ADAPTING ZERO CARBON HOUSES FOR TROPICAL CLIMATES - PASSIVE COOLING DESIGN IN THE PHILIPPINES

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Abstract:

Extensive research about passive house design in cold climates has been carried out in Europe in the last 2 decades and remarkable improvements have been achieved regarding the energy performance of buildings. For modern passive houses the heating load is no longer the main energy consumption aspect. Thermal comfort is being achieved by means of design and construction principles rather than by energy using appliances. As a consequence heating energy demand in passive houses has dropped by 90% compared to the existing building stock. This was a major step forward in the endeavor to transform the built environment from one of the main energy consuming sectors into being energy neutral or even net energy positive.

In comparison, for tropical climates far less documentation and examples are available. Only recently this climatic zone has gained attention of sustainable design initiatives. Cooling demand for residential, office and commercial buildings is still one of the main drivers for the constantly rising energy demand in the Philippines (and other tropical countries). Dealing with high humidity and an excessive heat load of buildings are the main challenges in order to provide thermal comfort for the users. In conventional modern constructions usually 200-400 kWh per m² and year are needed for the air conditioning systems. Limited access to electricity resulting in the need for back-up systems and high energy costs characterize the situation. Based on an analysis of traditional buildings a number of passive cooling principles can be derived that provide a sound basis for a modern Tropical passive house design.

Quantification and an indicator based benchmarking were the key strategies that made the passive house approach so successful, there is no reason why this would not work in hot climates as well.

The paper presents a systematic approach how to apply passive cooling principles in the tropics with a practical example of a Zero Carbon building realized in the Philippines.

Key words : Tropical zero carbon house; passive cooling; sustainable building; zero energy buildings, zero carbon design

1 INTRODUCTION

Over the last 20 years, the passive house has become synonymous with quality, comfort and ultra-low energy buildings that require little energy for space heating or cooling. These remarkable improvements have been achieved for cold climate with regards to the energy performance of buildings especially in Europe. For modern passive houses the heating load is no longer the main energy consumption aspect. Thermal comfort is being achieved by means of design and construction principles rather than by energy using appliances. As a consequence heating energy demand in passive houses has dropped by 90% compared to the existing building stock. This was a major step forward in the endeavor to transform the built environment from one of the main energy consuming sectors into being energy neutral or even net energy positive. Directive 2010/31/EU (EPBD recast) Article 9 requires that "Member States shall ensure that by 31 December 2020 all new buildings are nearly zero-energy buildings; and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings". Member States shall furthermore "draw up national plans for increasing the number of nearly zero-energy buildings". In other words the built environment is gradually transformed from being one of the main energy consuming sectors into being self-sufficient, or even into producing a surplus of energy. In tropical countries however research and demonstration is now picking up these topics and the prospects of zero carbon buildings are quite viable, especially with a view on the much higher solar irradiation compared to Europe. The Zero Carbon Resorts (ZCR) project is planning and building one of the first energy self- sufficient buildings in Palawan.

2 THE BUILT ENVIRONMENT

Applying the definition of sustainable development to building design, we could state that in sustainable building functions and construction components ideally correspond to the present needs of the occupants without causing problems for future generations. However for most modern buildings this is still not the case. In fact the construction industry has become the most resource intensive industry worldwide and is responsible for about 50% of the global resource consumption as well as for half of the worldwide generation of waste streams.

During the use phase, buildings are responsible for about 30% of the total energy demand. Changing the way we plan, build and use constructions of tomorrow can remarkably contribute to solving global problems like resource scarcity, shortage of fossil fuels, global warming, etc. Additionally these buildings will be healthier to live in and cheaper to maintain, creating value in the region rather that global resource and waste streams. In order to understand the environmental effects of a building and its use we have to look at its entire life cycle, from raw material extraction, construction and use of the building until deconstruction and recycling.

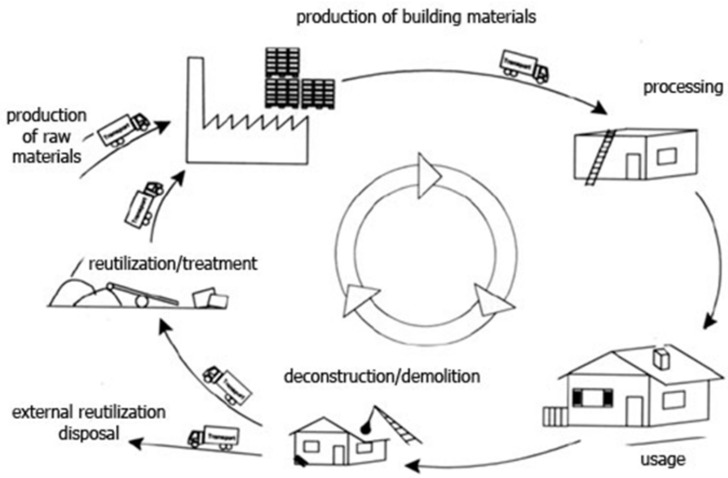

Figure 1 Life cycle

Improving the energy performance during the use phase has been the main concern of the early "green building" approaches. This was for a good reason, knowing that up to 80% of the entire energy consumption in a building is being used for either heating (in cold climates) or cooling (in hot climates). The total consumption can reach up to 200kWh/m^{2}year for a residential building and up to twice as much for offices or shopping malls. Looking at this consumption from the "energy service" point of view we can conclude that by far most of the energy consumption is directly related to providing "thermal comfort" to the occupants and users of the built structure. (WIMMER 2012)

You feel cold? Turn on the heating! and vice versa turn on the AC if you feel hot. Availability of electricity and appliances for cooling have stimulated these seemingly simple solutions, however we recognize the "side effects" of this problem solving approach later. We can recognize it when receiving our monthly energy bill, when experiencing brown outs due to grid overload and even when changing weather conditions, global warming and rising sea levels are dominating the news.

The good news is that providing thermal comfort allows for a lot more diverse solutions (FANGER 1970) than the switching on of technical appliances. An old church in southern Europe is an excellent place to escape to during a sizzling hot city tour, cool and comfortable by design not by technology. The same is true for the cool breeze in a lightweight structure such as an Ifugao house. Design principles and materials for both examples are totally different, the result is the same: thermal comfort for the occupant or visitor. It is obvious that thermal comfort cannot be defined by the temperature alone, as it is suggested by the digital control display of the AC unit. In fact it is influenced by a number of factors and of course it is also a subjective sensation.

3 THE CHALLENGE

For tropical climates far less documentation and examples are available on zero energy houses. Nevertheless there are plenty of good examples available for passive cooling designs, especially when examining traditional buildings, such as the "Ifugao" house.

Figure 2 (left) An “Ifugao house” (right) Heat gain comparison between cogon roof and galvanized iron roof

Thermal imaging reveals that the surface temperature on the inside of the roof remains in a tolerable level between 26°C and 30°C while a steel roof during the same weather conditions can peak up to 75°C. This shows how massive consequences from material choice are for the cooling load of a building. (WIMMER 2009)

Nevertheless foreign architectural models began to be widely adopted with little regard for tropical climate. The results are predictable, an enclosed buildings with glass windows that become unbearable ovens in summer. As it happens, air conditioning units are required in order to make this enclosed area comfortable which highly increases the energy consumption.

Cooling demand in buildings is still one of the main drivers for the constantly rising energy demand in the Philippines (and other tropical countries). Dealing with high humidity and an excessive heat load of buildings are the main challenges in order to provide thermal comfort for the users. Due to high temperature and the surrounding bodies of water, the Philippines has a high relative humidity. The average monthly relative humidity varies between 71 percent in March and 85 percent in September. The combination of warm temperature and high relative and absolute humidity give rise to high sensible temperature throughout the archipelago. It is especially uncomfortable during March to May, when temperature and humidity attain their maximum levels.
In conventional modern constructions usually 200-400 kWh per m² and year are needed for the air conditioning systems. Limited access to electricity resulting in the need for back-up systems and high energy costs characterize the situation.

Based on an analysis of traditional buildings on the other hand a number of passive cooling principles can be derived that provide a sound basis for a modern tropical zero energy house design. The challenge is to make use of the traditional design principles and elements that work for the buildings and translate them into a modern context.

It is obvious that thermal comfort cannot be defined by the temperature alone, as it is suggested by the digital control display of the AC unit. In fact it is influenced by a number of factors and of course it is also a subjective sensation.

The well-known thermal comfort equations derived by P.O. Fanger (FANGER 1970) combine the effect of 6 parameters:

- Metabolism
- Clothing level
- Air Temperature
- Mean Radiant Temperature
- Air Velocity
- Humidity

While metabolism and clothing are up the users’ behaviour the remaining parameters can be dealt with by the creative designer.

For the designer most relevant is the correlation of air temperature and humidity as well as the influence of surface temperatures (such as walls, ceilings etc.) and air movements on the comfort level of the occupants. The cooler the wall temperatures the bigger is the tolerance to higher air temperatures and the other way round. The typical situation in many buildings in the Philippines is that due to insufficiently insulated ceilings surface temperatures reach high levels (measurements of >45C on the ceiling are not an exemption) and in return ask for a lower air temperature that can only be achieved by excessive air conditioning. Another rule of thumb indicates that for every 1m/s of air movement 1 C air temperature increase is tolerated.

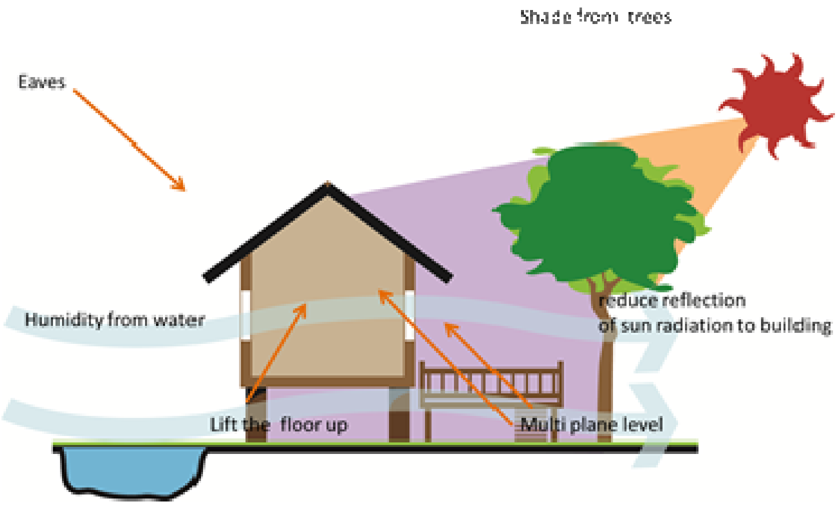

Figure 3 Passive Cooling methods

Knowing this correlations, almost automatically leads to a number of design principle which are commonly known as the "passive cooling" principles:

- Shading
- Reflection
- Insulation
- Radiation
- Ventilation
- Evaporation
- Heat sinks by thermal mass

These measures do not have to be expensive to construct, most likely they are even cheaper than the cooling equipment they are replacing and certainly they will continue to save on running costs every month. A combination of the above effects (shading, reflection, and evaporation) can for instance be realised with a simple and aesthetic shade house grown from vines on trellis, preferably with vines of a reddish or whitish leaf color (MOLLISON 2012) since those species reflect most of the sunlight. Together with the evaporation effect of the plants this can serve as a valuable source of cool air in combination with natural ventilation.

In the recent years tremendous achievements have been made in making buildings more energy efficient. Looking at the Passiv -house trend in Europe heating demand has been reduced by more than 90% at minimal additional investment costs, the benchmark of energy consumption has been lowered to 10kWh/m²year.

There is no reason why designers of tropical architecture should not be able to reach the same results by minimizing cooling demand.

And what can be done for the "thermal comfort" as the main energy consuming energy service we can consequently also do with all the other functions and energy services in a building. It is important to know that this energy services are a function of time and occupant behaviour as well as requiring different forms of energy. This concept is called "Supply-demand matching" in the Zero Carbon Resorts Project.

