportive and supervisory environments, in achieving a positive safety climate. Nevertheless, the study did not consider the direct influence of safety climate factors on safety behaviour.

In conclusion of BN based model results it is highlighted that probability of employees displaying good safety behaviour was 65.6%, indicating substantial potential for further improvement. However, it was imperative to first identify the factors that had the most influence on safety behaviour, so that a proper strategy to control those factors could be developed. By looking into each primary and other root nodes in both safety climate and personal experience factors, it was found that safety behaviour was more sensitive to safety climate factors such as management commitments and workmate's influences, and less sensitive to personal experience factors such as work experience and education experience. It should be noted that workmate's influence is closely related to team environment and work, which is one of the key components of organisational culture.

As found, it could be more efficient and effective to improve safety behaviour by controlling safety climate factors rather than personal experience factors in all simple strategies.

Behavioural Theory of Accident Causation

The behavioural theory of accident causation and prevention is often referred to as "Behaviour Based Safety (BBS)" has both proponents and critics.

According to (Geller, 1997) there are seven basic principles of BBS,

1- Interventions is focused on the employee behaviour
2- Identification of external factor that will help to understand and improve employee behaviour (from perspective of safety in workplace)
3- Direct behaviour with activators or events antecedent to the desired behaviour, and motivation of employee to behave as desired with incentives and rewards that will follow the desired behaviour
4- Focus on the positive consequences that will result from desired behaviour as a way to motivate employees
5- Application of the scientific method to improve attempts at behavioural interventions
6- Use of theory to integrate information rather than to limit possibilities; and
7- Planned interventions with the feelings and attitudes of individual employee in mind

Behaviour based safety plays very important role to change the organisations safety culture, behaviour based safety is little to do with codes, rules and regulations.

Safety Management Systems Model at Construction Site

Teo and Ling (2006) proposed a safety management systems model for construction sites. The research methodology adopted in this study consists of 15 steps. Surveys were conducted; safety experts were consulted and invited to express their views, either through interviews or workshops. The Analytic Hierarchy Process (AHP) and Factor Analysis were used to assist in identifying the most crucial factors and attributes affecting safety. The model was developed by means of multi-attribute value model (MAVT) approach. In conclusion the author admitted that the model developed in this study will not solve all safety problems on sites. What is more important in order to reduce the number of accidents is to have a proper framework to enhance safety on construction sites.

Safety Climate and Safety Performance Model

Relations among safety climate (safety attitudes and communication), psychological strains (psychological distress and job satisfaction), and safety performance (Reported accident rates and occupational injuries) was studied by (Siu et al. 2004). A questionnaire was administered to construction workers from 27 construction sites in Hong Kong (N = 374, M = 366, F = 8, mean age =36.68 years). Data were collected by in-depth interviews and a survey from February to May 2000. A path analysis using the EQS-5 was employed to test the hypothesized model relating safety climate, safety performance, and psychological strains.

The results provide partial support for the model, in that safety attitudes predict occupational injuries, and psychological distress predicts accident rates. The study flawed in its use of self-reported measures of accidents and injuries.

Antecedent or Activators, Behaviour and Consequence (ABC) Model

Proponents of BBS use the "ABC" model to summarize the concept of understanding human behaviour and developing appropriate interventions when the behaviour is undesirable (unsafe). (Geller, 1997) explains the model as follows:

"Behaviour based safety trainers and consultants teach the ABC model (or three terms contingency) as a framework to understand and analyze behaviour or to develop interventions for improving behaviour. As given in BBS, principle 3, the "A" stands for antecedent or activators events that precede behaviour "B" and "C" refers to the consequences following behaviour or produced by it. Activators direct behaviour, whereas consequence motivates behaviour".

STEPS TAKEN FOR IMPLEMENTATION OF BEHAVIOUR BASED SAFETY

Few steps that are presently taken to improve the behaviour based safety in organisations are here as under;

Getting Help from Safety Trainer and Consultants

Contractors are experts in contracting business, not in safety usually. It is observed that contractors give little considerations to follow/practice safety guidelines in their jobs. They are in stress to meet project deadlines. Since they are not experts in safety, they hire a professional safety director or consultant from outside. Initially, the professional safety director observes the existing safety culture in the organisation then he analyzes and finally proposes the necessary implementation guidelines to improve the safety climate. It is useful and very beneficial because contractors become too internally focused, but to get help from outside and a fresh set of eyes can help to spawn new thoughts and ideas and creates a strategy and vision.

Commitment from Organisation

Commitment from top management towards implementation of safety culture is the 2nd most important factor. Usually, organisations have a mind set that safety culture creation in an organisation is the responsibility of safety directors, they support the safety director but only from the sidelines. They won't involve in safety matters deeply. Top management must emphasize to bring this behaviour change and give utmost priority to lead not just support- the safety director's efforts. No doubt, this took time, energy, patience, commitment and financial resources. If upper management does not take the lead, then other team members will not buy into the importance.

Training and Coaching

Training and coaching factor has its vital importance towards implementation phase of behaviour based safety. Organisation must be willing to invest in training and personal development. Various ways provide trainings, coaching and refresher courses to the staff members. The most feasible option is to appoint an experienced safety-training organisation that is experienced in those particulars areas. The gaps shall be highlighted by the professional safety director. Follow trainings with good coaching for all levels of organisations. Not all categories of training modules are suitable for every organisation. They shall be designed according to the organisation's need. Direct coaching takes energy, time and money, but leaves a lasting impression. Above all the coaching should make sure that the safety message is personal to each and every team member. Every member must understand why safety is important to him.

System and Processes

Begin by conducting site safety evaluations. Direct feedback is given to those processes for which the job safety analysis/job hazard analysis was performed. Those processes critical for the productions are pointed out. Importance of human behaviour on safety is emphasized.

Consistent and Aggressive Accident Management Plan

A well recognised, practicable and efficient accident management plan shall be available. Drills shall be performed, deficiencies noted and very clear elaborations are delivered to the participants for improvement. Various Scenario Based Emergency Procedures (SBEP) shall be developed based on the associated hazards to the plant/site and practiced with the staff. These SBEP shall incorporate the role of local authorities as well. Hospitals and fire fighting departments are of the core value. A good communication link shall be practiced with the help of drills and improvements noticed highlighted.

Follow Through

This can be a long road. A safety system requires constant attention. There should be commitment every day from everyone to implement new action plans to help improve the safety culture. Changing the safety culture isn't done overnight, and instituting behaviour based safety requires as much as science as it does art. However, it is an initiative worthy of the investment necessary to see it succeed.

SAFETY STATISTICS

United States construction industry in 2005 suffered 1238 deaths. Britain in 2005/06, construction industry accounted for 28% of all work-related fatalities, with a similar number in injuries. In China, there were 2538 deaths recorded in construction industry. These relatively poor safety performance and accident records within the construction industry continue to cause concerns worldwide. In 2007/2008, 2.1 million people suffered from work related illnesses. Over 136,000 workers suffered injuries such as amputations, burns or fractures. 34 millions working days were lost in Great Britain (GB) due to injury and ill health. 229 people

were killed at work enforcement, 1028 offences were prosecuted by HSE. 354 offences were prosecuted by local authorities (Injuries Statistics 2008).

In many countries, safety has always been a major issue and often a problem in the construction industry in Hong Kong. Siu et al. (2004) stated thousands of people are killed annually in industrial accidents in Hong Kong, and the number of disabling injuries is also a staggering figure. For example, from Feb 1998 to March 1999, there were 35,986 cases of industrial accidents in all industrial undertakings in Hong Kong. Construction employees in Hong Kong incurred approximately 46% annual injury of all occupational injuries. Annual accident rate per 1000 workers in the Construction Industry was 248.6 and 199.1 in 1998 and 1999 respectively (Hong Kong Annual Digest, 1999).

SAFETY INTERVENTION STRATEGIES

Table 1 shows the statistics of many intervention studies applied for improvement in HSE. Table shows that the results obtained by the implementation of Behaviour Based Safety are more workable.

Table 1. Safety intervention strategies

S No	Approach	No of Studies	No of Subjects	Reduction %
1-	Behaviour Based	7	2,444	59.6%
2-	Ergonomics	3	N/A	51.6%
3-	Engineering Change	4	N/A	29.0%
4-	Problem Solving	1	76	20.0%
5-	Gov't Action	2	2	18.3%
6-	Management Audit's	4	N/A	17.0%
7-	Stress Management	2	1,300	15.0%
8-	Poster Campaigns	2	6100	14.0%
9-	Personnel Selection	26	19,177	3.7%
10-	Near-Miss Reports	2	N/A	0%

Developments in all areas are very fast. Same situation exists in construction industry as well. Modern methods of construction and new ways of performing tasks expedite the progress of work but on the other hand introducing new hazards. Traditional ways to handle these risks may not be appropriate. Therefore, a new systematic approach should be introduced to increase safe behaviours, reduce risky behaviours and prevent accident injuries and fatalities at work. One of the promising methods that could address this issue is using At-Risk Behaviour Analysis and Improvement System (ARBAIS) concept.

To reduce construction accidents and deaths, many researchers and practitioners have explored various techniques, including some practices in other industries. Although they may be well developed, it is still difficult to apply these practices in construction industry because of its unique features including:

(a) Continuous changes in construction workplaces;
(b) A peripatetic workforce; and
(c) Complex project and organisational arrangements.

This means that the construction industry, as a sector, demands more specific safety practices. Improvements in working conditions and innovations in the equipment used in the industry are not enough to improve safety performance because organisational culture and human factors also play critical roles.

Few researchers have explored the methodology to determine strategies to improve safety behaviour, particularly in relation to safety climate and personal experience, because of problems arising from the complex relationships between safety behaviour, safety climate, and human factors. A proper methodology is required to find strategies to improve safety behaviour from the complex relationship among various construction processes.

Many researchers adopted different strategies for reduction in HSE accidents and illnesses. Here a very few are described for reference. But HSE statistics has not improved noticeably. By reviewing the above mentioned interpretations and methodologies adopted by different researchers it can be very easily understood that much work is required for further improvement in behaviour based safety. Especially in construction Industry since no substantial studies are available.