4 THE ZERO CARBON RESORTS FLAGSHIP COTTAGE

The Zero Carbon Resorts project in the Philippines is funded by the European Union under Switch-Asia program. The ultimate goal of the project is to reduce the carbon emission of the tourism sector through energy and resource efficiency practices following a progressive 3R approach. The ZCR's 3R (Reduce-Replace-Redesign) intervention ranges from simple measures with low or zero investment to efficient high-end technologies depending on the innovation stage the establishments have already reached. Innovations are needed at all levels, from an efficient operation of energy-using products, to technical innovations in lighting, ventilation and cooling, up to sustainable architecture strategies.

During the “Redesign” phase, a zero carbon cottage has been designed and will be constructed, to showcase sustainable building and energy systems using appropriate technology solutions. The project’s added value comes in its acknowledgement of the local context and the fact that solutions are tailored accordingly.

The Overall objective of this showcase is to demonstrate the feasibility of an innovative building concept that significantly reduces CO_2 emissions and demonstrates resource-efficient solutions in the building sector. To this end, a highly resource and energy-efficient building will be built in Puerto Princesa Palawan. The showcase building will supply its complete energy services from a highly innovative energy-supply system using renewable resources. The building is therefore literally carbon neutral over its entire lifecycle and a milestone in sustainable building with an immense potential of replication and up-scaling.

It shows a minimum of grey energy over their entire life cycle, from production of materials to the use phase and the recycling possibilities due to a maximum utilization of regional renewable resources (bamboo), and a 100% energy-autonomous, demand-oriented system based on solar energy.

The planning was guided by the following principles:

- High functionality and quality
- Minimized consumption of energy and resources
- Use of regional building materials and renewable resources
- Sustainable planning considering the location and context
- Environmentally sound solutions for a healthy room climate
- Life cycle perspective including an easy separation of building materials during deconstruction and plans for recycling and reuse
- Economic efficiency of sustainable construction: during planning already the whole life cycle of the building (construction, use, removal deconstruction) is taken into account and the negative impact on the environment is minimized
- Dissemination of sustainable building technologies to a wider audience

Figure 4 ZCR Zero Carbon Cottage design by Arch. Edgardo Mallari

The whole building process as well as the results are monitored and prepared for knowledge transfer and dissemination. Monitoring devices will be installed to determine a quantified performance of the building and its operational consumption. These data will be available to the public for knowledge sharing and enables policy makers to have a basis for the revision of standards and guidelines for building and energy system in the whole of Philippines. The showcase will also feature the efficient devices and technologies installed that contribute to its low energy demand.

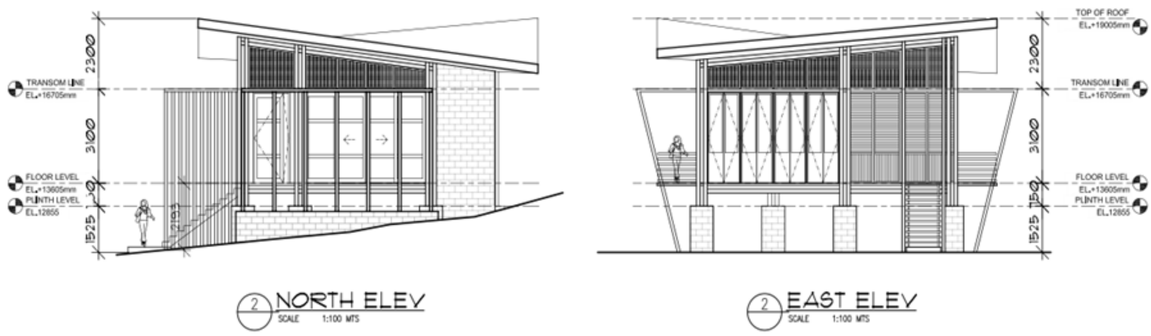

Figure 5 ZCR Zero Carbon Cottage design by Arch. Edgardo Mallari

The design process has been unique as well, since it originated from the Zero Carbon Resorts capacity building program, where 35 innovative Filipino architects have been trained. A number of design suggestions have been elaborated and the final design has been assigned to Arch. Edgardo Mallari, team lead of the participating architects group from the Green Architects of the Philippines (GreenAP).

Figure 6 ZCR Redesign Capacity Building in Puerto Princesa

5 SUSTAINABLE BUILDING MATERIALS

The environmental impact of a building is strongly influenced by the choice of building materials. Building materials made of renewable resources and regionally available materials are a substantial basis for sustainable construction. Especially biomaterials with a relatively short time of reproduction like grasses, bamboo etc. have a far better environmental profile compared to concrete, steel and aluminium but also compared to hardwood timber with a long growth period of 80years and more, these species are often protected for a good reason since they play an important role in the forest ecology.

The example S-House in Austria (www.s-house.at) has shown that the consequent use of regionally grown renewable materials can reduce the environmental impact of the building materials by a factor of 10 compared to conventional constructions. While the construction of the straw-wood-clay wall caused an ecological footprint of only 2364 (m^2a/m^2 wall), a comparable conventional wall construction (concrete, Styrofoam) consumes with 24915 (m^2a/m^2 wall) an area 10 times larger.

For the use of renewable materials in the tropics special challenges have to be mastered. Bamboo e.g. is an excellent candidate for zero carbon constructions is exposed to a number of vermin like termites and borers (bokbok in Tagalog). Those insects are well known to damage constructions within a relatively short period of time, if the bamboo is not treated.

Resistance to vermin is one of the reasons why "modern" construction materials like metal and concrete became so popular despite their high costs and unfavourable environmental profile.

The only alternative seems to be to treat the bamboo poles with chemicals in order to make them more durable. Conventional treatment methods use synthetic and/or toxic substances, which brings along another set of environmental problems. Promising newer treatment methods like "sap replacement" with less or non toxic salts have the disadvantage of relatively high costs and require special machinery to apply high pressure to the bamboo poles.

Looking back in history shows that for traditional buildings soaking in water of bamboo poles and mats (like sawali) has been used ever since with good results. The procedure was relatively simple and not harmful: the building material was placed in water ponds or in running water for several weeks to wash out starch from the bamboo which make it not attractive to insects.

In an effort to combine traditional treatment methods with modern know how, namely the fact that pressure treatment is far more effective in terms of penetration depth, I am suggesting a modified and inexpensive treatment method:

Pressure seawater treatment is being used for bamboo poles for the ZCR demonstration building. The pressure is being applied not by using compressors but by utilizing the natural pressure in deeper waters. In practical terms this means that the bamboo poles will be brought off shore and dropped in seawater, 30meters below the surface. Down there a controlled seawater treatment with 4bar pressure is being applied naturally and without additional energy use. After the required retention time (currently evaluated from experiments) the poles are dried and used for the construction. No adverse environmental effect is expected from the pressure seawater treatment.

6 CONCLUSION

Only recently the tropical climatic zone has gained attention of sustainable design initiatives. While in Europe heating is the main energy requirement, the tropical climates have to focus on cooling and dehumidification. By using passive design concepts and principles, thermal comfort for tropical buildings can be achieved. The ZCR flagship cottage of the ZCR project will be a living proof for applying passive design in a modern context. The project's added value comes in its acknowledgement of the local context and the fact that solutions are tailored accordingly.

A combination of traditional knowledge and modern design is applied in the ZCR cottage in order to achieve the best possible solution. Already in the planning stage the criteria for easy deconstruction and an optimal reuse are drawn into account in order to prevent waste and disposal problems in the future.

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ASSESSING THE IMPORTANCE OF BUILDING MATERIALS OVER THE LIFE CYCLE OF BUILDINGS USING OPERATIONAL ENERGY IMPACT MATRIX

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Abstract: The building sector is the single largest contributor to global greenhouse gas emissions. On the other hand, the building sector also has a substantial emission saving potential. The research focus on the energy use and greenhouse gas emissions of buildings has traditionally been on the operational energy and the related GHG emissions. However, recent research has shown that when buildings become more energy efficient, the role of building materials becomes more important in life-cycle perspective. This paper suggests that the life-cycle greenhouse gas emissions and the relative importance of building materials can be estimated by simple evaluation of impacts of operational energy use. A simple assessment tool, operational energy impact matrix is presented in order to enable rough evaluations on the relative importance of building materials and total emissions over the life cycle of a building. The impact matrix as such, can assist in defining the relative importance of materials and operational energy use, in order to focus emission-reduction efforts on the most crucial life cycle phases of buildings. The paper shows how the total greenhouse gas emissions of the case-building varies from 0.4 tn/m2 to 6.1tn/m2, depending on the level of operational energy use and unit emissions. Also, this paper shows that the relative share of materials may vary from 5 to 65% for the same absolute amount of material-related greenhouse gas emissions.

Key words: *greenhouse gases (GHG), building materials, operational energy, impact matrix*

1 INTRODUCTION

The research focus on the energy use and greenhouse gas emissions of buildings has traditionally been on the operational energy and the related GHG emissions (Sartori and Hestnes, 2007, Hernandez and Kenny, 2011). The focus on operational phase has been justified, as the operational energy use of buildings has been a dominant factor in the buildings' life-cycle energy use by contributing as much as 95% to the lifetime totals in the past (Sartori and Hestnes, 2007). The topic has been also discussed in such review papers as Ramesh et al. (2010) and Yung et al (2013), and their findings have showed that the operational energy use is still the biggest contributor to the lifetime energy use in many cases, with share of some 80-90% of totals.

However, the current development towards energy efficiency, for example in the European Union and also in other parts of the world is pushing the operational energy use down. As a result, the importance building materials increases. This is due to the simple fact that energy savings are achieved in most of the cases with a combination of increased insulation thicknesses and more advanced building systems. Both of these factors increase the material needs and material-related emissions of buildings. If the operational energy use is lowered at the same time, the role of materials increases in both absolute and relative terms.

As review by Sartori and Hestnes (2007) shows, the embodied energy of buildings can account for up to 50% of lifetime totals in low energy buildings. Furthermore, if the energy use of buildings reaches a "zero-energy"-level, and consumes no (net) operational energy, all the energy use during a building's life-cycle is due to the embodied energy of building materials, as Hernandez and Kenny (2011) point out. In order to ensure energy efficiency and low emissions over the whole life cycle of a building, the embodied energy and material-related emissions need specific attention, especially when designing highly energy-efficient buildings.

The current research results are quite hard to generalize, as the analysed cases vary in many different ways. For example, when applying the current body of literature, which focuses oonn cold/developed countries, into tropical, developing countries, extreme caution should be taken, due to a number of differing parameters, as Ruuska (2013) points out. This paper looks into two of these parameters with a strong effect on the results: the role of level of operational energy use and the unit emissions from energy production. The focus is on assessing how these two factors affect the total life-cycle greenhouse gas emissions of buildings and how the relative importance of materials changes, as these two factors are altered. A new simple assessment tool is presented here, the operational energy impact matrix.

2 RESEARCH METHOD

This research shows how the level of operational energy use and the related emission factors affect the relative importance of building materials, when concerning the life-cycle greenhouse gas emissions of a building. Previous studies, such as, Ruuska and Häkkinen (2013) has showed that the relative share of material-related emissions can vary greatly, when the level of operational energy use and the energy production methods and carriers are altered. In their study the authors compared a detached house with district heating to a similar house with geothermal heating. As a result of lower operational energy use and different heating energy production methods and energy carriers, the relative share of materials rose from 17% to 33% of lifetime totals between cases. The results show that same absolute emission values from building materials can be perceived in different ways, depending on the level of operational energy use, and unit emissions for energy production.

This study uses the same case-building as the paper of Ruuska and Häkkinen (2013). The building is a detached house with wooden building frame and two apartments. The structures are standard structures in Finnish housing production. The heating methods used in this study are direct electrical heating and ground heating.

This paper studies how the role of level of operational energy use and the unit emissions for energy use affect the total greenhouse gas emissions of a building, and the relative importance of embodied energy. The impacts of operational energy use are assessed by comparing two alternative heating systems, other factors staying constant. The impacts of unit emissions are assessed by comparing the calculation results with energy production profiles of different countries.

2.1 Geographical location and building design

This study assumes that if a building and its structures are able to provide satisfactory indoor air conditions and functionality in a certain geographical location, it will also do so in other geographical locations with similar climate. This study uses the Köppen-Geiger classification for categorizing climatic conditions (Peel et al. 2007). The original building, which is located in Helsinki, Finland, is first assessed in Finnish climatic conditions and then placed in alternative locations sharing similar climate.