RESEARCH METHODOLOGY

At-Risk Behaviour Analysis and Improvement System (ARBAIS)

During literature review it was found that At-Risk Behaviour Analysis and Improvement System (ARBAIS) were implemented in process industries. The results were found good. The model is applied in process industry as an On-line At-Risk Behaviour Analysis and Improvement System (e-ARBAIS). The same model cannot be applied in Construction Industry because of the differences in processes. Construction projects change radically, and the workforce also changes radically, not only with each project but during each project. In addition, the work environments vary with processes. These characteristics of construction projects may be an obstacle to applying behavioural safety programs that need certain length of time to educate the management and the workforce, gather data, assess results, feedback, and improve working behaviour. But it can be applied with some modifications. The application of ARBAIS model in Construction industry is looked favorable and it is hoped that successful results can be achieved.

This paper will describe the framework for application of At-Risk Behaviour Analysis and Improvement System (ARBAIS) model in Construction Industry. The study is intended to establish an alternative to the BBS. The ARBAIS utilizes psychological input to play a role in making the routine observation process. In the first phase contractor firms who have HSE management system will be selected. A meeting will be conducted to describe them about the concept of ARBAIS. Site visits will be conducted and a list of unsafe acts will be prepared. Potential unsafe acts will be highlighted. A detailed review of contractors HSE statistics will be performed. By comparing potential unsafe lists developed and contractor's statistics, critical unsafe actions will be selected. Only two major unsafe acts will be selected per day. A meeting will be conducted with staff members and labours at site. Full concept of ARBAIS will be described to them. A flag will be prepared for the unsafe acts selected with the help of HSE committee. The area of application of ARBAIS is highlighted. There

are many places in which ARBAIS can be applied for example excavation, earth fill, concrete work, working at height, masonry works, scaffolding preparation activity, flooring etc. with the mutual agreement of HSE committee an area for application of ARBAIS selected. Only two major potential unsafe acts related to this specific area would be selected. Every worker when he comes to mark his attendance/punching card has to take up a flag on which the unsafe action of yesterday work related to that particular area was written. If he saw unsafe act he has to take the flag if he don't saw this unsafe act no need to take the flag. The number of flags remaining would be counted at the end of the day. Management can be easily view the potential unsafe act at the work site. By this practice 3 to 4 flags for the questions will be prepared and put up at different work areas. No need for the labours to say anything to anybody. This cycle will be run for one month period. No employee will know what the question of the next day is. The interest develops between the employee and they participate actively. Data collected will be presented in HSE management committee meetings for their review. HSE management committee will select the most frequently occurring unsafe act and view the possibility that how it can be eliminated form site.

By seeing management's commitment towards improvement of unsafe acts the labour would be highly encouraged to further participate in this ARBAIS system. Once the system is implemented vital improvements can be easily observed. A safety behaviour culture is generated/created at site.

Comparison of Ordinary BBS and ARBAIS

The ARBAIS is a new concept that currently gaining popularity in the process industries. In this work, the ARBAIS concept will be modified to suit the nature of Construction Industry. Table 2 shows a comparison between the BBS and ARBAIS.

Table 2. Comparison of ordinary BBS and ARBAIS

Element	Ordinary BBS	ARBAIS
Training	Training given to observers on how to define unsafe behaviour and how to provide feedback.	No training needed. All will participate in the observations. Only briefing on what is ARBAIS and how it works.
Checklist	Checklist must be used to go through all items and see which does not comply.	No checklist is used.
Observation Frequency	Observers are required to make certain observations in a certain period, i.e. 1 observation a week.	Observation is done on daily basis or flexible adjustment to frequency can be made.
Cost	Additional cost for training and printing checklist.	Minimum cost since training and checklist are not required.
Feedback	Feedback is given directly when observation is complete, whether it is positive or negative. Results of observation need to be reported to HSE committee for further analysis.	Feedback can be given either face to face or through the database to prevent "sick feeling" with peers. HSE committee uses the same set of data for further action.
Involvement	Only those who are trained will be involved in the observations. To involve all, much training is required.	All will be involved in observation process.
Management Commitment	Management commitment determines the success of the process. Most BBS fail due to poor management commitment.	Database displays the management participation and thus motivates management to further commit and improve the program.

Framework of At-Risk Behaviour Analysis and Improvement System (ARBAIS) Model

Figure 2 shows the framework of ARBAIS model.

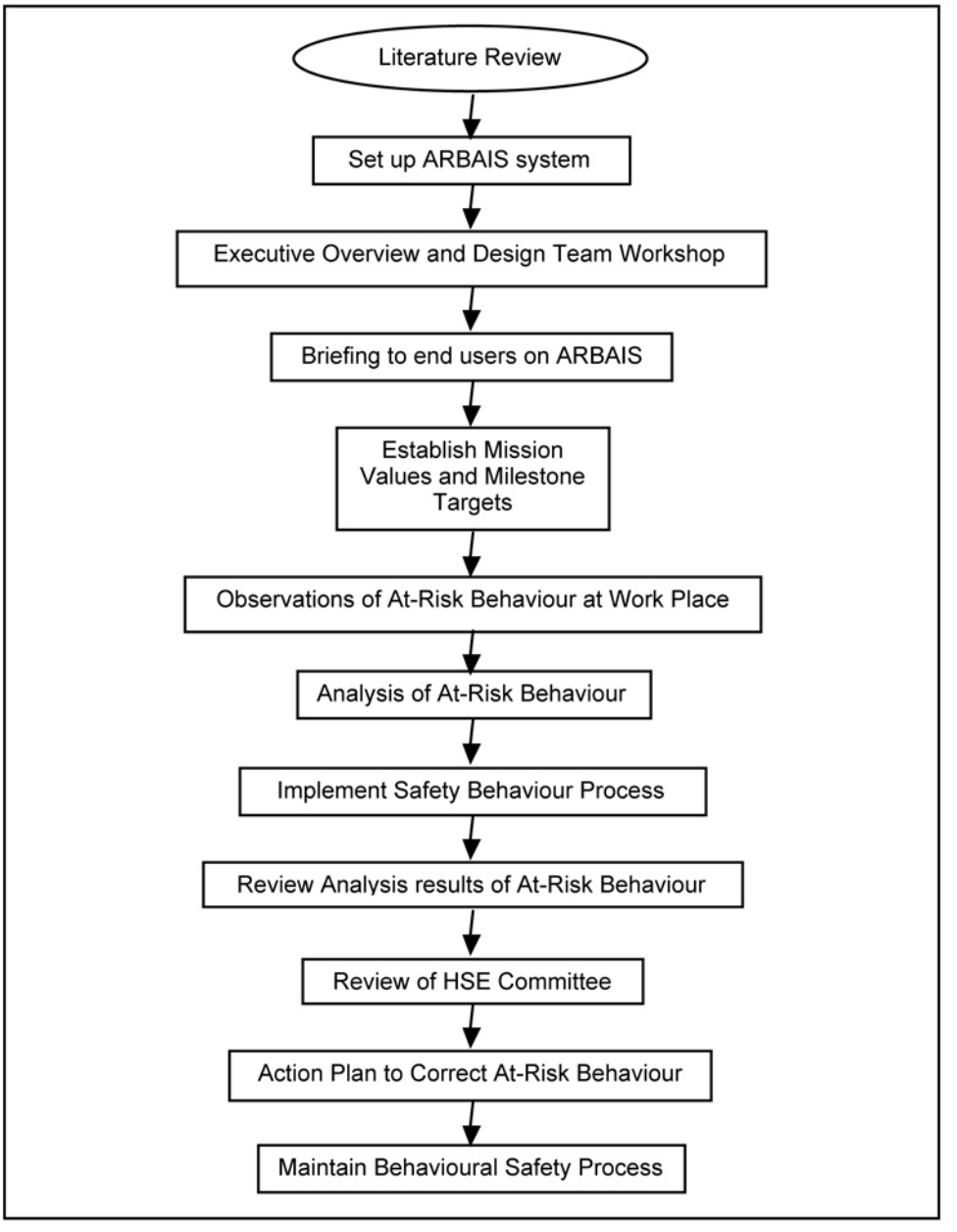

Figure 2. Framework of ARBAIS model

CONCLUSION

The ARBAIS has a potential to reduce injury in the organisation if implemented with a thorough plan and strong commitment from all organisational levels. The main idea behind ARBAIS is to serve as replacement to current BBS programs. It needs very few resources, good involvement of labour and low cost, besides easy to implement and also in collecting data. The questions selected to eliminate the unsafe acts will be repeated in a limited time frame. It also reminds the staff about the unsafe acts by looking about the provision of earlier unsafe act. They will not repeat the same act today. This helps to provide a psychological effect to the labours on the safe behaviour and promote habitual awareness. This eventually promotes a safety culture in an organisation. During implementation of ARBAIS model a well designed framework, effective communication between safety department and staff and efficient follow up of the data will be given high priority. The method, once implemented could reduce injuries and fatalities due to workers unsafe actions.

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THE EFFECT OF SUGAR BASED RETARDER ON GEOPOLYMER CONCRETE IN DIFFERENT CURING CONDITIONS

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Abstract
Geopolymer is an alternative binder to Portland cement which can contribute to the reduction of air pollution from OPC production. However the current limitation of geopolymer concrete is only applicable to precast concrete industry therefore this research was conducted for cast in situ application. Commercial admixture commonly applied in geopolymer concrete researches was replaced with sugar based retarder to delay the setting time of fresh geopolymer concrete. Different curing methods, namely ambient, external exposure, and oven curing were adopted. Compressive strength results showed that the inclusion of sugar based retarder could improve the concrete performance, whilst external exposure curing provided the most optimum condition for geopolymer concrete strength.

Keywords: *Geopolymer Concrete, Cast In Situ, Sugar Based Retarder*

INTRODUCTION

Numerous problems have been associated with cement production. Emission of CO_2 and toxic gasses and depletion of raw materials have motivated for the utilisation of greener cement technology (Environment of Canada, 2007). In the meantime, concrete industry is the main consumer of this material and increasing demand of concrete in the world already surpasses 8.8 billion tons production per year (Mehta, 2002).

In order to address this issue, several materials were proposed to replace cement function in concrete. Waste materials that contain silica and alumina were applied to replace some cement portion in concrete. Cement replacement material (CRM) was named after these materials to describe their function in concrete. Pozzolanic reaction product that occurs between CRM and hydration paste has significantly improved conventional concrete properties. Fly ash, microwave incinerated rice husk ash (MIRHA), ground granulated blast furnace slag (GGBS), and silica fume (SF) are several examples of CRM that are commonly used (Nuruddin et al, 2008). However, this material can only replace certain percentage of cement portion in concrete. In 2002, Malhotra has developed high volume fly ash concrete but can only replace Portland cement no more than 60% without reducing concrete performance.

In 1978, Davidovits introduced a new material that can be used as an alternative binder to cement. This material was named as geopolymer for its reaction between alkaline liquid and geological based source material (Davidovits, 1994). The reaction product from this material can be used to bind aggregate together and formed concrete. Inspired by this, Hardjito and Rangan in 2002 established a research on fly ash based geopolymer to study the engineering properties of this concrete. Steam and oven curing were employed by Rangan to accelerate the polymerization process of this geopolymer concrete.

The main constituents of geopolymer concrete are alkaline liquid and source material. Alkaline liquid is usually a combination of sodium hydroxide or potassium hydroxide with sodium silicate or potassium silicate (Barbosa et al, 2000). The use of only alkaline hydroxide activator will result in low reaction rate compared to those containing soluble silicate (Palomo et al, 1999).

The addition of sodium silicate solution to sodium hydroxide solution will enhance the reaction rate between alkaline liquid and source material (Xu et al, 2000). Commonly, source material is of geological origin based material that is rich in silica and alumina for instance fly ash. Fly Ash is a byproduct from the operation of coal generated power plant. Waste created by a typical 500-megawatt coal plant includes more than 125,000 tons of ash and 193,000 tons of sludge from the smokestack scrubber each year. More than 75% of this waste is disposed of in unmonitored onsite landfills and surface impoundments (UCS, 2008). Therefore proper disposal and utilisation of these ashes are needed to preserve the ecosystem from severely or permanently damaged by the uncontrolled coal plant waste disposal. Utilisation of fly ash in geopolymer concrete industry will significantly support this objective.

The application of geopolymer concrete is mostly affected by its curing method. The elevated temperature curing supplied by electric equipment generated hot steam or dry heat but this method limited the application of geopolymer concrete for precast environment and not for in situ concrete work. Workability also plays an important role in geopolymer concrete quality and the commercial retarder was replaced with sugar based retarder that is more environmental friendly.

RESEARCH METHODOLOGY

Materials

NaOH supplied was in pellet form with 99% purity and 8 Molar NaOH solution was used for all mix proportions in this research. While Na_2SiO_3 used was with specific proportion of Na_2O: 14.73%, SiO_2: 29.75%, and water: 55.52%. Fly ash used in this research contains oxide compositions as shown in Table 1.

Table 1. Fly Ash Chemical Composition

Oxide	Percentages (%)
SiO_2	51.19 %
Al_2O_3	24.00 %
Fe_2O_3	6.60 %
CaO	5.57 %
MgO	2.40 %
SO_3	0.88 %
K_2O	1.14 %
Na_2O	2.12%

Experimental Setup

Mix proportions were designed with different amount of sugar to investigate their effect on the geopolymer concrete properties. Constant amount of NaOH and Na_2SiO_3 were used throughout the mix proportions. This mix proportions were adopted from Wallah et al, 2006 works with some modifications to adjust them with current alkaline liquid specifications. The

details for each mixture are shown in Table 2. Alkaline solutions were prepared 1 hour before mixing process started to prevent precipitation of NaOH in the solution. Mixing process was divided into two stages, dry mix and wet mix. In dry mix, coarse aggregate, fine aggregate and fly ash were mixed together in rotating pan mixer for 2.5 minutes. Alkaline and sugar solutions were then poured into the dry mixed material and continued for wet mixing for 1.5 minutes. Fresh geopolymer concrete was then hand mixed to ensure the mixture homogeneity. Casting of fresh geopolymer concrete was done in 100 mm x 100 mm x 100 mm cube moulds and compacted using mechanical vibrator.

Table 2. Mixture Proportion Detail

Mix Code	Fly Ash	Coarse	Fine	NaOH (kg/m^3)	Na_2SiO_3	Water	Sugar
A1	350	1200	645	41	103	35	3.5
A2	350	1200	645	41	103	35	7
A3	350	1200	645	41	103	35	10.5
A01	350	1200	645	41	103	35	0
A02	350	1200	645	41	103	52.5	0
HG	350	1200	645	41	103	35	10.5
EE	350	1200	645	41	103	35	10.5
O1	350	1200	645	41	103	35	3.5
O2	350	1200	645	41	103	35	7
O01	350	1200	645	41	103	35	0
O02	350	1200	645	41	103	52.5	0

Concrete specimens were exposed to four different curing regimes, namely external exposure curing, ambient curing, oven curing, and hot gunny curing, to observe their effect on the development of geopolymer concrete strength. In external exposure curing, concrete specimens were placed inside a plastic chamber to expose them to the sunlight heat until the testing day, as shown in Figure 1. In oven curing, the concrete specimens were placed in electric oven with temperature 65°C for 24 hours, after 24 hours, the specimens were kept at ambient condition, as shown in Figure 2.

Figure 1. External exposure curing

Figure 2. Oven curing

In ambient curing, concrete specimens were placed outside the laboratory room but still protected from rain and direct sunlight, as shown in Figure 3. While in hot gunny curing, concrete specimens were covered for 48 hours with gunny sack that was previously immersed in hot water, as shown in Figure 4. The hot gunny was covered with plastic sheet to prevent the heat being released immediately to the environment with the gunny replaced for every 24 hours. Hardened concrete samples were then tested for their compressive strength at 3, 7, 28, and 56 days. Except for oven curing samples, the test was conducted on 1, 3, 7, and 28 days.

Figure 3. Ambient curing

Figure 4. Hot gunny curing

RESULT

Compressive strength results were observed on hardened concrete sample at different curing ages. The complete strength results are shown in Table 3. Figure 1 and Figure 2 illustrates the compressive strength of geopolymer concrete samples in ambient curing condition and oven curing condition respectively, while Figure 3 describes the comparison of compressive strength from each curing condition.

Table 3. Compressive Strength Results

Mix Code	day				
	1	3	7	28	56
A1	n/a	11.10	19.20	34.52	37.42
A2	n/a	9.82	16.40	30.85	32.65
A3	n/a	9.50	14.11	19.73	21.92
A01	n/a	10.47	15.32	27.80	31.50
A02	n/a	8.58	14.44	27.03	31.57
HG	n/a	5.00	9.00	15.00	16.96
EE	n/a	34.50	42.30	48.70	50.60
O1	31.86	33.56	32.57	37.03	n/a
O2	36.20	36.10	36.58	39.80	n/a
O01	23.04	23.42	24.13	24.33	n/a
O02	33.31	34.39	34.14	35.30	n/a

As illustrated in Figure 5, it is clearly shown that the inclusion of sugar at certain amount could improve geopolymer concrete properties. The setting time was much affected with the inclusion of sugar in the mixture. Fresh geopolymer concrete in this research would start to set after 20 minutes if sugar was not added and with certain amount of sugar the setting time could be delayed until 30 minutes. With the same amount of extra water added, 1% of sugar in ambient curing could increase the compressive strength up to 18.79% compared to non sugar mixture, as shown in Figure 5.

Wallah et al, 2006 has explained that water is not involved in polymeric reaction and will be expelled during curing process. It is verified by sample A01 (10% extra water, 0% glucose) and sample A02 (15% water, 0% glucose). The difference in compressive strength between these two samples is insignificant. The difference at 56 days was only 0.22% between A01and A02.