2.2 Geographical location and impacts from energy use

Energy production methods and carriers vary between countries. This results in that the location of the building affects the amount of emissions from operational energy use. This means that for example, the greenhouse gas emissions from households' energy use vary widely from country to country, even if the operational energy use stays at the same level. It should be pointed out that these factors also have an impact on the emissions from the building material production, but to a smaller extent.

2.3 Geographical location and impacts to building material production

Even though the environmental impacts of energy use are not constant between countries, the differences in impacts from material production are not as dramatic as for household energy consumption. This is due to that the emissions from material production are not only from electricity use, but also from use factories' own energy production. Typically, the processes for production of basic materials are quite similar from one country to another. Also, following the free movement of goods and services inside the European Union, many of the building materials are traded across country-borders. It is not realistic to assume that all the building materials for a building are produced inside the borders of that specific country. Partly due to these factors, a common European database, ELCD, exists. The database allows the assessments of building materials with European-level, not country-based environmental profiles. This paper takes a simplified approach to this issue by assuming that the environmental impacts of building materials stay constant between the assessed countries.

3 OPERATIONAL ENERGY IMPACT MATRIX

The operational energy impact matrix is a simple assessment tool, which is introduced here. It can be used to present calculation results of the impacts of operational energy in a visual form. It can also be used to assess the effects of changes in the operational energy use, and unit emissions on different factors, such as life-cycle total greenhouse gas emissions, or relative share of emissions of building materials.

The operational energy impact matrix has two axes: the vertical axel shows the level of operational energy use and the horizontal axel indicates the unit emissions of consumed energy. It is presented in the following figure 1.

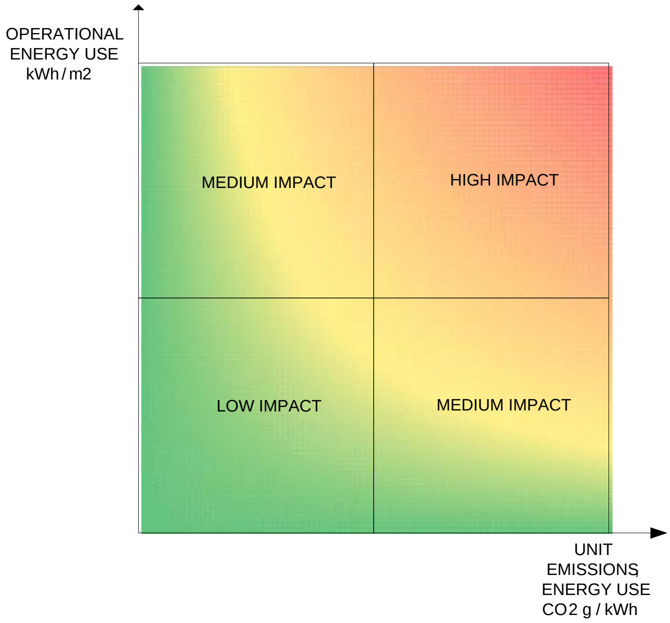

Figure 1 The operational impact matrix

The impacts of operational energy use are directly related to the operational energy use and the unit emissions of energy. This means that the highest impacts are caused when the operational energy use and unit emissions for energy production are the highest. These high-impact cases are represented by the top-right corner of the matrix, which are coloured red.

Respectively, when the operational energy use and unit emissions are the lowest, the impacts are also low. The bottom-left corner of the matrix represents these low-impact cases in green colour.

Two remaining areas represent medium-level impacts, where the level of impacts is not as unambiguous as in the two other corners of the matrix. In these areas, the emission can vary from low to high, being medium-level on the average. The values in medium impact-areas are the lowest near to the axes (where either energy use of unit emissions approach zero), and the highest, furthest to the axes. The colours on these areas go from green (low) to red (high).

3.1 Setting the minimum and maximum values of the matrix

The minimum and maximum values for the axes of the matrix can be set case by case, to best illustrate the scenario under study. This paper uses a general matrix that can be used to plot most of the cases globally. The minimum values of the axes are set to zero, to represent zero-energy buildings and renewable energy use. The maximum value for energy use is set to the level of 180 kWh/m2, and the unit emissions for energy are set to 1000 g/kWh, based on literature sources and energy statistics.

4 RESULTS AND DISCUSSION

This chapter shows environmental impacts of the case-building, assessed in terms of greenhouse gas emissions in five European countries. All the locations share the same climatic zone (Köppen-Geiger Dfb). The countries and locations are: Finland (South), Estonia, Poland (East), Romania (North-West) and Sweden (Stockholm region).

The results are expressed in line with the terms used with the operational energy impact matrix. Firstly, the level of operational energy use is presented for all the cases, followed by the unit emissions for the energy use.

4.1 Level of operational energy use

The life-cycle operational energy use of the case-building comprises of three separate components, which are: energy for space heating, energy for hot water and energy for household electricity. The heating (and cooling) needs of buildings are location-specific, as they are highly dependent on the external temperatures. However, the two other components: energy for hot water and energy for appliances are strongly dependent on user-behaviour, not geographical location. Therefore, they are set to remain constant from one location to another.

The heating energy calculations need to be done for separately for all the locations. The calculations are based on heating degree days, which describe the severity of cold over a specific time period, and take into account the temperature differences between indoor and outdoor conditions (Eurostat, 2013a).

The heating energy need can be projected from one location to another, if the heating degree days of both the locations are known. If, for example, the annual heating energy need for a building in Helsinki is 100kWh/m2, then the heating energy need for a similar building in Stockholm can be defined with the help of heating degree days. In this case the relation of heating degree days between Stockholm and Helsinki is 3853/4445, which equals to 0.87. This means that the heating energy of 100 kWh/m2 in Helsinki would equal to 87 kWh/m2 in Stockholm.

The following table 1 presents the heating degree days (5-year averages) for Helsinki and the four alternative locations.

Table 1 Heating degree days (5-year averages) for Helsinki and four alternative locations, based on Eurostat (2013b)

Location	Heating Degree days (5-year average) 2005-2009)	Scaling factor to Helsinki
Finland (South)	4445	1,00
Estonia	4138	0,93
Poland (East)	3427	0,77
Romania (North-West)	3047	0,69
Sweden (Stockholm)	3853	0,87

The energy for space heating varies from one geographical location to another, while the two other components remain constant. The scaling factors presented at the previous table are used in the conversion of heating energy consumption from one location to another. The following tables show the energy consumption of the case-building, divided into three separate items: energy for space heating, energy for hot water and energy for household electricity.

First of the tables, table 2 shows the energy consumption for the cases with electrical heating, and table 3 shows the energy consumption for ground heating.

Table 2 Energy consumption of the cases with electrical heating for energy for space heating, energy for hot water and energy for household electricity. The energy consumption is expressed in terms of annual consumption of energy per unit floor area (kWh/m2). The table also presents total energy consumption for 50-years life-cycle.

Energy consumption	Case 1, Finland	Case 2, Estonia	Case 3, Poland	Case 4, Romania	Case 5, Sweden
Heating (kWh/ m2, a)	59	54	45	40	51
Hot water (kWh/ m2, a)	24	24	24	24	24
Household elect. (kWh/ m2, a)	38	38	38	38	38
Total (kWh/ m2, a)	121	117	108	103	114
Total, 50a (kWh/ m2, 50a)	6064	5859	5391	5156	5684

Table 3 Energy consumption of the cases with ground heating for energy for space heating, energy for hot water and energy for household electricity. The energy consumption is expressed in terms of annual consumption of energy per unit floor area (kWh/m2). The table also presents total energy consumption for 50-years life-cycle.

Energy consumption	Case 1, Finland	Case 2, Estonia	Case 3, Poland	Case 4, Romania	Case 5, Sweden
Heating (kWh/ m2, a)	23	22	18	16	20
Hot water (kWh/ m2, a)	10	10	10	10	10
Household elect. (kWh/ m2, a)	38	38	38	38	38

Total (kWh/ m2, a)	72	70	66	64	68
Total, 50a (kWh/ m2, 50a)	3576	3494	3306	3212	3423

4.2 Unit emissions for energy use

The greenhouse gas emissions from buildings' lifetime energy use are highly dependent on the energy production methods and carriers of a specific country. This section presents the emission factors for the five calculation cases. The emission factors are based on European data on CO2 emissions per one kilowatt-hour of delivered electricity (EEA, 2013).

The emission factors for electricity production in Europe vary greatly between countries. Sweden, for example, has an extremely low emission factor as the majority (85%) of electricity was produced either by hydro or nuclear power in 2009 (SI, 2011). These energy production methods are considered CO2-emission free in the statistics. On the other hand, Estonia produced only 6% of the energy in 2009 with renewable energy and it does not have nuclear power production.[1] The unit emissions for energy use are presented in the following table.

Table 4 Country-level CO2-emissions for electricity, unit emissions for energy use in terms of CO2-emissions per kilowatt-hour of energy use (g CO2/kWh), based on EEA (2013).

Country	CO2-emissions (g/kWh)
Finland	178
Estonia	990
Poland	810
Romania	584
Sweden	44

4.3 Impacts of operational energy use

Due to the wide range of variation in emission factors, the operational energy use leads to highly varying emissions from case to case. The greenhouse gas emissions from annual and lifetime operational energy use are presented in the following tables. They are calculated, based on the data of previous tables 2, 3 and 4.

First of the tables, table 5 shows the energy consumption for the cases with electrical heating, and table 6 shows the energy consumption for ground heating.

Table 5 Greenhouse gas emissions of the cases with electrical heating from operational energy use (total). The emissions are expressed in terms of annual CO2-emissions per unit floor area. The table also presents total greenhouse gas emissions from energy consumption for 50-years life-cycle.

Emissions	Case 1, Finland	Case 2, Estonia	Case 3, Poland	Case 4, Romania	Case 5, Sweden
Total (kg CO2/ m2, a)	22	116	87	60	5
Total (kg CO2/m2, 50a)	1078	5799	4369	3012	248

1 As this paper uses the official statistics in the calculation, it should be noted that the hydro and nuclear power production have upstream and downstream emissions, which are not included in the energy statistics. If these differences were taken into account, the difference between the minimum and maximum values would become smaller

Table 6 Greenhouse gas emissions of the cases with ground heating operational energy use (total). The emissions are expressed in terms of annual CO2-emissions per unit floor area. The table also presents total greenhouse gas emissions from energy consumption for 50-years life-cycle.

Emissions	Case 1, Finland	Case 2, Estonia	Case 3, Poland	Case 4, Romania	Case 5, Sweden
Total (kg CO2/ m2, a)	13	69	54	38	3
Total (kg CO2/m2, 50a)	636	3458	2679	1876	149

4.4 Emissions from building materials

The material-related greenhouse gas emissions of the case-building are 39 tonnes. More detailed calculations can be found from the paper by Ruuska and Häkkinen (2013). The main sources for emissions are material production for construction and renovation (32 tonnes), building and demolition work (6 tonnes) and transportations (1 tonne). The total floor area of the case-building is 141m2, so the emissions of 39 tonnes translate to unit emissions of 0,27tn /m2.

4.5 Results in the operational energy impact matrix

This chapter shows the results presented in the previous tables in the operational impact matrix and discusses the results. The first subchapter shows the total life-cycle greenhouse gas emissions for the five cases with two alternative heating systems. The second subchapter shows the relative importance of building materials.

Total life-cycle greenhouse gas emissions

The following figure 2 shows the total life-cycle greenhouse gas emissions of the five cases plotted into the operational impact matrix. The first series, with white circles, is for the building with the electric heating and the second one, with the grey circles, is for the building with ground heating. Each of the cases is placed in the matrix according to the level of operational energy use and unit emissions. The cases are represented by circles, whose area is scaled according to the total life-cycle greenhouse gas emissions.

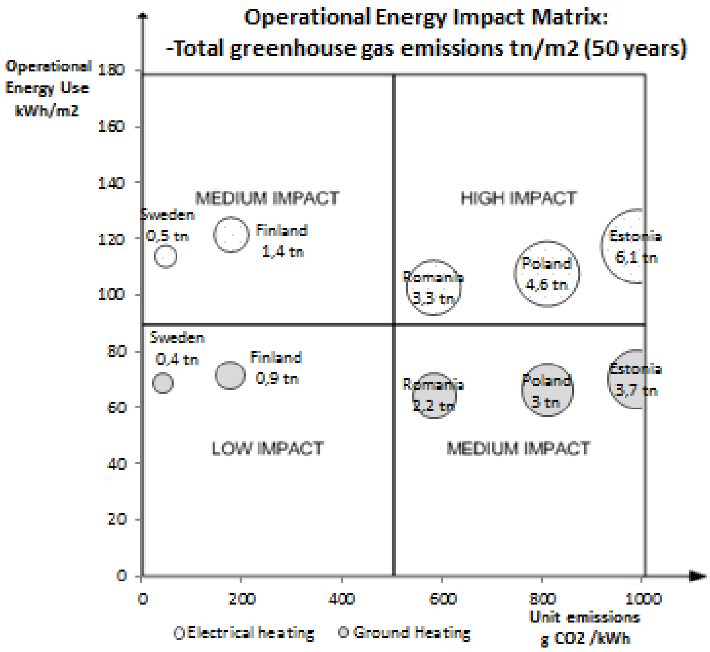

Figure 2 Total greenhouse gas emissions of the cases (tonnes of CO2 / m2, over a 50-year life-cycle) plotted on the operational energy impact matrix

It can be seen that the highest total life-cycle greenhouse gas emissions occur in the high impact sector of the matrix. The highest impacts are for the case of Estonia, with electrical heating. The emissions for this case are 6.1 tonnes of CO2-emissions per m2 over a 50-year life-cycle. At the other end, the lowest greenhouse gas emissions occur in the case of Sweden, with ground heating. The emissions for this case are 0.4 tonnes of CO2-emissions per m2 over a 50-year life-cycle.

The impact of changes in the level operational energy use can be seen when moving from the cases on top (electrical heating) to the cases on the bottom (ground heating). The total life-cycle emissions are reduced by 19-39%, when the level of operational energy use is lowered.

The impact of unit emissions can be seen when moving between the cases from one country to another. When moving from the cases with high unit emissions (on the right) to cases with lower emissions (on the left), the result is a 90% drop in total emissions between the maximum (Estonia) and minimum (Sweden) cases.

The results show how the life-cycle greenhouse gas emissions are significantly different in the different parts of the matrix. The impacts can be significantly lowered by either lowering the operational energy use, or moving towards low unit-emission energy sources. In real building projects, individual builders have control over the operational energy use of the building, by for example, selection of building systems and insulation thicknesses. The unit-emissions of a specific location, instead, are typically country-specific and cannot be altered by builders. However, on-site and local renewable energy production can be potentially used to decrease the amount of purchased energy from the national grid, in countries with high unit emissions.

This paper suggests that legislative actions should focus towards actions which could push buildings towards the low impact sector. This can be done by a combination of energy-efficiency and low-emission energy production.

Relative share of building materials

The following figure 3 shows relative share of material-related greenhouse gas emissions of the five cases plotted into the operational impact matrix. The first series, with white circles, is for the building with the electric heating and the second one, with the grey circles, is for the building with ground heating. Each of the cases is placed in the matrix according to the level of operational energy use and unit emissions. The cases are represented by circles, whose area is scaled according to the building materials' relative share of lifetime total greenhouse gas emissions.

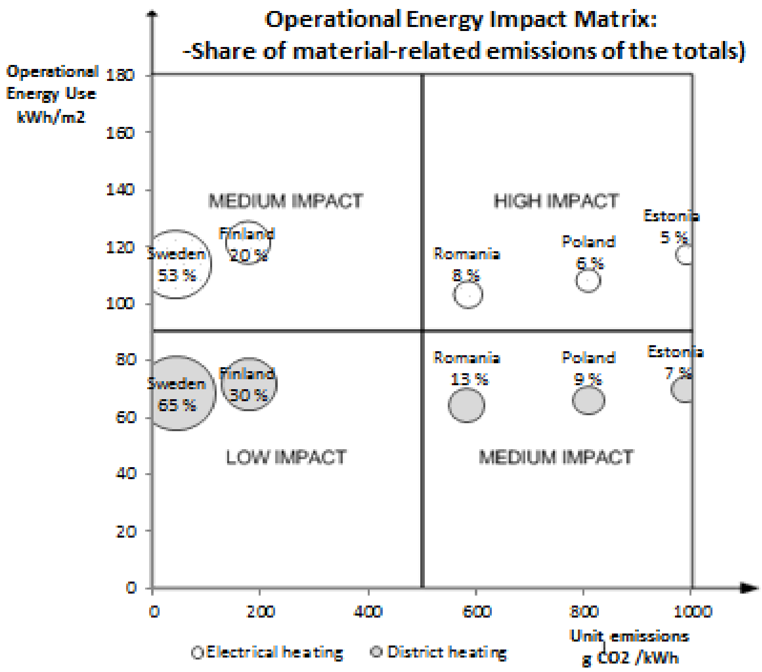

Figure 3 The relative share of material-related emissions of the cases (percentage of total life-cycle greenhouse gas emissions over a 50-year life-cycle) plotted on the operational energy impact matrix

The figure shows that the lowest percentage shares of materials occur in the high impact sector of the matrix. The share is the lowest in the case of Estonia, in which it equals to 5% of totals with electric heating. Respectively, the highest shares occur in the low impact sector, where the relative share of materials is 65% for the case of Sweden with ground heating.

The impact of changes in the level of operational energy use can be seen when moving from the cases on the top (electrical heating) to the cases on the bottom (ground heating). The relative share of materials increases by 2 to 12 percentage points when the operational energy use is reduced. For the case of Estonia, the increase is from 5% to 7% and for the case of Sweden, the increase is from 53% to 65%.

The impact of unit emissions can be seen when moving between the cases from one country to another. When moving from the cases with high unit emissions (on the right) to cases with lower emissions (on the left), the result is an increase from 5% of Estonia, to the 53% of Sweden (for electrical heating). Similarly for ground heating, the move from high to low emissions raises the role of materials from 7% to 65%, from Estonia to Sweden.

The results show that the relative share of the material-related emissions are lowest in the high impact sector of the matrix and highest in the low impact sector. However, it is also important to notice that in the medium-impact sectors, the material-related emissions are the highest closest to the axes (near-zero energy use / renewable energy) and lowest when furthest from the axes (high operational energy use or high unit emissions.

The results suggest that the focus on greenhouse gas reductions should shift towards building materials when moving from high impact area to the low-impact area. This is also true, when moving towards the zero-energy buildings or zero-emission energy in the medium-impact sectors. This information is valuable, when focusing country-level emission reduction actions.

6 CONCLUSION

The operational energy impact matrix provided to be a useful tool for simple assessments concerning total life-cycle greenhouse gas emissions of buildings and importance of building materials. It is a simple tool, which allows rough evaluations by plotting information from multiple data tables into a single visual presentation for analysis.

The results of this paper suggests that if a building under study falls into the high impact sector (with high unit emissions and high operational energy use) the total life-cycle greenhouse gas emissions are the biggest. Also, for such buildings, the relative importance of material-related emissions is low.

Respectively, if a building is in the low impact sector (with low unit emissions and low operational energy use) the results are the contrary. Cases in the low impact sector have the lowest life-cycle greenhouse gas emissions and the relative importance of material-related emissions is the highest.

These results and the matrix as a tool can assist in focusing greenhouse gas reduction efforts to the right life-cycle phases.

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COMMUNITY BRIDGE: BUILDING RESILIENCE WITH BAMBOO

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Abstract: Situated on riverbanks, three communities of Matina Crossing Federation (*Matina Fed*) in Davao City, Mindanao have to rely on bamboo makeshift bridges for their access to the main street. The makeshift bridge is unsafe and flushed away each time the river floods. Nevertheless, the municipality was reluctant to replace the bridge due to the informal status of residents' land tenure. On November 2009 *Matina Fed* expressed their wish for a replacement bridge and started a savings group with guidance from the Homeless People's Federation Philippines Inc. (HPFPI). During a design workshop in January 2010 the challenge was shared with "community architects" from countries in the region. The replacement bridge will also be bamboo, but new technologies will be incorporated. Further, the Matina Crossing Federation took the lead in activities related to the project; on administration, materials procurement, mobilization for labor and food, and on hosting related workshops. In April 2011 two Indonesian bamboo carpenters stayed in the community and led the construction of the bridge. In one month the entire bamboo structure is completed. Another month was needed for roofing and mortar injection. Finally, three-inch thick concrete was poured for the floor. The 23 m span bamboo bridge was completed with cost of PHP 450.000 (around USD 10.000) that is paid by loans. In June 2011 a devastating flash-flood carried debris which battered the bridge. The bridge survived, and even served as a safety platform. The bridge continues to serve the communities for more than two years up to the time this is written.

Key words: bamboo, alternative, riverside, infrastructure, participation

1 THE PEOPLE'S PROCESS

1.1 A Community's Struggle

Situated behind the busy Matina Crossing in the southern part of Davao City, Philippines, is a 9.8 Ha parcel of land with an absentee landowner. Known as the Arroyo Compound, the land has been settled for around forty years and developed into an informal settlement. Crisscrossed by Matina River, some makeshift bridges serve as the main access to Arroyo Compound. Nevertheless, Arroyo Compound is home to, among others, four community associations, namely, *Saint Paul, Saint Benedict, Matina Balusong,* and *Shalom.* The four communities form the Matina Crossing Federation (*Matina Fed*). In late 2009, *Matina Fed* represents 488 families, which consist of food vendors, drivers, construction workers, masseurs, shop-keepers, security-staff, and other urban workers.

Since November 2009 *Matina Fed* is a member of the Homeless People's Federation Philippines, Inc. (HPFPI), a *people's organization* which aims to fulfill housing needs and tenure security of its members. *Matina Fed* took initiative to upgrade their access bridge; the need for which was expressed during a participatory design workshop hosted by the community in February 2010. Further, *Matina Fed* members take the lead in all activities related to their bridge project, including processing papers, permissions, and requests to the municipality; procuring materials; mobilizing community people to provide volunteers and food during preparation and construction; and undertaking workshop preparations in the community.

On December 2010 the community faced a demolition threat that was purported by a claimant of the land. The demolition did not occur and was dubbed as illegal. In fact, community members managed to respond quickly and halt the process. Despite the rising insecurity, the community was eager to carry on with the bamboo bridge project. Soon, the construction of the bridge's foundation began. The savings groups took an initial loan of PHP 300.000 (around USD 6.500) that was later re-negotiated to PHP 450.000 (around USD 10.000) along the course of the project. The loan is shouldered by 145 households, the active savings members within *Matina Fed* (Orendain and Co: 2011b).

1.2 The Civil Society Partnership

HPFPI is a network of 200 urban poor community associations and saving groups across the regions of Luzon, the Visayas, and Mindanao. Since its inception in 2002 until now HPFPI have spread to 14 cities and 16 municipalities country-wide. The NGO Philippine Action for Community-led Shelter Initiative (PACSII) is providing managerial and operational supports for HPFPI, while the Technical Assistance Movement for People and Environment, Inc. (TAMPEI) hosts young professionals and architects interested in HPFPI's housing initiatives. HPFPI, PACSII, and TAMPEI are collectively referred to as the *Philippine Alliance* (HPFPI-PACSII: 2010).