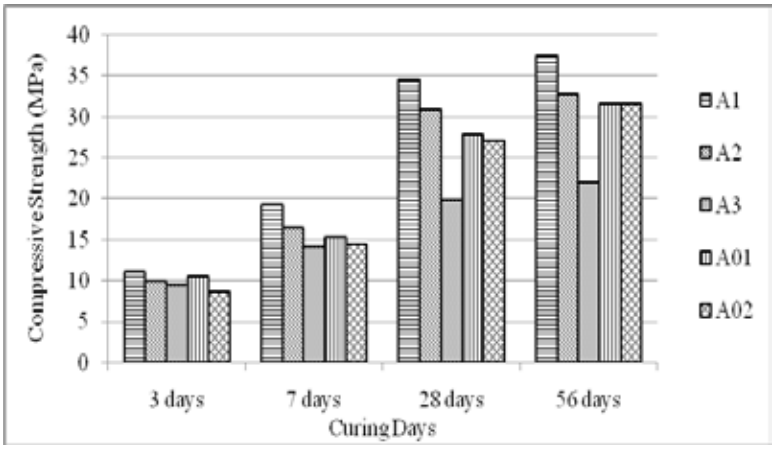

Figure 5. Compressive strength results of ambient curing geopolymer concrete

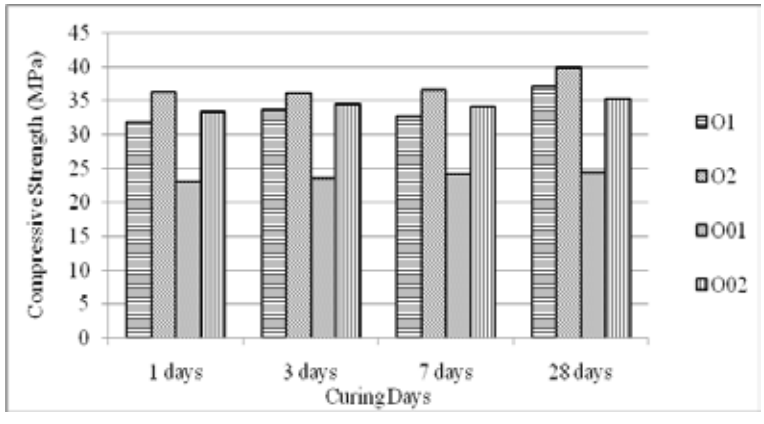

Figure 6. Compressive strength results of oven curing geopolymer concrete

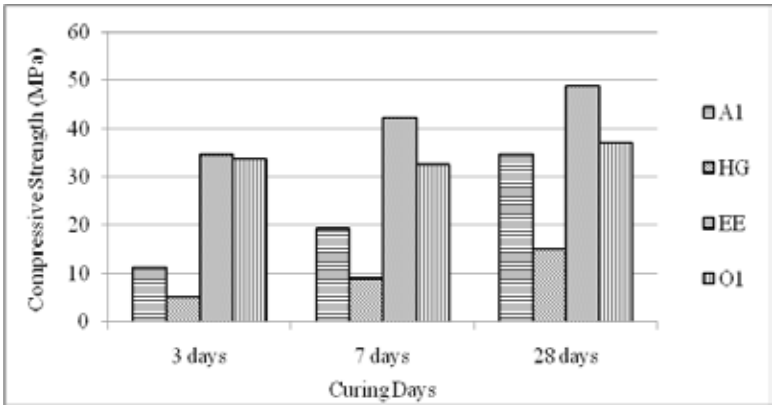

Figure 7. Comparison between each curing method

In oven curing, inclusion of sucrose also provides positive effect to the concrete strength, as shown in Figure 6. The availability of elevated temperature in this method was supporting the polymer reaction. Comparison was also made between ambient curing, oven curing, hot gunny curing, and external exposure curing. It is clearly shown in Figure 7 that environment with high moisture content, which was represented by hot gunny curing sample, could not provide good condition to geopolymerisation process. Temperature increment to ambient provided better improvement to the concrete strength. It was similar with oven curing. However the most significant improvement was performed by external exposure curing. Even though the highest temperature in external exposure was 55°C, but it appears that gradually increment of temperature provide better environment to the geopolymer concrete strength development.

With the availability of sufficient heat during first period of geopolymerisation, certain stage of moisture content could possibly prevent concrete specimens from internal cracking due to high heat exposure; however excessive moisture content will decelerate the reaction process. Sucrose helped fresh geopolymer concrete to maintain its moisture content longer; hence reducing the possibility of internal cracking when exposed to high temperature. The reduction of cracking possibilities could significantly improve the specimen's strength. The strength differences could reach 31.51% higher if compared to oven curing, 41.08% higher if compared with ambient curing, and 224.67% higher if compared to hot gunny curing.

CONCLUSIONS

The inclusion of sugar based retarder has successfully improved fly ash based geopolymer concrete performance, as observed in the compressive strength results between these curing methods, external exposure curing provided the most optimum curing condition to geopolymer concrete. It was believed that gradual increment in the temperature presented an important role to the fly ash based geopolymer concrete performance.

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BUILDING MAINTENANCE: A PATH TOWARDS SUSTAINABILITY

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Abstract
This paper explores the potential of building maintenance as one of many ways to advocate sustainability in the built environment in particular during the building operation. The first objective is to provide an overview of the sustainability issues and building maintenance through literature and theory reviews. The second objective is to analyse building defects in the Malaysian university campuses. And this is achieved through questionnaire survey. The questionnaires were administered on 50 university maintenance organizations. With a 66% response rate, the findings suggest that some defects require maintenance urgently than the others and on the basis of which it is concluded that resources should be directed to the more urgent ones while the less urgent ones could be included in the subsequent maintenance rolling programme (i.e. planned maintenance). The research found that lift failure, faulty electrical systems and roof damages were the defects that respondents considered extremely urgent to maintain. Defect analysis is significant for universities to be seen as a role-model in advocating sustainable maintenance management system for their buildings and engineering services.

Keywords: *Defects, University Buildings, Maintenance Management, Sustainable Building*

INTRODUCTION

Sustainable development is a concept that integrates various criteria including "energy efficiency, durability, waste minimisation, social impacts, good indoor environment, durability, pollution control, life-cost, user-friendliness, user comfort and others" (Zainul, 2006). The built environment which the building form part, is the largest consumers of natural resource, consume about 40% of the global energy use and produce most of the world wastes at same time responsible for the production of about half of the world carbon dioxide (Kallaos, 2010). Arguably, the building sector is the most dominant sector in the built environment. For instance, the building alone contribute about one-third of the global energy use (Wee, 2009). Therefore, if the building is operate at optimum level, it could help in meeting the desire carbon dioxide reduction, waste reduction, reduction in energy and promote healthy living. From one hand, buildings require maintenance to be sustainable. According to Sherwin (2000), maintenance contributes to sustainability in three basic ways: it holds noxious to the bare minimum level, reduction of energy and resources emission by ensuring the durability and availability of the building facilities. Finally, it provides information to the designers on the features of already installed components.

The importance of the green building initiative cannot be stressed enough. In fact, what really comes to mind on the mention of sustainable is building. However, there is also the need for sustainable maintenance which is a "maintenance system that meets the value system of the present users without compromising the ability of meeting the value system of the future users" (Olanrewaju and Kafayah, 2008). Under the sustainable maintenance concept, maintenance demand is initiated based on the user value system consideration and with the consideration of environmental issues. This paper seeks to examine building in the context of sustainability drives and to analysis defects in the university buildings in Malaysia. This

research collected primary data through questionnaire survey. Data obtained were analyzed using SPSS to produce descriptive statistics. The major conclusion drawn from the survey was that although there are many different defects, but some require extreme attention than the others. The paper concludes by arguing that building maintenance is a strategic issue for academic institution. The failure of universities to accept maintenance as a core service is serious failure to a sector that prides itself as vehicle for scientific and technological advancement. Universities have responsibilities for prudent management of resources.

THEORETICAL FRAMEWORK AND BACKGROUND

Sustainability means different things to different people. For the purpose of this paper, terms including green building, eco-building, sustainable building and energy efficient building are synonymous with sustainability and they are sometime used interchangeably. Sustainability is a vogue and vague term. However, it is a 'positive vogue' (Cole. and Lorch, 2003). Sustainability places emphasis on the efficient balance between nature and the built environment, while taking into account the impact of man's activities on the environment in meeting the need of the present generation without inflicting harm to the future generation. Christensen (2005) defined sustainability as the "ability to provide healthy human-influenced existence or process symbiotic with allowing, encouraging or capturing stability with natural variance over generations." From the definition,'sustainable buildings can be defined as building that strives to preserve the economic, ecological, spiritual, social and cultural requirements for societal well-being, and at the same time preserve the natural environment for future use (Olanrewaju and Kafayah, 2008). Cement which is a major building material contributes significantly to carbon dioxide emission. Sustainable building provide energy saving, water saving, healthier indoor environment, better connectivity to social facilities and amenities (public transport) embracing recycle initiative (Wee, 2009).

The fundamental goals of the sustainability agenda include the ability to reduce carbon dioxide emissions by at least 60% from its current level by 2050 (Killip, 2006). While new building can be designed in accordance with the sustainable agenda, building cannot remain new throughout its life span. They require maintenance in order to attain its design life. The need for maintenance in buildings will only intensify as the value of the building and the associated engineering services must be preserved and sustain for the building to be meaningful to its users since;

"Even before a building is completed, nature begins to destroy it systematically, and gravity, winds and seismic movements constantly test the stability of the structure" (Allen, 1995 and 2005).

Accordingly, birth, growth, maturity, decline, decay, death, and rebirth are fundamental stages in all natural cycle and so too with building, although human like to keep the cycle under control through maintenance until its death suit human purpose (Allen, 1995 and 2005). There are usually several factors or combinations of several factors that lead building to fail in value. Building may not performed satisfactorily as a result of inadequate design, poor workmanship, defective materials and components, wrong installations and applications and failure to provide the required maintenance. However, assuming the initial design was adequate for the intended use, quality of workmanship was high, materials and components selected were of high quality and installed properly hence any inconsistency from the predicted service life can

be attributed to maintenance. Supporting this point further, many researchers contended that sustainability could not be achieved if adequate maintenance is not expanded to the building stocks (Wood, 2005). New buildings must be designed and operated in a sustainable manner.

Internationally recognised systems for assessing buildings environmental performance such as LEED (Leadership in Energy and Environmental Design) in US, GBC (Green Building Challenge) and BREEAM (Building Research Establishment Environmental Assessment Method) in UK, HQE (High Environmental Quality) in France, CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) in Japan and VERDE in Spain, include building and services maintenance as part of the assessment criteria (Sinou and Kyvelou, 2006). See also (Seeley, 1987). Nationally, the newly launched Green Building Index (GBI) Malaysia also clearly articulates maintenance as a critical component towards meeting the sustainable development goal. Apparently to provide holistic framework for sustainable construction, maintenance consideration is significant. A sustainable building must be easy to maintain any way! Building maintenance constantly affects everyone's life because people's comfort and productivity is relative to the performance of the building they live, learn, conduct research and work in (e.g. home, offices, schools, university and markets), not to mention the impact it have on social fabric and economic growth (Rendeau, Brown and Lapides, 2006).

While initiatives including refurbishment, alteration, conversion and reconstruction are one off, maintenance is a must in the building life cycle. The recent amendments to the building regulations that compel sustainability issues be considered during any building maintenance work (Wood, 2005) is a point that maintenance is essential towards the sustainability agenda. The amendments stipulate that all repair and replacement objectives must go down well with the ideas of sustainability. If a building is not well maintained, certainly it will affect the users' quality and productivity. It will generate more wastes and more funds will be required to keep such building operational. Buildings that fail in their efficiency-criterion or do not meet the required maintenance standards will certainly produce more waste and pollutants (e.g. toxic build-up, carbon dioxide emission), affect users' well-being, as well as consume more energy, water and other resources (Olanrewaju and Kafayah, 2008).

Basically, there is no way all existing buildings can comply with the sustainable agenda without going through the painstaking of maintenance processes. It is practically impossible to replace or rebuilt all organization or nation buildings at one time. Even a nation, no matter how endowed it is cannot embark on such unachievable mission. The following is an illustration. The replacement costs of sixties buildings in English universities alone is estimated to cost £11 billion (Rawlinson & Brett, 2009). Building designed to comply with sustainability must be maintained to continue to perform, however. This is because, no building is maintenance free. However, as soon as a building is completed, maintenance starts. About 70% of the building operating costs is attributed to maintenance (Rendeau, Brown and Lapides, 2006 & Booty, 2006) and about 90% of the life time of building projects requires maintenance work (Mills, 1994 and Zavadskas & Vilutiene, 2006).