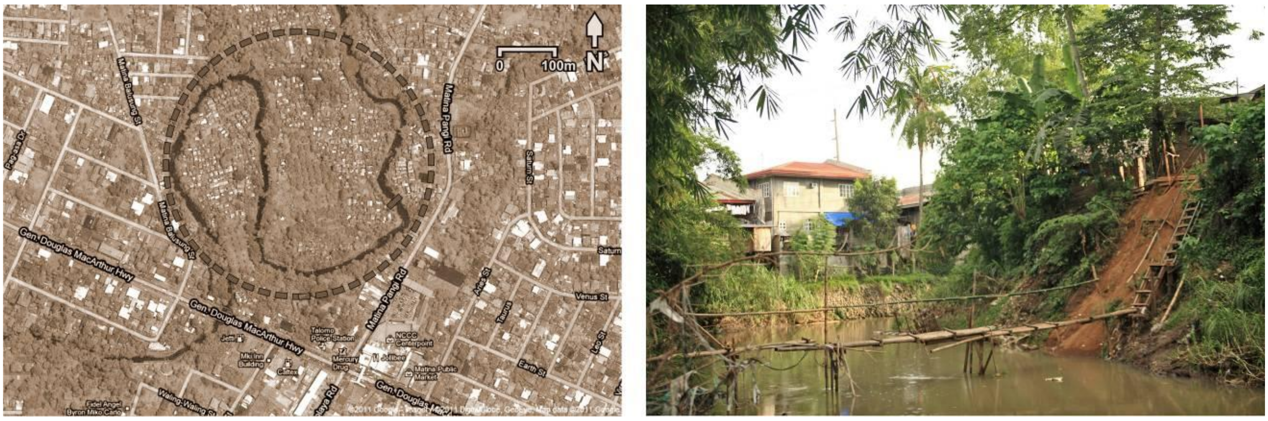

Figure 1 Map of the Matina River (left) and the makeshift bridge prior to development (right)

Local academic institutions also took part in the Matina bridge project. The Department of Engineering of the University of Mindanao provided technical engineering computations in load and structural analyses of bamboo bridge frames and assistance in foundation works. University of the Philippines Mindanao gave input in the bridge concept design, design properties and assistance in workshop preparation. Another link with the academic world is through a course paper submitted to HDM-Lund (Fitrianto: 2011). Actually, the work also caught the attention of a bamboo engineer-researcher in Coventry, UK but due to time constrains there was no academic research conducted in parallel with the project.

In the regional network, the *Philippine Alliance* is affiliated with the Asian Coalition for Housing Rights (ACHR). ACHR is founded on 1988 as a common platform for Asian housing activists and community workers to facilitate exchanges and collaboration (ACHR: 2010). ACHR provides financing and technical assistance through the program of Asian Coalition for Community Action (ACCA) that was first launched in 2009. The bamboo bridge project is part of ACCA, a community-driven upgrading based on women's savings groups, implemented across Asia through local organizations (Papeleras et al.: 2012).

Alongside ACHR's regional activities on housing with the urban poor communities in Asia there are architects and professionals that have been involved through provision of technical assistance. "Community architects" is a common denomination though the individuals vary from community builders, artisans, architecture students, professors, NGO professionals, architects, and other professionals (Luansang et al.: 2012). In June 2010 the Community Architects Network (CAN) was established in Chiang Mai, Thailand (CAN: 2013).

Through CAN, the bamboo advocates of *Sahabat Bambu* (SaBa) from Yogyakarta, Indonesia were invited to collaborate on the bridge project. SaBa mainly provided technical guidance in the design and construction of the Matina bridge and provided facilitation in the training workshops. The author was in charge of the project as a community architect on behalf of both CAN and SaBa.

Figure 2 The bamboo belt along the equator (left), the Filipino folklore of *si malakas at si maganda* (right)

2 BAMBOO: STRONG AND BEAUTIFUL

One of the *Philippine Alliance*'s efforts in its development initiatives is to explore alternative building technologies and materials that are low cost, community friendly, environmentally sound, and locally available; i.e. technologies that can easily be managed, handled-by, and transferred to the communities. Thus, bamboo came as one of the interests of the Alliance.

2.1 Bamboo in Nature

Bamboo belongs to the family of grass (*Gramineae*) that grows around the equator belt both in the tropics and the sub-tropics. Geographically, bamboo is found in areas up to 47^{o} north in the island of Sakhalin and 46^{o} south in Argentinean Andes (Ohrnberger: 1999). There are more than 1.200 *species* of bamboo that have been identified and categorized into 90 *genera* (INBAR-FAO: 2007). In common among the family of grasses, bamboo sustains adverse soil. In nature, bamboo stands can be found from coastal land up to altitudes of 4.200 m in northern Yunnan and 4.500 m in the Andes of Chile.

Bamboo is also recognized by its type of root systems called *rhizome*. In this regard, there are three kinds of bamboo. *First*, the *monopodial* bamboo where shoots grow distanced from one to another, which is also called *running bamboo*. *Running bamboo* is found in the sub-tropics and they are expansive if given a sympathetic environment; e.g. *Phyllostachys pubescens* that is native to Japan and China. *Second*, the *sympodial* bamboo where shoots appear adjacent to each other thus configures a clump; *clumping bamboo*. Clumping bamboo accounts for the most of the tropical woody bamboo. *Third*, often a combination of both root formations is the *climbing bamboo*, which commonly appears as herbaceous bamboo.

In 4-6 months a bamboo shoot reaches its full height. In a year, branches develop and in another year, leaves completed. From two years on, branchelets develop and leaves are renewed. In three years of age a culm reaches maturity and the peak of its strength; the wall densifies, its silica-rich skin hardens, and its specific gravity increases. A culm remains strong until five years old when strength gradually decreases. As bamboo is vastly diverse in shape and characters, it is advisable to refer to local experience i.e. the local community, when it comes to the question of best use and potentials of each species.

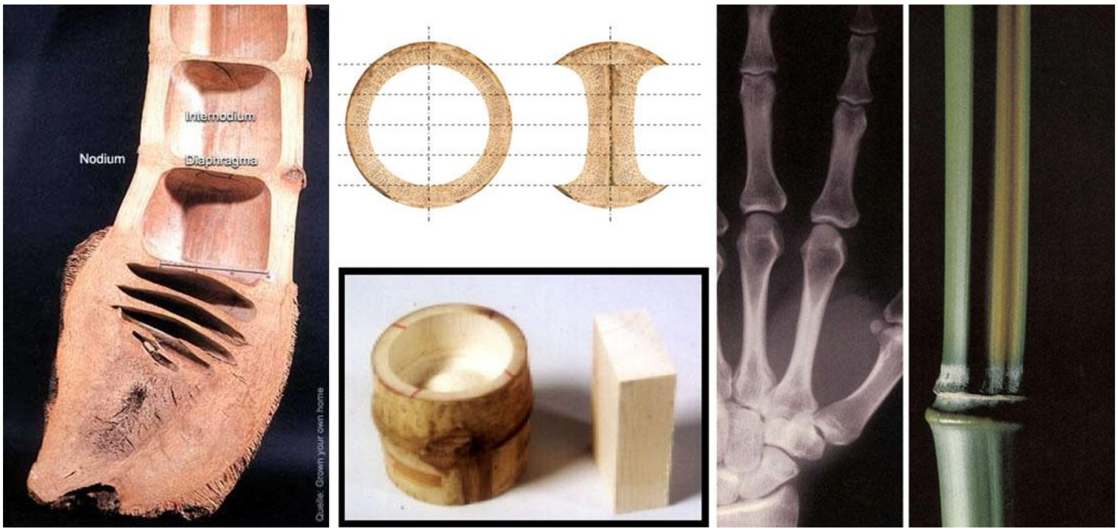

Figure 3 Section of root stem shows telescopic growth of bamboo (left), surface area of bamboo section (bottom center), recomposition of surface area shows how bamboo acts like an I-beam to all directions (top center), identical forms; between bamboo node and human skeleton (right).
Photos from (Janssen: 2000) and (Vélez et al.: 2000)

2.2 Bamboo in Culture

The Filipino folklore of *si malakas at si maganda,* which literally means the strong and the beauty, is about the first couple of human beings descent to the earth after a hummingbird pecked and cracked a giant bamboo. By being strong and beautiful, bamboo presents in many Asian cultures. Bamboo is used extensively from kitchen and household utensils to houses, fences, and bridges. Young bamboo shoot is a source of good nutrition, a common diet found in many Asian cuisines.

2.3 Bamboo in Architecture

Bamboo is among the oldest building materials known to the human race. Nevertheless, some significant achievements happened during the last three decades. This is associated with growing interest in alternative technologies which began in the 1960s. The same period when the urbanization rate was increasing, putting pressure on housing needs in urban areas of the Global South. Experiments in bamboo for building purposes took place in the Philippines (McClure: 1953), but nowhere else as intensely as in Colombia (Hidalgo-López: 2003). In 1999 an earthquake in the Colombian region of Armenia crippled modern structures but people's housing using the vernacular *bahareque* construction survives, hence bringing bamboo to the forefront as safe and reliable building material (Vélez et al.: 2000). However new techniques accumulated, there is still an age-old stigma on bamboo as the poor man's timber.

The equation is slowly changing around the beginning of 21th century when bamboo is used in luxurious projects as the new beauty along with the notion of *green architecture* and *sustainable design*. Among noteworthy projects is the *Greenschool* in Bali, Indonesia and *Ecolodge* resort in Guangdong, China (Meinhold: 2010) (Prince Claus Fund: 2009). From these projects, Colombia-based practitioners such as Jörg Stamm and Simón Vélez became known to the architecture and design community in Asia as leading bamboo innovators. The bamboo news arrived in the Matina community as well, through presentation slides by the community architects.

2.4 Some Technical Aspects

In terms of structural properties, bamboo has good strength in bending, in tension, and in compression if parallel to grain (Trujillo: 2009). It also has excellent strength to weight ratio. An experiment with vascular bundle, the tube-like element which transports moisture in living bamboo, reveals superiority in tension strength of bamboo over steel. However, it is difficult to draw the whole extent of this potential out of the laboratory and the biggest challenge lies around bamboo joinery methods (Arce-Villalobos: 1993). To overcome this, experienced bamboo architect like Simón Vélez lean towards compressive joints in his designs. Bamboo joinery and bamboo preservation have been the main topics which have long grabbed the attentions of many (Dunkelberg et al.: 1985, Janssen: 2000).

3 WORKSHOPS FOR CAPACITY BUILDING

3.1 Bridge Design Workshop

The February 2010 workshop held in Digos City and Davao City involved community leaders, builders, students, academes, and architects aligned with community efforts on housing. On a weekend, *Matina Fed* hosted a participatory design session where participants were divided in groups and asked to design a bridge. Beforehand, presentations on fundamentals or general aspects of bridges were given by engineers and architects from PACSII and SaBa. This was meant to break the norms that a bridge is solely an engineering product under authorship of professionals. The workshop resulted in six designs which were presented and discussed in the forum through modest and beautiful drawings and scale models. The one-and-half day workshop at the community was so lively, bringing a strong sense of ownership to the bridge project. Since then, the community architects maintain a close relationship with *Matina Fed*.

Figure 4 Participatory design workshop; democratizing design process and a medium for engagement

3.2 Subsequent Workshops

Between August 2010 and January 2011 there are mini-workshops on topics of (1) bamboo cultivation and clump management, (2) bamboo treatment, and (3) bamboo house construction held with community members. The series of workshops culminates at the regional workshop of *Bamboo for Sustainable Communities* which is held in January 2011 in Davao City. In the workshop examples of bamboo-based livelihood such as bamboo handicraft and furniture is presented and discussed (Orendain and Co: 2011a). Along with participants from the country-wide network of the *Philippine Alliance* there were community architects from Thailand, Cambodia, Vietnam, and an architect-volunteer from Colombia. The workshop facilitation is led by the Indonesia team, which includes two experienced traditional bamboo carpenters.

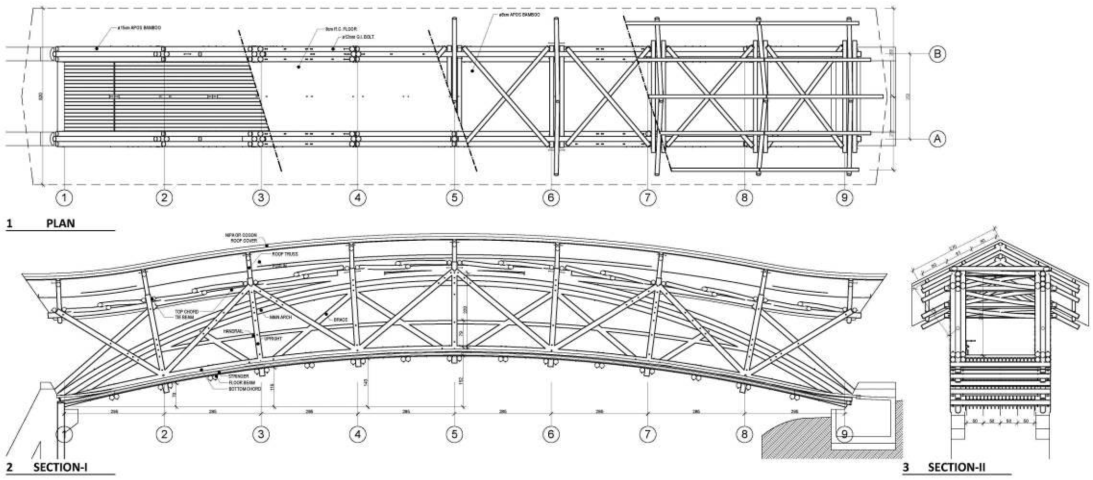

Figure 5 Technical drawings of the Matina community bamboo bridge

4 BRIDGE DESIGN AND BAMBOO TECHNOLOGIES

In October 2010 the architects consolidated the six designs from the community into one; a truss bridge with a center column. However, when the recurring threat of flash floods became apparent during construction of the center foundation in November 2010 the community insisted on a free-span bridge design. This put a fresh challenge to the architects. A new design is needed for the 23 m span between the banks. The first approach was by looking at precedents of modern bamboo bridges, then emailing other bamboo experts and friends. Through their generosity, opinions, suggestions, and help were obtained. It took three months to fully develop the design; a Howe truss pre-tensioned with arches that benefits from the natural curve of the bamboo (Stamm: 2009). A consultation with Jörg Stamm in Bali on March 2011 provides input to the design and concludes the design development.

4.1 Design Modeling

Modeling has long been part of architectural design work stream. Today, computer generated models are commonly used as they are fast and accurate. CAD software with 3D native such as ArchiCAD is very helpful for bamboo design, especially to mitigate collision in complex bamboo arrangements. In the field of engineering, STAAD is among the favorite software familiar to engineering students to analyze space-frame structures like the bridge's design in Matina community. However, since CAD models are merely virtual it needs to be complemented with physical scale models.

To make a scale model, bamboo skewers with section of ø3 mm are available in supermarkets. They are perfect to represent ø12 cm bamboo in 1:40 scale model (Tulay na Kawayan: 2011). Push pins from the stationeries section is used to join the skewers. To insert the pins, holes are made with help of mini-drill; commonly used for electronic chip boards. Indeed, the use of glue in the scale model is intentionally avoided. Thus, the scale model would mimic the steel bolts joinery in reality. When tested with loads the scale model is able to show deformations and failures; provides useful feedback for the design development. Steps of building a scale model are analogous with construction steps of the real bridge. At the end, the scale model is an excellent design communication tool.

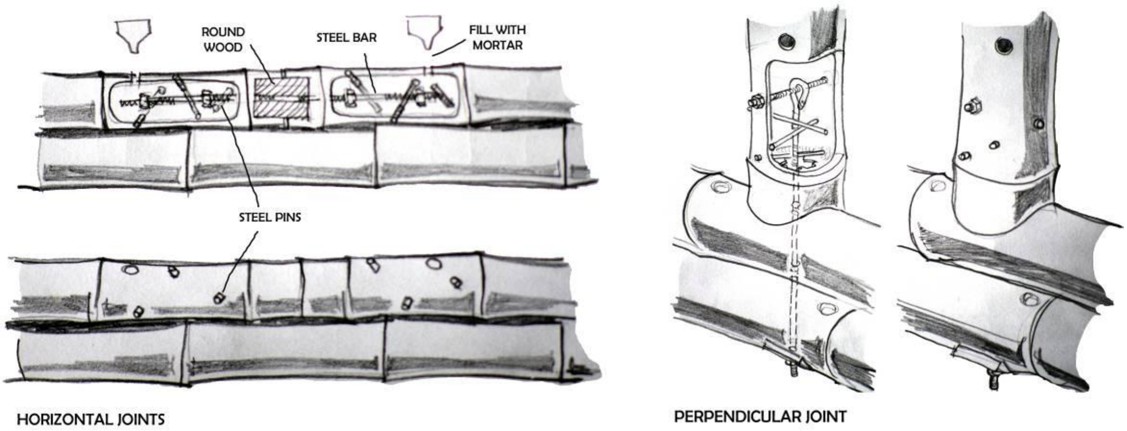

Figure 6 Example of main joineries incorporating steel bolts and pins with mortar filling

4.2 The Species of Bamboo

After a mistake in selection of bamboo, which causes delay in construction schedule, it is assured that the bamboo species to be used for the bridge is the giant bamboo of Southeast Asia that is locally known as *apos* (*Dendrocalamus asper*). The *apos* were purchased at PHP 90 (around USD 2) per culm from non-production clumps on a private mango farm in Serawan, around 10 km west of Toril district, on a moderate slope at the lower part of Mount Apo. While the "mistaken" stock of large but thin-walled *botong* (*Dendrocalamus latiflorus*) is used for the workshop in January 2011. Some remaining *botongs* were used for tertiary members in the bridge along with *tungkan* (*Bambusa blumeana*), another species that is common in the local bamboo market. The three bamboo species mentioned are natives (Roxas: 2010).

Figure 7 Vertical Soak Diffusion (VSD) plant adjacent to the bridge's site (left) and illustrations of the treatment process (right)

4.3 Treatment of Bamboo

If not properly treated, bamboo will not last more than four years. Treatment is imperative in having a permanent bamboo structure. A minimum 25 years lifetime is expected given the bamboo structure is well protected from rain and from humidity that may generate from contact with soil. A treatment facility is constructed at the vicinity of the bridge site consists of 4 m height concrete portals topped with 6 m bamboo cover structure high enough to treat 9 m poles. Through gravity, the Vertical Soak Diffusion (VSD) system is aimed to replace bamboo's sugary sap with 7% solution of *borax* and *boric acid* (B+B), thus the bamboo is unattractive to pests known as *bukbok* (*Dinoderus minutus*). In Indonesia, VSD system is developed around 2000 by the Environmental Bamboo Foundation (EBF: 2005) and further improvised by SaBa. While there is a general acceptance to B+B as the "least poisonous" substances, a report says prolonged contact and inhalation may harm fertility. Therefore, the use of rubber gloves and masks for workers is suggested.

4.4 The Foundation

In parallel with bridge's design development and bamboo treatment was the construction of the foundation. The new bridge is located at the same spot with the old one, in a river section with sufficient distance from bends and protected from erosion. A pair of reinforced concrete foundations compensates the 5 m height difference between the banks which is separated by 23 m. The foundation that is designed by Eng. Joeffry Camarista from PACSII would transfer lateral forces from the arched bridge to the ground. The total cost of foundations with community labor was billed around PHP 115.000 (USD 2.500).

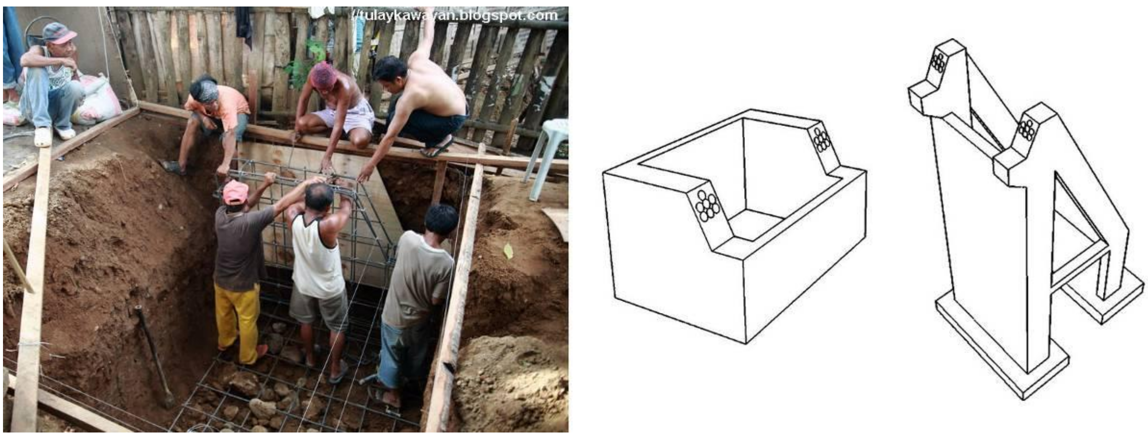

Figure 8 The foundation set

5 CONSTRUCTION AND NATURE'S TEST

5.1 Construction of Bamboo Components

With presence of two Indonesian bamboo carpenters, April 2011 was spent on construction of the entire bamboo structure. For convenience, the frame assembly location is set right next to the foundation. Not an ample area for work but just big enough to fit the frames and 5-10 workers. Six days is spent for each frame, the bridge's main carrier. The third week saw the installment of the pair of frames onto the foundation using a false bridge/scaffolding, bamboo rolls, three chain-blocks, hung to adjacent trees, and all of the men in the community. Indeed, the bridge is designed as "handmade" as there is no access for heavy equipment to the site. The fourth week is spent to install floor trusses, roof trusses, triangles, and diagonals. The whole bamboo structure is spray-washed and rubbed with sand until clean then coated with plastic varnish to protect the bamboo from sun. Intense sun exposure may accelerate drying of bamboo and spur hairline cracks in bamboo. A video documentation showing the construction process is available in *Youtube* (Kampung Kota: 2012).

Figure 9 Men push a completed frame to the foundation (left), sand-cement mortar injection on main joints (right)

5.2 Roofing and Mortar Injection

In May 2011 the work continues with roofing and flooring of the bridge. For the roof cover *nipa* leaves (*Nypa fruticans*) that is a vernacular material for people in area is used. A good bamboo design requires generous roof overhangs; a thorough protection from rain and ultraviolet light. In preparation for mortar injection on primary joints at the floor level, ø7/8 inches (ø21 mm) hole is drilled in designated bamboo internodes. Cement-sand mortar in ratio of 1:2 is prepared with regulated fluidity that is possible to flow through the holes with help of a plastic cone. It is aimed that the solid mortar would transfer loads between bamboo walls and the steel components; threaded bars, bolts, and pins.

5.3 Flooring

The basic idea of the bridge's floor structure is having a mould for 4 inches-thick concrete shell, which serves as the final finish. Over the floor trusses is ø8-10 cm bamboo stringers arranged to full width. Over the stringers is *amakan* or bamboo mats. A layer of tarpaulin is laid to retain moisture during concrete curing. Above that, steel bars of ø5 - ø7 mm is arranged in 15x15cm grid. Finally, 4 inches-thick of fresh concrete is poured to the floor. This was done in one day through community work and a mobile concrete mixer. The concreting starts from each of bridge's end and finishes at the center. Fresh concrete practically exposes the structure to a uniform load of not less than 9 tons, however there is no deformation recorded. The concrete floor contributes lateral stability to the bridge, provides maximum comfort for passengers, while also anchors the bridge to its foundations. Moreover, concrete surface is a good solution for durability of wear.

5.4 Completion and the Flood of July 27

As the concrete floor cured the bridge is technically completed and by the end of July 2011 a date is chosen for inauguration with plan to invite the city mayor. However, a huge flash-flood on 27 July at midnight swept the community and destroyed many houses. The new bridge was battered by debris that is brought by the flood and endured. In fact, it served as an evacuation platform and lifeline in the aftermath, providing access for emergency response and first aid. The inauguration was postponed until December 23 in the midst of house repair activities in the community.

5.5 Post Occupancy Issues

There is a damage on one floor truss created by debris from the flash flood, but does not compromise the structural integrity of the bridge. During the first three months of usage, the bridge is in close observation. The first three month period is critical as loads search for equilibrium, joints tighten, and the bamboo shrinks due to air-dry process. From observation there is no visible deformation on the bridge. Around one year after, in November 2012, a personal visit to the bridge confirms no problem on immunization of bamboo. Since beginning the bridge is guarded full time. Each pedestrian user is asked for PHP 1 (around 20 cents) contribution per day and PHP 5 for motorcycle/tricycle user per day. This generates income for repayment and maintenance fund; for expenses of regular roof repair and varnish coating. As this is written, the bamboo bridge is already serving Matina community for two years.