Sustainability is a concept that cut across all types of buildings such as commercial buildings, hospital buildings, residential buildings and educational buildings. University buildings are places where people live, work, learn, teach and do research. University buildings are procured to create suitable, conducive, and adequate environment that support, stimulate and encourage

learning, teaching, and innovation and research. Thus, with any inadequacy with the building facilities, the prime objective of the university will be difficult if not impossible to achieve. A failure in the supply of the require services is a loss in value to the university institution, users and other stakeholders. Maintaining the buildings is essentially required to delay defects to ensure that the buildings perform optimally throughout its design life.

Building defect has many different definitions. To some it means the shortcomings with the design and construction practices. But to some, it implies the inadequacies that arise from building wear and tear. Some will argue that it is a combination of these factors. Design and construction lead defects are defects caused due to wrong methods of construction, poor materials and bad labour. Granted, the primary causes of building defects are inevitably interconnected, the focus of this paper is on the maintenance caused by wear and tear. The design and construction lead defects constitutes another arena of specialists study that is beyond the scope of this paper. Unfortunately, there is no known clear definition for wear and tear in construction literature. Even architectures and construction dictionaries (Fleming, Honou and Pevsner, 1999; Cowan and Smith, 2004; Harris, 2005; Bucher, 1996; Ching, 1997; Comerma, 2007 and Curl, 1999) can hardly define the concept. Wear and tear is a combination of two separate words: wear (phrasal verbs: wear down, wear in, wear off, wear on and wear out) and tear (phrasal verbs: tear apart, tear at, tear away, tear down, tear into and tear up). According to Collins Cobouild Advanced Learner's English Dictionary (2006), wear and tear "is the damage or change that is caused to something when it is being used normally".

To the Webster's New Explorer Encyclopaedic Dictionary (2006), wear and tear is "the loss, injury or stress to which something is subjected by or in the course of use; especially: normal depreciation. In other words, wear and tear is a depreciation, reduction or fall in the functional performance or value of a building or engineering services that arises as a result of normal or fair use. Contributing to the normal use phenomenon is age of the buildings or services, natural weather condition, inadequate maintenance. Therefore, wear and tear is a defect that takes place in the operation stage of building. It is cause by use, weather and age of the building. It is an undesirable or inadequate condition in the buildings that affects the serviceability, performance, acceptance or appearance of the buildings or their combination. Examples of building wear and tear defects are cracked walls, decayed timber, decayed metal rails and pipes, sagging to a roof, clogged water closet, faulty lift, faulty windows and doors, leaking showers, water seepage and sagging ceilings. Building defects are identified by the users themselves or through inspection by those concerns with the facilities management.

The effect of defect on the conditions, appearance and performance of building depend on the function requirements of the buildings. For instance, a condition that might be acceptable for resident building could require immediate maintenance in the case of university buildings. Defect does not only affect the building appearance and performance, but could also lead to accidents and even death (Aagaard, de Place Hansen, and Nielsen, 2010).

Building defects account for about 20% of building maintenance cost (Chanter and Swallow, 2007). Therefore the proper consideration of defect in total maintenance management cannot be emphasized enough if the achieving sustainability is critical. However, there is no available comparable numerical data on the extent of defects in university buildings in Malaysia, it is possible that they suffer from a similar degree of care and neglect like other institutional buildings. Based on available data obtained from the Malaysian Ministry of

Higher Education, it is suggested that maintenance expenditure had expanded by nearly 85% from 2004 to 2008. For instance, expenditure on maintenance was about RM 340 million in 2004 while it increased to more than RM 600 million in 2008. However, comparing these amounts with the total expenditure on education, it can be inferred that government is investing roughly 1 % on buildings maintenance. This amount is however inadequate to cater for the maintenance backlogs.

Elsewhere, it is established that organization, need to allocate between 3% and 5% of the value of it building stocks for maintenance. However, it is very unclear, whether increase in allocation and expenditure will ever improve the building performance, increase users satisfactions and to contribute to achieving sustainable development. Because even if there is increased in the allocation, maintenance could only be given tactical attention rather value-based consideration. However, it is affirmed that information on the nature, degree and kind of defects will dictate when the repair work is to be undertaken, and allow future works to be programmed and financed as part of the maintenance rolling programme.

Proactive and holistic understanding of the nature and kind of specific defects is imperative for total maintenance management. Holistic understandings of defects focus the maintenance organizations to the users' maintenance requirements. Consequently, instead of focusing attentions on defects that are not very essential in the users value systems, organization resources is directed to defects that affect users satisfaction, i.e. *user care*. Maintenance is actually about users' well-being not necessarily the buildings *per se*. Buildings are procured for sake of the services (i.e. comfort, protection and esteem) they offer to the users. Building users have the potential and capability to react if they are not satisfied with the performance of the building. It is the correct functional performance of the building that the users desire not the physical condition of the building. To the extent that the building is capable of allowing the users to perform their functions, then the building is a source of value creation to the required service of accommodating, learning, teaching and doing research; with specific reference to the university buildings.

RESEARCH DESIGN AND METHOD OF DATA ANALYSIS

A quantitative research method by questionnaire survey approach was used to collect primary data. The questionnaire was divided into three parts. The first part is to capture the respondent's profiles while the second part focuses on background information. The third section provides feedback on the defects associated with the university buildings. The questionnaires were administered on all the fifty recognized universities in Malaysia. Though it is not the intention of the research to carry out census, but all the universities were involved in order to enhance the response rate. The questionnaire was modified after Arditi and Nawakorawit (1999), Chanter and Swallow, (2007), Ilozor, Okoroh, Egbu, & Archicentre (2004) and Seeley (1987) and a series of discussions with those concerned with management of the university buildings. Twenty eight wear and tear defects in buildings were addressed to the respondents. The data collection and collation commenced in July 2009 and lasted through to October 2009. This long period of the survey duration was as a result of the respondents' inabilities to complete and return the questionnaire on time.

Data analysis was performed using two different computer packages: SPSS and Microsoft Excel to generate descriptive statistics. Descriptive statistics provide information regarding

the distributions of datasets or variables. In a research, respondents supplied different opinions on a concept or variable addressed to them. Often each of the variables cannot be explained in detail or does not even require to be explained individually. Therefore, a mid-score or value is determined to explain the varying values or opinions. The mean technique is used to calculate the average degree of defects in the buildings. Standard Deviation was employed to calculate the level of spread of each of the individual value from the mean score. The degree of urgency of each of the defects is determined by the frequency of the respondents that agreed with each of the defects. For instance, where the mean score falls between 1.0 and 1.5 the defect is considered as not urgent at all. See Table 1 for other distributions. This cut off point is used, because the lowest possible mean score is 1. However, it was understood, that natural scale originates from zero (0) which in this case is not require.

Missing data (i.e. where the respondent refused to tick where applicable or there is multiple entry), could impact negatively on the outcome of the findings, however such effect could be improved during data analysis by either replacing the missing data with the mode or mean of the data. However, in this paper, the missing data will not be treated as such; instead the data was left as it is so that the outcomes will not in any way be influenced. However, this tends not to be a problem in the study as nearly all the questions were answered by the respondents.

Table 1. Average Index Evaluation Metric

Scale	Evaluation (interpretation
1.00 – 1.50	Not urgent at all
1.51 – 2.50	Not very urgent
2.51 – 3.50	Urgent
3.51 – 4.50	Very urgent
4.51 – 5.00	Extremely

DATA ANALYSIS

Respondents' Profile

A total of 50 questionnaires were sent out to the maintenance organizations of universities. Thirty three questionnaires were returned and analyzed for this study. The response rate was 66% and was considered satisfactory for postal survey. According to Muijs (2004) and Sekaran (2004), 30% is the common response rate for postal survey. However, this high response rate was possible because of the long survey duration and the numerous reminders sent to the respondents. Prior to the main data analysis, reliability test was performed on the data and found the data is very reliable (Cronbach's Alpha: 0.930). 17 of the universities surveyed were private universities while the remainder 16 were publicly owned universities. Analysis of the outcome of the survey shows that most of the respondents possessed sound academic qualifications. The survey revealed that about 50% of them possessed Bachelor degree and 21.9% had obtained MSc degrees (Table 2). The survey revealed that most of the respondents held strategic positions.

Table 2. Respondent's Highest Academic Qualification

Qualification	Frequency	Percentage
Bachelor degree	15	46.9
Master degree	7	21.9
Other	10	31.2
Total	32	100.0

Nearly 32% of the respondents were actually maintenance managers while about 19% were facilities managers. Substantial positions of the "other" are director of development or maintenance "executive" (this is another title or term used for maintenance manager). From the analysis of the survey, 52% of the universities spent less than RM 10 million each on maintenance annually while about 10% spent about RM 30 million each on maintenance per annum (Table 3). Similarly, about 22% of the surveyed universities occupied less than 280,000 m^2 built up area while more than 40% occupied more than 1,400,000 m^2 built up area. Majority (42%) of the buildings were about 15 years old while only about 10% were between 30 to 50 years old. Therefore, this it could be inferred that most of the university buildings were not that old *per see* yet considerable amount of money is invested for the maintenance albeit there are considerable complaints about university maintenance practices. Most of the universities employed less than 30 employees each on full time basis (Table 4). Only 16% of them actually employed 140-170 full time employees even though two organizations (6.2%) have 60 – 90 and 110 – 140 employees on their full time pay rolls each respectively.

Table 3. Annual Maintenance Budget

Budget	Frequency	Percentage
Less than 10	16	51.6
10 to 20	12	38.7
20 to 30	1	3.2
30 to 40	2	6.5
Total	**31**	**100.0**

Table 4. Respondent Working Experience

Experience	Frequency	Percentage
Less than five years	15	46.9
Five years to ten years	7	21.9
Ten years to fifteen years	5	15.6
Fifteen years and above	5	15.6
Total	**32**	**100.0**

Analysis of Defects in University Buildings

The outcomes on the degree of urgency of the different defects are shown in Table 5. It shows an overview of data obtained, the level of urgency, variability and the mean scores. The mean score indicates the degree of urgency for each of the defects. The average mean score is

3.45. Fifty percent of the defects have their individual mean score more than the average mean score. In general, most (31.82%) of the survey respondents considered all the defects as urgent while considerable size (23.62%) considered the defects as extremely urgent. Just fewer of the respondents viewed the defects as not at all urgent (2.83%).