Figure 10 Debris brought by July 27 flash flood (left) engulfed the bridge (right), and the concrete floor which seamlessly connects the bridge to its foundation saves the bridge.

6 CONCLUSION

6.1 The Bamboo Renaissance

The beginning of 21st century saw the return of bamboo in architecture. The entire negative stigma is not completely erased, bamboo is on the way to it. In the case of Matina bridge project, bamboo is reintroduced and discussed in a more holistic way; not limited to construction but also including cultivation and its treatment. This aims for a profound new appreciation to the new *but* old material. The Matina communities rediscover bamboo's beauty and strength from the bridge which manifested their determination and hard work. However, another aspect that is certainly of community's concern is the accessibility and affordability of bamboo. There is no guarantee that accessibility and affordability is secured, as much of bamboo clumps grow on private farms. Besides, preservation requires sound management. A good collaboration among various local groups including the authorities remains as one of the key factors in up-scaling and mainstreaming bamboo to benefit communities.

6.2 Social Renewal

There are several learning curves passed through in parallel during the bridge development processes. Lessons learnt not only by the architects but also; by students and academes; by community volunteers on learning their new skills; by community women on project management and on community finance. New relationships were created and existing relationships strengthened. The inter-collaboration and support to each other counts for the success of the Matina bridge project. As an early conclusion, the bamboo bridge of Matina community in Davao City has shown that a reliable, affordable, and sustainable community infrastructure development is possible. The bamboo bridge is now an icon of the community's resilience; their ability to provide the best solution for their own development needs.

Figure 11 The Davao bamboo bridge (left); an affordable and reliable basic infrastructure serves to improve the life of many (right)

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DESIGN OF GREEN EMERGENCY HOUSING FOR CALAMITY – STRICKEN COMMUNITIES

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Abstract: Philippine public infrastructure lags many years behind other countries, especially with its Asian neighbors. Given the country's susceptibility to damaging natural disasters, this may be an excellent opportunity for the country to enhance its disaster preparedness when it comes to evacuation shelters. This paper presents transient evacuation centers as the best emergency shelter suited for victims of calamities. A modular design was conceptualize which allows expansion and subdivides structures into multiple units for easy relocation as requirements change. Eco-friendly construction, using recycled container vans, is utilized for simple assembly and installation. There were two layout plans consisting of first option container vans stacked at three-storey level and the second option with only two container vans heaped on top of each other to form a two-storey structure. Each structureunit houses an average of 32 double-deck bed for the two-storey layout and 46 double-decker bed for three-storey complete with wall fans and CFL lamps. A separate van for the administration office, wash area, kitchen area and rest rooms are provided for. Solar electricity was also included in the system. The layouts were based on hypothetical available land area based on typical land areas alotted by local government. Introducing an alternative shelter using used container vans is achievable, more economical compared to conventional concrete structure, and easier to install and dismantle. The establishment of the said emergency shelter was suggested as these would enhance the country's ability to establish an immediate but acceptable evacuation shelter for displaced citizens of the community.

Key words: Container Vans; Steel Framing; Green Design; Solar Panels; Accessibility

1 INTRODUCTION

Being located in the Pacific Ring of Fire, the Philippines is frequented by different types of calamities such as typhoon, flooding, earthquake, and volcanic eruption, that claim thousands of lives of Filipinos without a year spared. Effects of these calamities with its magnitude unimaginable, wreak havoc leaving people homeless and no access to other basic needs like food and water as lifelines, transportation and communication are down. Emergency evacuation centers play a very important role in these times of crises.

Emergency evacuation centers are a required aspect of any recognized crisis operations plan. When an urgent situation arises and these shelters are needed, the general public expects that officials have thoroughly planned their implementation process. To assist communities with accomplishing this goal, guidelines have been established by the Philippine Red Cross (PRC). It states "to provide relief in times of disasters and to carry on measures to minimize the suffering caused by them." Disaster preparedness is one of the major components of its program that aims to prepare especially the vulnerable communities in the event of calamities.

Burford & Gengnagel (2004) defined evacuation shelter systems as a type of building construction for which there is a vast range and diversity of forms, structural and assembly solutions. They are designed to provide weather protected enclosure for a wide range of human activities. Enclosure requirements are generally very simple, with the majority needing only a weather protecting membrane or skin supported by some form of erectable structure. In all applications, both the envelope and structure need to be capable of being easily moved in the course of normal use, which very often requires the building system to be assembled at any prepared sites. Structures can vary in scale depending on the area to be built upon. Consequently, design requirements vary considerably with application and size of enclosure.

Whenever there are natural calamities, affected families flock school buildings and multi-purpose gymnasiums or halls even churches that are used as evacuation centers. The economic and social costs of using school buildings and open space structures as evacuation centers are just too high. School classes are hampered to give way to families seeking refuge. But these facilities are not normally intended for such purposes for an extended period of time as the rebuilding of the stricken communities takes time. Situations in these types of emergency facilities are horrible and we usually see people stripped of their dignity.

These scenario is not new to the Philippines, we have them long time ago, what we do not have are emergency facilities to that are really intended for evacuation, easy to produce or construct, economical, and environment-friendly.

2 PROJECT OBJECTIVE

The main purpose of this project was to design a green emergency housing system for calamity-prone communities using used container vans as evacuation shelter. Related to the realization of the above objective, the following were carried out:

- Determining an appropriate lay-out of the floor plan for the entire system;
- Designing the structural framing and the foundation that is generally fit to variable soil condition (case study: Cagayan de Oro City and Marikina City);
- Proposing a plan for the electrical and water supply system;
- Utilizing solar energy as an alternative source of electricity.

The above objectives were accomplished using the National Structural Code of the Philippines for structural safety, the National Building Code of the Philippines for the accessibility, and the Steel Manual for steel works. To aid in the development of the research, computer software such as Google Sketch-Up, AutoCAD and STAAD were utilized.

3 THE STRUCTURE

During calamities, a huge number of families are evacuated to areas normally assigned to public school buildings and gymnasiums. Nevertheless, these facilities when occupied impede the learning activities of our youths and the physical and social activities which are supposed to be held in the gymnasiums. Permanent structures dedicated for evacuation is a good option, however, this entails bigger budget for the purchase of lot and construction of the massive structure.

A cheaper alternative that this project provides is a housing facility using used container vans. The mobility of the components of the housing facility makes it cost effective with regards to its construction suited for any location. It could be easily transported by trailer trucks on land, by cargo ships, and even air lifted especially in areas where road accessibility is impossible.

By not using timber and concrete, we will then be able to save trees and natural resources and minerals for future generation to use. We will use old container vans as our main material in this project; thus, lessening the problem on the disposal of old container vans. In addition, we will use solar panels to conserve energy. Solar energy leaves a small carbon footprint and can power the center well enough by saving and producing enough energy of its own, without the need of electricity produced by others.

4 PROJECT LOCATION FOR THE CASE STUDY

The project is an evacuation housing center that will be located, for now primarily at these two areas within the Philippines. The areas are pre-identified by the respective local government as generally safe for evacuation. Such locations are pre-selected on the criteria of ground stability being out of harm's way from fault lines, landslides, and land subsidence; flood hazards being located in an elevated area distant from the dangers of flash floods; accessibility to transportation and water supply. Two location sites as case study are initially proposed: Marikina City and Cagayan De Oro City shown in Fig.1.

Figure 1 Project Location for the Case Study – Marikina City and Cagayan De Oro City

3 METHODOLOGY

3.1 Project Development

To arrive at the suitable layout of the system and its components for efficiency of the compact and mobile emergency housing the researchers, questionnaires were handed out to those who have first-hand experiences in evacuation centers, as well as those who have been affected by the calamities were taken into consideration. The experiences and ideas of staff and volunteers from government and civil society are all crucial elements of every aspect of this external evaluation. The researcher conducted personal interviews that include representatives of government such as the National Housing Authority (NHA) and National Disaster Risk Reduction Management Council (NDRRMC), the Local Government Unit (LGU) of the cities chosen as case study, and non-governmental organizations. In addition, a review of relevant literature and reports written for such articles were conducted.

The evacuation housing is comprised of 2-storey and 3-storey bedrooms quarters, with separate unit for the restroom and shower area.

The concept starts with the determination of the layout of double-decker bedroom area and other units. This determines the location of the openings such as doors and windows and the utilities such as lighting, ventilation, convenience outlets for administration office, water taps for the restrooms, etc. This will also determine the relative position of the structures or container buildings that will maximize the area without compromising ease and comfort of the evacuees. Sample proposed layout is shown in Figure 2.

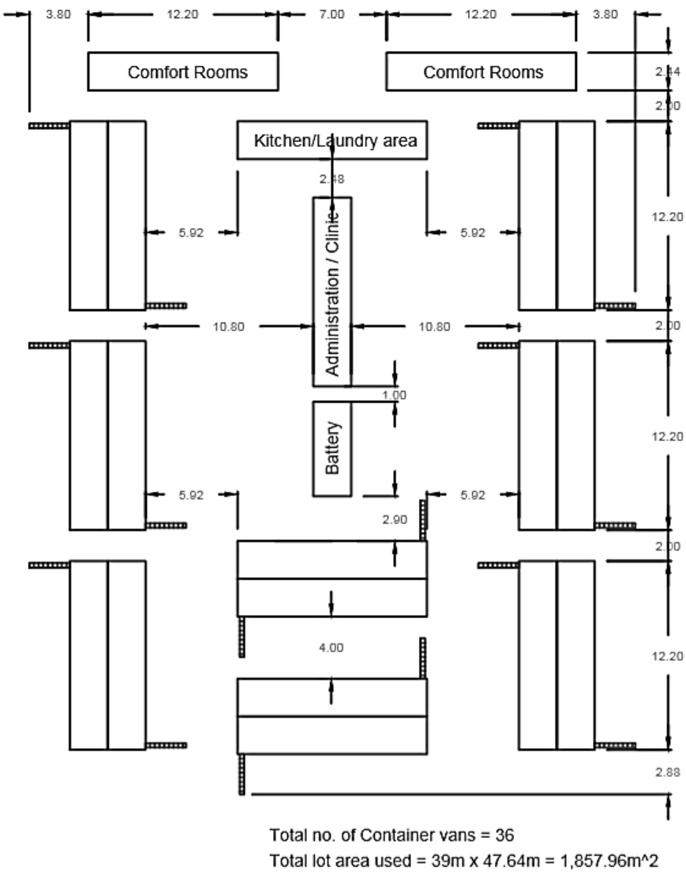

Figure 2 Sample proposed layout.

The units will be made from used container vans that are already bound for disposal. These will be fabricated in a designated facility in locations that is/are strategic for the transport of the units.

The installation of the units at the site starts with the preparation of the ground. Identification of the soil type helps determine the foundation to be used for the two-storey and three-storey units. Structural reinforcement for the two-storey unit is done on site. Two-storey installation is done when crane or any lifting equipment is available.

The project is a mobile housing and the location for the installation of which is at pre-determined sites by the national government agencies/local government units (LGUs). Being installed only for the purpose of temporary abode for evacuees of calamities, these units will be permanently placed in the location with the local barangay maintaining it as a place to stay for transients in times of emergency. Nevertheless, the structures are designed to be easily detachable for transfer of location or for reconfiguration of layout of the system.

Figure 3 a. Front elevation view of the 3-storey container van structure;
b. Side elevation view of the 3-storey container van structure.

3. 2 Design of the Structure

Design codes were extensively used in the study to make sure of the efficiency and reliability of the structure. The National Building Code of the Philippines was followed to ensure a liveable structure. For the structural design, the National Structural Code of the Philippines (NSCP 2010) and ASTM Steel Manual were used as the basis for the computation of the substructure and the superstructure components of the anchor that secure the piled container vans. It is complemented by the analysis made thru the STAAD structural software. Final design was drawn in AutoCAD and simulated with the use of Google Sketch-Up for a 3D visualization.

Computation of total factored loads was based on the prescribed formulas by the NSCP 2010. Structural design of the superstructure is analysed via STAAD structural software. Substructure was computed manually with input of soil properties based on Soil Investigation reports of nearby projects provided by the LGU.