Lift failure was the most (1) extremely rated defect followed by faulty electrical equipments while the least most considered defect was faulty towel rail (28) after bad soap holder (27). In fact, nearly 64% of the respondents considered faulty lift as extremely urgent concurrently 54% of the respondents considered faulty electrical equipments as extremely. Although considerable size of the respondent (n=2) considered lift failure as not very urgent and only one of the respondent did not considered electrical equipments as very urgent. On the other hand, many (27.3%) of the respondent did not consider the maintenance of faulty towel rail as urgent at all while most of the respondents also considered it as not very urgent to maintain.

The outcomes of the survey shows most of the respondents (45.5%) did not consider the maintenance of soap holder as urgent at all even though many of them (27.3%) considered it maintenance as urgent yet considerable part (18.2%) of the respondents considers it as not urgent at all to maintain. While most (37.5%) of the respondents did not considered the maintenance of washing machine as not very urgent quite a number (15.6%) of them see it as not to require urgent maintenance. Although many (18.2%) of respondents consider the maintenance of windows as.

Table 5. Distribution of Urgency of Defects in University Buildings

Defect	Frequency of Respondents on Degree of Agreements (%)					Statistics		
	Not at all Urgent	Not very Urgent	Urgent	Very Urgent	Extremely Urgent	Mean	SD*	Ranking
Damaged window	0.0	15.2	48.5	18.2	18.2	3.39	0.97	17
Clogged water closet	0.0	3.1	25.0	37.5	34.4	4.03	0.86	7
Floor tile failure	0.0	48.5	39.4	9.1	3.0	2.67	0.78	24
Wall tile failure	0.0	48.5	45.5	6.1	0.0	2.58	0.61	26
Faulty shower	0.0	33.3	39.4	18.2	9.1	3.03	0.95	22
Faulty fan	0.0	21.1	51.5	24.2	3.0	3.09	0.76	19
Damaged ceiling	0.0	30.3	39.4	21.1	9.1	3.09	0.95	20
Faulty door locks	0.0	6.1	33.3	36.4	24.2	3.79	0.98	10
Faulty towel rail	27.3	39.4	21.2	6.1	6.1	2.24	1.12	28
Faulty water dispenser	3.0	39.4	42.4	12.1	3.0	2.72	0.84	23
Faulty bulbs	0.0	6.1	54.5	21.2	18.2	3.52	0.87	13
Faulty air conditioning system	0.0	3.0	27.3	27.7	42.4	4.09	0.91	4
Faulty electrical circuit	0.0	3.0	12.1	30.3	54.50	4.36	0.82	2
Lifts failures	0.0	6.1	9.1	21.2	63.6	4.42	0.90	1
Faulty taps	0.0	15.6	40.6	31.2	12.5	3.41	0.91	16
Damaged roof structure	3.0	3.0	15.2	24.4	54.5	4.24	1.03	3
Collapse drains	0.0	18.2	33.3	27.3	21.2	3.52	1.03	14
Faulty communications appliances	3.0	3.0	33.3	24.2	36.4	3.88	1.05	8
Failed furniture and fittings	0.0	9.1	33.3	39.4	18.2	3.06	1.09	21
Faulty door	0.0	12.1	45.5	21.2	21.2	3.52	0.97	15
Sink leakage / blocked	0.0	6.1	39.4	30.3	24.2	3.72	0.91	12
Bad soap holders	18.2	45.5	27.3	9.1	0.0	2.27	0.88	27
Pipe leakage	3.0	6.1	33.3	21.2	36.4	3.82	1.10	9
Faulty washing machine	15.6	37.5	28.1	6.2	12.5	2.63	1.21	25
Faulty fire alarm	3.0	6.1	15.2	30.3	45.5	4.09	1.07	5
Faulty heat extractor	3.1	28.1	25.0	21.8	21.9	3.31	1.2	18
Faulty fire extinguisher	3.0	15.2	15.2	36.4	30.3	3.76	1.15	11
Faulty smoke detector	0.0	6.5	19.4	38.7	35.5	4.03	0.91	6
Total Average Index	**2.83%**	**18.02%**	**31.82%**	**23.73%**	**23.62%**	**3.45**	**0.96**	**Urgent**

*SD= standard deviation.

extremely urgent yet many (15.2%) of them also see it not very urgent albeit none of the respondents consider it as not urgent at all. Majority (36.4%) of the respondents consider the maintenance of faulty door locks as very urgent, 33.3% of the respondents perceive it as urgent and 24.2% consider it as extremely urgent. Nearly 46% of the respondents consider door defect as urgent but considerable (21.2%) each consider it as very urgent and extremely urgent respectively. Most (39.4%) of respondents consider maintenance of sink leakage and clogged as urgent yet many (30.3%) of them consider it as very urgent while 24.2% believe it require extremely urgent attention.

DISCUSSIONS OF THE OUTCOMES OF THE SURVEY

University buildings in Malaysia are characterized by ceramic sanitary appliances and fittings. The administrative and academic buildings are with split air conditions while hostels fitted with three bladed fans. The walls are plastered and rendered in cement and sand prepares to emulsion paints. The maintenance managers of universities managed extensive array of buildings such as residential (hostels and staff apartments), administrative, academic and religious (e.g. mosques) buildings. Malaysia is in a hot tropical zone. The temperature is humid with rain fall throughout the year. Defects influence maintenance costs and users satisfactions. In order to ensure the performance of buildings, defects must be effectively and efficiently managed. The user value system needs to serve as a basis for maintenance initiation and execution. From the survey, it is observed that 50% of the defects have their individual means score are more than the average means score. Hence, implying that these 14 defects should be given urgent priority during maintenance.

Unfortunately, there is not much this study can borrowed from available literature with respect to defects in university buildings in Malaysia. Much of the available literature focused only on design aspects. Available literature on the area of educational buildings maintenance management in Malaysia was either on the types of maintenance management procedures or users satisfactions with the building performance. Albeit, not with specific reference to measure the severity or urgency in the defects. Therefore, the outcome of this research cannot be compared with the outcomes of existing body of knowledge. In fact, the list of the defects (Table 3) was drawn from foreign materials, discussions with those concerns with university building maintenance in Malaysia and personal observations.

Nonetheless, it is interesting to found that respondents ranked lift failure as the top most extreme defect, closely followed by faulty electrical system and damaged roof structure, air conditioning and fire fighting equipments. This could be interpreted that user safety and user well being are of the paramount consideration. Life failure is indeed a life threatening issue particularly when is it being used. It can be very unbearable experience to the passengers if they are trapped in a faulty lift. Access to all part of buildings is a fundamental requirement of a building (particularly for university buildings where students with varying need are present). To the disabled, lift failure could be disaster. Since the disabled might not be able to access some part of the building and the facilities without functional lift. Wheelchair bound people simply cannot used staircases.

Without doubt, faulty electrical systems are very serious defect as it can also lead to death. Defective roofing can allow water penetration to a building and cause substantial damage including structural damage to timbers, household items, reading materials, fitting and

furniture, sick building syndrome, indoor air quality etc. Faulty air conditioning systems could lead to indoor thermal discomfort, the growth of mould leading to sick building syndrome and pathogenic diseases. Faulty air condition also facilitates water seepage.

Water closet is also ranked high. This is expected. Clogged water closet could be very disturbing aside that it cannot be used, it produced offensive odours. Concurrently, pipe leakage is ranked high by the respondents. Often clogged water closet and pipe leakage caused disruptions and frustration in toilet and bathroom. Damaged windows will undoubtedly leave the occupiers insecure from potential burglars, thieves and rapists. Faulty windows could also allow dangerous insects like mosquito (dengue) into the buildings. Faulty communication appliances are also considered very urgent. In this era of information and communication technology (ICT), any breakdown is considered dreadful. For instance, changes in lectures and tutorials are quite often, and this must be communicated to the students accordingly. There is some time when students cannot attend classes due to faulty locks while waiting to be attended to by the maintenance organization. Although, there is low cases of fire outbreak in Malaysia but when such thing happened, it could be frustrating if fire extinguishers are not available or in good condition.

CONCLUSION

This study has been able to identify, quantify, prioritize and categorize defects in university buildings in Malaysia. Defects consideration in university buildings are important criteria in buildings performance evaluation. Twenty one defects were ranked very urgent or extremely urgent. This will in effect facilitates a comprehensive and clear understanding of the degrees of the various defects. The analysis of the degrees of the defects contributes to the management of defect in the buildings. This is crucial for universities to be seen as a role-model in having efficient maintenance management system for their buildings and engineering services. Defect classification is a core function of maintenance managers. For prudence, effort should directed to the extremely urgent defects then the very urgent and finally to the once that are not very urgent. Probably it is the only way, that the ever inadequate fund will be spent wisely and users' satisfactions can be achieved and maximized accordingly. However, defect degree in term of urgency ought to be self evaluation, supposedly by the users themselves–but this research was done on the reverse order apparently to understand the providers' perspectives. Further works is ongoing to achieve this objective. The defects addressed in this paper do not include defect that relate to substructure works (foundations cracking, foundation bowing, foundation settlement). Though the list of the defects may not be exhaustive due to the vast nature of the building maintenance concurrently with the problem of nomenclature the list are indicative of the defects in buildings that users are regularly concern about.

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BIO-BRIQUETTES TECHNOLOGY IN POWER AND HEAT GENERATION – A SUSTAINABLE SOURCE OF ENERGY

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Abstract
Malaysia and Indonesia contributed in excess of 100 million tons of waste generated from the Oil Palm Industry in the form of empty fruit bunch (EFB) and other fibrous waste generated in the extraction of crude palm oil. A technology was developed and patented to recycle the waste from EFB, fronds, palm kernel shells, and mesocarp fibers into useful sustainable and renewable products called bio-briquettes. These wastes has moisture content of 60-70% for EFB and mesocarp fibre, and 34-40% for palm kernel shell, and calorific value of 5.0 - 18.0 Mj/kg. A processing technology was developed to process these low quality biomass fuels into high quality solid bio-briquettes with moisture content in the range 8-12%. Depending on the formulations and the sources of the raw biomass, the final solid bio-briquettes can have calorific values in the range of 18-25 Mj/kg. With calorific values matching that of coals with low moisture content, the bio-briquettes can be used as a heating source and in power generation especially for small renewable energy power plant or in co-generation of large scale power plant. The bio-briquettes yields a carbon content of at least 45 % by weight and is an attractive source of renewable and sustainable material eligible for carbon credit under the Clean Development Mechanism (CDM) scheme. With an estimated margin of production of 45 % or better, the potential revenue from this product is equivalent and competitive to coal currently available in the commodity market for power generation. A higher margin can be obtained if the product is used for domestic heating due to its novelty value. As a contribution to mankind, bio-briquettes are developed from waste which is renewable and sustainable and at the same time provide a source of energy in our quest for alternative energy.

Keywords*: Biomass; Alternative energy; Renewable energy; Palm based bio-fuel*

INTRODUCTION

In the past decades, the frenzy for alternative energy have resulted in many nations setting aside special priority and incentive to attract researchers in coming up with this alternative source of energy. It was later enhanced by the need to look into sustainable and renewable energy as well. One of these alternative sources of energy is in the area of biomass development and potential to meet the world's growing energy needs. Many studies have been undertaken to assess the future biomass energy potential (Berndes, 2001). The range of the future potential of biomass energy is large.

The upper limit can be very high at 1,130 EJ in 2050, (Hoogwijk, 2002). The lower limit is assessed at 85 EJ. The upper limit is mainly caused by a high figure for energy farming at either surplus agricultural land or degraded land.

The rapid depletion of fossil fuels needs an alternate replacement and most developed nations are pursuing the development of biomass for thermal generation. In Malaysia,

fortunately, the country has ready biomass resources. The biomass resources must be utilized and converted into useful product through efficient processes to ensure that the end product will be a sustainable renewable resource of energy of the future.

In 2001, Malaysia announced its Five Fuels Diversification Strategy with renewable energy (RE), in particular biomass, as the fifth component. The Ministry of Energy, Water and Communications (MEWC), instituted an administrative policy target of 5% of grid-connected electricity generation or 500 MW from RE by the end of 2005.The Small Renewable Energy Power (SREP) Program was introduced to encourage and intensify the utilization of RE for grid-connected electricity. However, the achievement of SREP Program was rather disappointing with various issues such as fuel supply, high financing costs and tariff being identified as the major stumbling blocks (Malaysian Energy Centre, 2005). In 2006, the RE contribution to grid-connected electricity was revised to 350 MW by MEWC.

The biomass industry as a whole is not so encouraging from the aspect of financing because the financial institutions have always insisted on tangible operation beyond prototype prior to any subsequent consideration for financing of biomass project although the technical capability has been well addressed in the past. Such stringent requirements and high capital cost at the onset have discouraged many capable entrepreneurs from pursuing the biomass project. This paper discusses the challenges faced by the local entrepreneurs using home grown technology on biomass derived from oil palm waste.

BIOMASS RESOURCES FROM THE PALM OIL INDUSTRY

The biomass waste resources in Malaysia are predominantly contributed from the palm oil, wood and agricultural industries. Nevertheless, the palm oil industry accounts for the largest biomass waste production in Malaysia and in Indonesia (http://www.undp.org.my).

Malaysia, both east and west, has in excess of 4.0 million hectares of oil palm plantation. The processing of oil palm products occurs in palm kernel crushing factories, oleo-chemical plants, and palm oil refineries, but by far the most common are the basic palm oil mills. There are over 450 mills in Malaysia with total milling capacity in excess of 80 million tons of fresh fruit bunches (FFB) per year. Processing capacity of each individual mill ranges from 10 to 120 tonnes of FFB per hour. Due to the seasonality of the crop in terms of peak production of FFB, many privately owned mills have difficulties in obtaining FFB for their production during low seasons because the majority of the suppliers of FFB are from the small land holders.

The milling processes in the palm oil industry produce large amount of solid wastes in the forms of EFB, mesocarp fibres and palm kernel shell. Typical example of solid wastes production rates by a mill processing 60 tonnes per hour of FFB is summarized in Table 1 (Shamsuddin, 1985). The wastes produced amount to about 50 percent of the original FFB processed. It can be seen that the wastes itself have high water content from Table 1.

Table 1. Solid Wastes Production Rate From A Mill Processing 60T/HR of FFB

Waste Type	Amount Produced, kg/hr	
	Wet	Dry
Palm Kernel Shell	3,340	3,140
Mesocarp Fibre	9,160	6,530
Empty Fruit Bunches	14,960	4,910

These wastes have highly variable fuel characteristics and properties, governed by their moisture and residual oil contents, as summarized in Table 2.

Table 2. Fuel Properties of Palm Solid Waste

	Empty Fruit Bunches	Mesocarp Fibre	Palm Kernel Shell
a) Proximate Analysis, % (As received)			
• Volatile Matter	18.0-20.0	53.2-56.1	58.0-61.6
• Ash	1.3-1.6	2.1-2.5	1.4-2.1
• Moisture	61.4-72.9	28-31	9.0-11.7
• Fixed Carbon	7.5-10.3	12.8-16.3	24.6-27.5
b) Calorific Value, MJ/kg (Dry Basis)	14.6	14.8	19.0
c) Ultimate Analysis, % (Dry basis)			
• Carbon	40.8-49.5	48.3	47.6-52.4
• Hydrogen	5.9-7.8	7.2	6.0-6.3
• Sulfur	< 0.1	< 0.1	< 0.1
• Nitrogen	0.5-2.0	1.0	0.6-0.8
• Oxygen	40.6-48.2	41.1	40.2-43.4
• Ash	1.5	2.1	2.0

(Source:Shamsuddin, 1985; Shamsuddin and Sopian, 1995; Hussin, 2006)

Shamsuddin and Liew (2009) reported that 20 kWh of electrical power is required to process one ton of FFB . Most palm oil mills depended on the palm kernel shells and the mesocarp fibers for their own source of biomass fuel in the production of steam from the biomass boilers to extract oil and to generate electrical power for internal processing requirements. With abundance supply of biomass waste resources, most palm oil mills' energy system is designed to be cheap and highly inefficient due to the efficiency of the low-pressure boilers distribution system. The overall efficiency of the boiler system for co-generation is generally less than 40 percent. Since most palm oil mills are privately owned, the waste EFB is carted off the mills for a nominal sum by a third party for various purposes. The low quality EFB due to its high moisture content in excess of 60 percent, are use as landfill materials, incinerated for their ash contents to be blended as chemical or organic fertilizer, or left to rot in plantation as a primary

source of fertilizer to the land. All of these activities on EFB left behind substantial negative carbon footprint since these activities generate green house gases (GHG).

Academically, the current total FFB produced in Malaysia is sufficient to supply fuel equivalent to 2,500 MW power plant, approximately the size of Manjung Power Plant from the wastes alone (Malaysian Palm Oil Board, 2007). This exercise is in futile because it is not possible to gather all the wastes resources to produce a single gigantic power plant with a generation capacity of 2,500 MW. At best, local generation of small power plant is possible although the locations of such small power plant must be in the vicinity of palm oil mills. Commercially, it is logistically impossible unless a final product in the form of bio-briquettes is made to supply as fuel to the power plant. Even that, only co-generation blended with coal is possible with the large power plant.

Currently, the commercial of EFB has been 'plaque' with many opinions although all of the supply chain related to EFB agreed that EFB has commercial benefit. A majority of the commercial gains of EFB as mulching materials does not benefit the reduction of GHG. It is a conservative form of bottom line materials due to the escalating cost of fertilizer but unfriendly to the environment and a source of negative carbon footprint. The use of EFB as a source of fuel for renewable energy generation and other industrial heating requirements including domestic heating has far better benefits, tangible and intangible. Its utilization will contribute towards reducing fossil fuel carbon emissions to the atmosphere, and is qualified for carbon credit under the CDM enacted through Kyoto Protocol.

To overcome the logistic aspect on biomass utilization, an approach to convert the low quality EFB to high quality solid bio-briquette becomes an attractive option. This approach is now discussed herein.

BRIQUETTING PROCESS DEVELOPED

EFB by itself is of low quality and high in moisture content. It is bulky to be transported around. As such, the production of bio-briquettes is most suitable adjacent to the palm oil mills to ensure the supply of raw materials and to minimize logistic cost. The initial quality of EFB is determined if the EFB obtained have been pressed further to remove water and to enhance oil recovery in the secondary recovery process by the palm oil mills. The typical cost of EFB ranges from RM 5 to RM 15 per ton depending on the quality of EFB.

This EFB needs to be upgraded, processed and transformed into high quality solid bio-fuel before it can be successfully utilized as alternative fuel and energy resource. It was also found that aged EFB depletes the opportunity of converting EFB into bio-briquettes due to bacterial activities in the decay processes of EFB.

Briquetting is the process of compacting loose biomass residues, such as EFB and other palm residues, into higher density and uniform fuel. The process improves the physical, fuel properties and combustion characteristics over those of the raw biomass. Thus, the briquetting process involves the proper understanding on the physical behavior of EFB and its interaction with machines and natural additives derived from wastes.

This paper presents current effort to develop processing technology to transform low quality EFB into high quality solid bio-fuel briquettes. A similar effort was undertaken by the Malaysian Palm Oil Board, MPOB, however, with a different process sequence and machineries (Nasrin et al, 2006).

The main processes involved in the production of bio-briquettes from EFB and wastes are removal of moisture content (dewatering), fragmentation of lumped mass of EFB to be compatible with the final size of the bio-briquettes, sieving, ejection of alien materials, dessicating, compounding and formulating, and finally extrusion and briquetting.

The dewatering process is the first step in ensuring minimum amount of moisture is needed to be removed in the drying process to optimize the use of heat, indirectly, the power. The pressing method, typically done by palm oil mills in the secondary oil recovery is used to extract additional oil by removing the moisture content from the EFB. Usually, the pressing process removes between 50% - 60% of the moisture content from the raw material.

A press shredder is used to execute the primary size reduction. The feeder is able to process up to 4 to 6 tons of fiber output per hour. The shredder shreds the EFB into short fiber with sizes ranging from 25mm to 40mm although in the supply to power plant, the optimal size of up to 150 mm can be adopted since the bio-briquettes will be pulverized at the power plant during blending for maximum combustion. The larger sized bio-briquettes can cut production cost by at least 15 % although the marketability of such size for domestic heating has yet to be accepted by the consumer.

A segregator machine is used to loosen or break off lumpy short fiber. A rotary screener is used to separate wet short fiber from wet over sized fibers or wet long fibers. Oversized and long wet fibers are then recycled into the shredder machine to get the desired size.

The processed raw materials are then fed to a screw feeder for the compression process. The screw feeder is operated by a motor using a v-belt connection. A mixing and compounding silo is used to mix and compound the short fibers and the raw material before it is fed to the briquetting machine. A briquetting machine is used to compact the fibers by up to at least 4 times the initial bulk density of the loose fibers into the desired sizes through staged compression assembly technique. The process of compacting into briquette is done without the use of any binding agent. In some cases, carbonization of the bio-briquettes can be done to obtain a smooth finish on the outer skin for aesthetic reason especially for domestic heating.

The compressed raw material is then passed through a hot barrel consisting of three heater zones, ranging from 160^{O}C to the highest temperature of 250^{O}C for the combination process. Lignin or organic admixtures can be used as a binding agent to integrate the shredded fibers. The temperature can be regulated to accommodate the different moisture content of the raw material.

The first heater zone is primarily functioning as an additional dryer of the raw materials. The second and third heater zones focuses on binding the agent for the raw material fibers. Temperature is constantly monitored, as to avoid over-drying, which may cause the fibers to be burnt throughout the heating process. The diameter and length of the briquette produced can be adjusted accordingly to the required size.

The process flow diagram for the solid bio-fuel briquette production is given in Figure 1. The designed machines can be used to produce bio-briquettes from other biomass such as rice husks and saw dusts. The compounding of all these materials can eventually lead to an optimized production of bio-briquettes for the nation.

QUALITY OF BIO-BRIQUETTES

The main type of raw material used in the production of the solid bio-briquette is the EFB (70 % or more) due to its vast resources. Typical sample of EFB is shown in Figure 2. However, the other palm mills residues, the mesocarp fibers and the palm kernel shells, are also added in small proportions compared to the EFB to test the quality of several formulations.

This paper reports on the quality of three different formulations of palm-based solid bio-briquettes, namely, the Sam001, Sam002 and Sam006 derived from two separate mills for the EFB. The raw materials compositions and the source palm oil mills of the solid bio-fuel briquettes are summarized in Table 3. Figure 3 shows typical samples of the finished palm-based bio-fuel briquettes.

Table 4 summarizes the fuel properties of the palm-based solid bio-briquette formulations produced from the process. The samples were tested at TNB Research Fuel Testing Laboratory, an accredited fuel testing laboratory, a subsidiary of TNB, the national power utility company. The fuel testing procedures were carried out according to the ASTM Standards D5865-04 for the gross calorific values and D5142-04 for the proximate analysis.

The fuel properties, as summarized in Table 4, for the briquette formulations show that they are similar to the lignite-subbituminous types of coal. The properties are also comparable to the previous work of (Nasrin et al, 2006). The solid bio-fuel briquettes have a better fuel properties and quality as compared to the original raw residues from the oil palm milling processes.

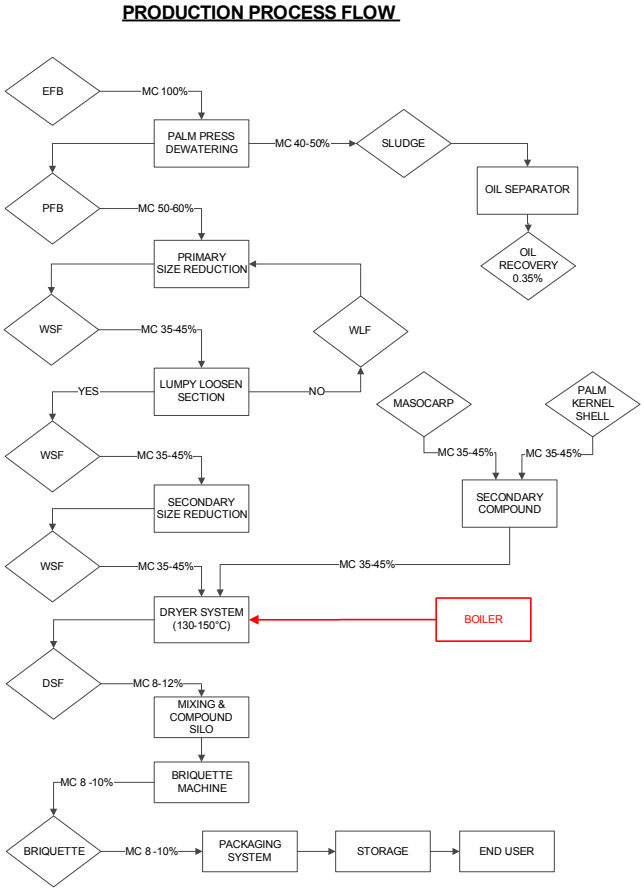

Figure 1. Process flow diagram of the solid bio-fuel briquettes production

Figure 2. Empty fruit brunches

Figure 3. Palm-based solid bio-fuel briquettes

Table 3. Three formulations of bio-briquettes from two palm oil mills supplying EFB

Formulation No.	Briquette raw materials	Source Palm Oil Mill
Sam001	EFB (100%)	Mill A: Located in southwest Perak, with 2% residual oil in EFB
Sam002	EFB (80%) and Mesocarp Fibre (20%)	Mill A
Sam006	EFB (100%)	Mill B: Located in southwest Perak, with 5% residual oil in EFB

Table 4. Fuel Properties of the palm-based solid bio-fuel briquettes

	Formulation No.		
	Sam001	Sam002	Sam006
a) Proximate Analysis, % (As received)			
• Volatile Matter	69.9	67.7	64.7
• Ash	2.4	2.0	2.7
• Moisture	11.9	10.8	9.8
• Fixed Carbon	15.8	20.21	22.8
b) Calorific Value, MJ/kg (Dry Basis)	18.8	19.7	25.0

CURRENT COMMERCIAL CONSIDERATION

Currently, while the technical aspect of converting EFB and wastes into useful bio-briquettes is considered mature, the machine aspect in the production of bio-briquettes is far from perfect although prototypes have been proven to be reliable and workable. There are inherent difficulties in dealing with EFB. The high silica content results in high maintenance of machines due to excessive wear and tear. While the front end machines in the process flow are generally approaching to a mature stage, the back end machines are still at the initial commercial stage with much room for improvements. It is anticipated that the development of the back end machines will be the center stage for the next three years in the production of bio-briquettes.

The physical properties of EFB in itself must be well understood. The dewatering process and drying process are difficult to understand due to the fiber properties of the EFB. In a nutshell, it exhibits 'non-linear' behavior in the extraction of water from the fibers. While this is a complicated process to understand, it has long been suspected that capillary action of the fibers is the main contributory factor in the dewatering and drying process.

There was much hype on the supply and demand of EFB in Malaysia for the past three years. At one juncture, there was a threat on the supply side due to the speculation of the paper market derived from EFB. With the cost of recycled paper hovering at USD 400 per ton, such speculation will not mature since the production cost cannot be sustained due to the low cost of recycled paper. Thus, the EFB price, at best will be at its peak around RM 20 per ton. Average current price is at RM 8 per ton. Nevertheless, it would be advantageous to secure the supply side through a venture with palm oil mill to minimize logistic cost.

At the moment, market survey indicated that bio-briquettes price can be maintained at USD 80 per ton for loosely packed end product. If high end market is the target, then, a well packed end product can reach a price of USD 120 per ton.

Current indicative production cost hovers around 45 % to 55 %. The final determining production cost is dependent largely on the logistic cost and power cost.

CONCLUSIONS

The solid bio-fuel briquettes provides an alternative and better route to the more practical and economical exploitation of biomass resources as fuel. With better fuel properties and quality, the briquettes would easily find acceptance and applications in the industry. In the case of the palm oil milling residues, especially for the EFB, the processing costs can be kept to minimum if the briquette processing facility is integrated with the mills.

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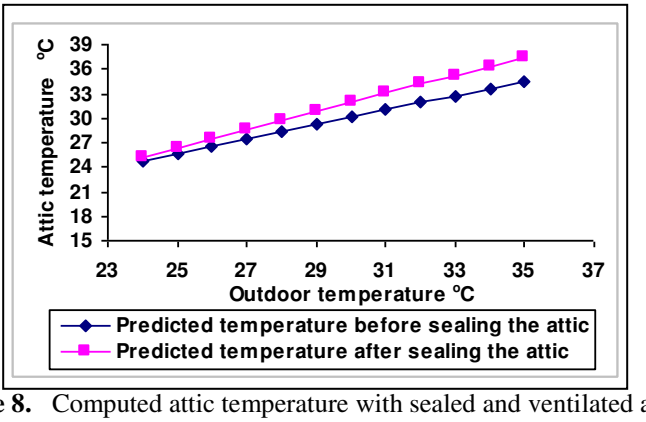

Figure 8. Computed attic temperature with sealed and ventilated attic

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

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

Table Line: 0.5pt.

Table 1. Recommended/Acceptable Physical water quality criteria

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

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

Reference: Times New Roman, 11pt. Left indent 0.25inch, first line left indent – 0.25inch. Reference should be cited in the text as follows: "Berdahl and Bretz (1997) found…" or "(Bower et al. 1998)". References should be listed in alphabetical order, on separate sheets from the text. In the list of References, the titles of periodicals should be given in full, while for books should state the title, place of publication, name of publisher, and indication of edition.

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