3.3 Loads and Codes

As stated in the NSCP 2010, buildings, towers and other vertical structures and all portions thereof shall be designed to resist the load combinations specified in it and the special seismic load combination. The most critical effect can occur when one or more of the contributing loads are not acting. All applicable loads shall be considered, including both earthquake and wind, in accordance with the specified load combinations considering dead load, earthquake load , estimated maximum earthquake force that can be developed in the structure, load due to fluids with well-defined pressures and maximum heights, load due to lateral pressure of soil and water in soil, live load, except roof live load, including any permitted live load reduction, roof live load, including any permitted live load reduction, ponding load, rain load on the undeflected roof, self-straining force and effects arising from contraction or expansion resulting from temperature change, shrinkage, moisture change, creep in component materials, movement due to differential settlernent, or combinations thereof, and load due to wind pressure.

Where load and resistance factor design is used, structures and all portions thereof shall resist the most critical effects from the following combinations of factored loads prescribed in the code.

Dead loads consist of the weight of all materials of construction incorporated into the building or other structure, including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and fixed service equipment, including the weight of cranes.

The actual weights of materials and constructions shall be used in determining dead loads for purposes of design. In the absence of definite information, it shall be permitted to use the minimum values given in the code.

The tare weight of 40-footer container van is 3680 kg with dimensions are L = 40 ft, W = 8 ft, H = 8.5 ft. For the two-storey structure, 4 container vans were used and for the three-storey, 6 container vans with total weight of 144.40kN and 216.60kN, respectively.

Live loads shall be the maximum loads expected by the intended use or occupancy but in no case shall be less than the loads required.

As stated in the code, floors shall be designed for the unit live loads as set forth in the code. These loads shall be taken as the minimum live loads of horizontal projection to be used in the design of buildings for the occupancies listed, and loads at least equal shall be assumed for uses not listed in this section but that creates or accommodates similar loadings. Where it can be determined in designing floors that the actual live load will be greater than the value set by the code, the actual live load shall be used in the design of such buildings or portions thereof. Special provisions shall be made for machine and apparatus loads.

Where uniform loads are involved, consideration may be limited to full dead load on all spans in combination with full live load on adjacent spans and alternate spans.

Floors shall be designed to support safely the uniformly distributed live loads prescribed in the code. For the condition of concentrated or uniform live load, loads are combined in accordance with the provisions in the code as appropriate. The combination producing the greatest stresses shall govern.

The uniform live load used for the container van structure is based on the prescribed minimum in the NSCP for wards and rooms which is 1.9kPa. Average floor area was assumed equal to the floor area of the container van which is 12.2m x 2.44m. This translates to 226.15kN and 339.22kN of weight to the two-storey and three-storey structures, respectively.

3.4 Wind Loads

Buildings, towers and other vertical structures, including the Main Wind-Force Resisting System (MWFRS) and all components and cladding thereof, shall be designed and constructed to resist wind loads as specified in the code. There are three methods prescribed: Method 1 – Simplified Procedure; Method 2: Analytical Procedure; and Method 3 – Wind Tunnel Procedure.

The method used in the study is Method 2 – Analytical Procedure. The design wind force for solid freestanding walls is determined by Eq. (1). The equation is dependent on the wind pressure which is dependent on the wind velocity. Table 1 shows the prescribed wind velocity for provinces of different zone classifications. Fig. 4 shows the demarcation of the different zone classifications.

Table 1 Wind Zone for the Different Provinces of the Philippines

Zone Classification (Basic Wind Speed)	**Provinces**
Zone 1 (V = 250 kph)	Albay, Aurora, Batanes, Cagayan, Camarines Norte, Carnarines Sur, Catanduanes, Eastern Samar, Isabela, Northern Samar, Quezon, Quirino, Samar, Sorsogon
Zone 2 (V = 200 kph)	Abra, Agusan del Norte, Agusan del Sur, Aklan, Antique, Apayao, Bataan, Batangas, Benguct, Biliran, Bohol, Bulacan, Carniguin, Capiz, Cavite, Cebu, Compostela Valley, Davao Oriental, Guimaras, Ifugao, Ilocos Norte, Ilocos Sur, Iloilo, Kalinga, La Union, Laguna, Leyte, Marinduque, Masbate, Misamis Oriental, Mountain Province, National Capital Region, Negros Occidental, Negros Oriental, Nueva Ecija, Nueva Vizcaya, Occidental Mindoro, Orient l Mindoro, Pampanga, Pangasinan, Rizal, Romblon, Siquijor, Southern Leyte, Surigao del Norte, Surigao del Sur, Tarlac, Zambales
Zone 3 (V = 150 kph)	Basilan, Bukidnon, Davao del Norte, Davao del Sur, Lanao del Norte, Lanao del Sur, Maguindanao, Misamis Occidental, North Cotabato, Palawan, Sarangani, South Cotabato, Sultan Kudarat, Sulu, Tawi-rawi, Zamboanga del Norte, Zarnboanga del Sur, Zamboanga Sibugay ....

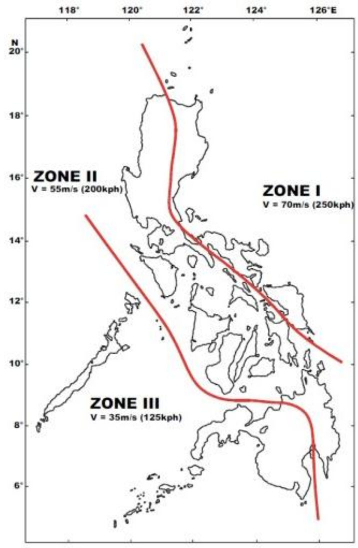

Figure 4 Philippine Wind Velocity Map

$$Force = A \times P \times C_d \times K_z \times G_h \quad (1)$$

Where
A, projected area
P, wind pressure which is a function of wind velocity
C_d, drag coefficient
K_z, exposure coefficient
G_h, Gust response factor

Wind speed used for both project is 200kph. Gust response factor used is 1.25, coefficient of drag is 2.0 while exposure coefficient is 1.0. For the three-storey structure, this results to a total force of 449.03kN.

3.5 Earthquake Loads

Average gross weight of the 40-foot container van is 30, 480 kg. The project site in Marikina City and Cagayan de Oro City can be found in the Zone 4 classification of the seismic zone map of the Philippines shown in Fig. 5. Seismic importance factor, I is set to 1.0 i.e. for standard occupancy structures. Soil Type is soft soil.

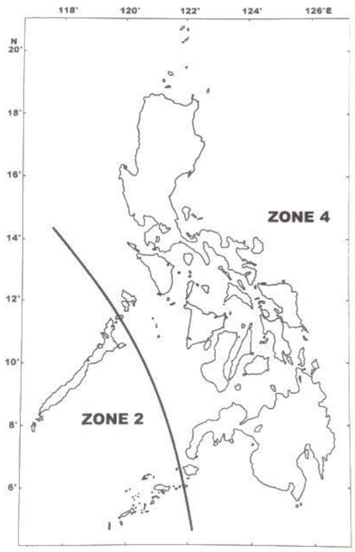

Figure 5 Seismic zone map of the Philippines

Total weight of the structure was computed together with the fundamental period, T. Factors were based on the prescribed in the code to compute the base shear. For the three-storey container van structure at Zone 4, a total base shear is computed at 331.54kN and distributed throughout the floors of the building.

The design base shear in a given direction is determined from Eq (2) provided in the code.

$$V = \frac{C_v I}{RT} W \tag{2}$$

Where

V, design base shear at a given direction

C_v, seismic coefficient

I, importance factor

W, total seismic load

R, numerical constant representative of the inherent over strength and global ductility capacity of lateral-force-resisting systems

T, elastic fundamental period of vibration

The design parameters determined from investigation reports, from the code, and from the computations were used in designing the superstructure that holds the container vans intact. These are used as input to the STAAD software to analyse the superstructure. A screen shot of the graphical user interface (GUI) is shown in Fig.6. The steel section used for the two-storey is W14x48 while for the three-storey W14x61 (Top) W18x97 (Sides).

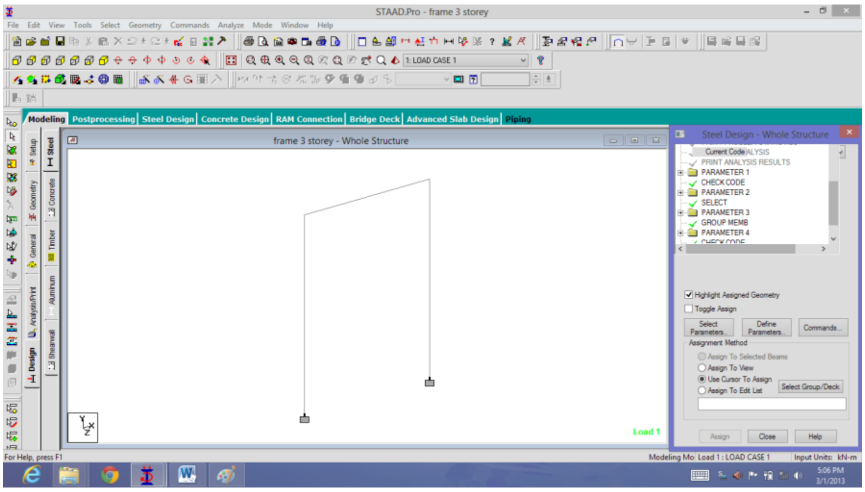

Figure 6 STAAD framing for the three-storey superstructure.

3.6 Foundation Design

Foe the design of the footing, the Allowable Stress Design is used with factored loads prescribed in the NSCP to the determine the service load. Sizing of the footing is dependent on the effective soil pressure. Parameters used for the design of the footing were based on the soil investigation report of a nearby project which is obtained from the city hall's building official. The typical size of footing calculated for the three-storey structure located in Marikina City is 1.6m x 1.6m.

3.7 Other Components of the System

Water supply and wastewater plan were provided in the study. Nevertheless, the details were not shown in this paper for brevity. Solar panels were installed at the roof of the structures to capture the sun's energy for lighting of the evacuation center. Oftentimes, the grid is shutdown during calamities such as typhoon and earthquakes. The details of the electrical supply that incorporates solar electricity is not shown in this paper to shorten it. Images of the system is shown in Fig. 7.

Costing of the project is summarized in Tables 2, 3, and 4.

Table 2 Summary of cost estimation for the two-storey layout plan.

	TWO STOREY LAYOUT PLAN					TOTAL
	SITE WORKS & PRELIMINARIES	ARCHITECTURAL	PLUMBING	STRUCTURAL	ELECTRICAL	
MARIKINA CITY	590,000.00	15,011,138.84	178,669.96	1,243,458.19	2,599,312.40	*19,622,579.39*
CAGAYAN DE ORO CITY	590,000.00	15,011,138.84	178,669.96	1,162,282.86	2,599,312.40	*19,541,404.06*

The two-storey layout plan was designed to accommodate 512 adult evacuees. The cost per head is approximately PhP38,000.00.

Table 3 Summary of cost estimation for the three-storey layout plan.

	THREE STOREY LAYOUT PLAN					TOTAL
	SITE WORKS & PRELIMINARIES	ARCHITECTURAL	PLUMBING	STRUCTURAL	ELECTRICAL	
MARIKINA CITY	510,000.00	11,680,769.24	178,669.96	588,880.30	2,576,289.40	*15,534,608.90*
CAGAYAN DE ORO CITY	510,000.00	11,680,769.24	178,669.96	578,115.71	2,576,289.40	*15,523,844.31*

The three-storey layout plan was designed to accommodate 368 adult evacuees. The cost per head is approximately PhP42,000.00.

Table 4 Cost comparison of using used container vans versus conventional reinforced concrete.

COST DIFFERENCES IN CONVENTIONAL STRUCTURE

Two-storey	Savings per sqm	Overall Savings
Marikina City	Php 6, 949.07	Php 7, 550, 377.69
Cagayan De Oro City	Php 7, 023.78	Php 7, 631, 553.02

Three-storey	Savings per sqm	Overall Savings
Marikina City	Php 7, 198.20	Php 6, 106, 836.82
Cagayan De Oro City	Php 7, 210.89	Php 6, 117, 601.41

A comparison with a typical reinforced concrete structure of the same requirements was compared with the case study. It gave a considerable amount of savings that made the proposed project feasible.

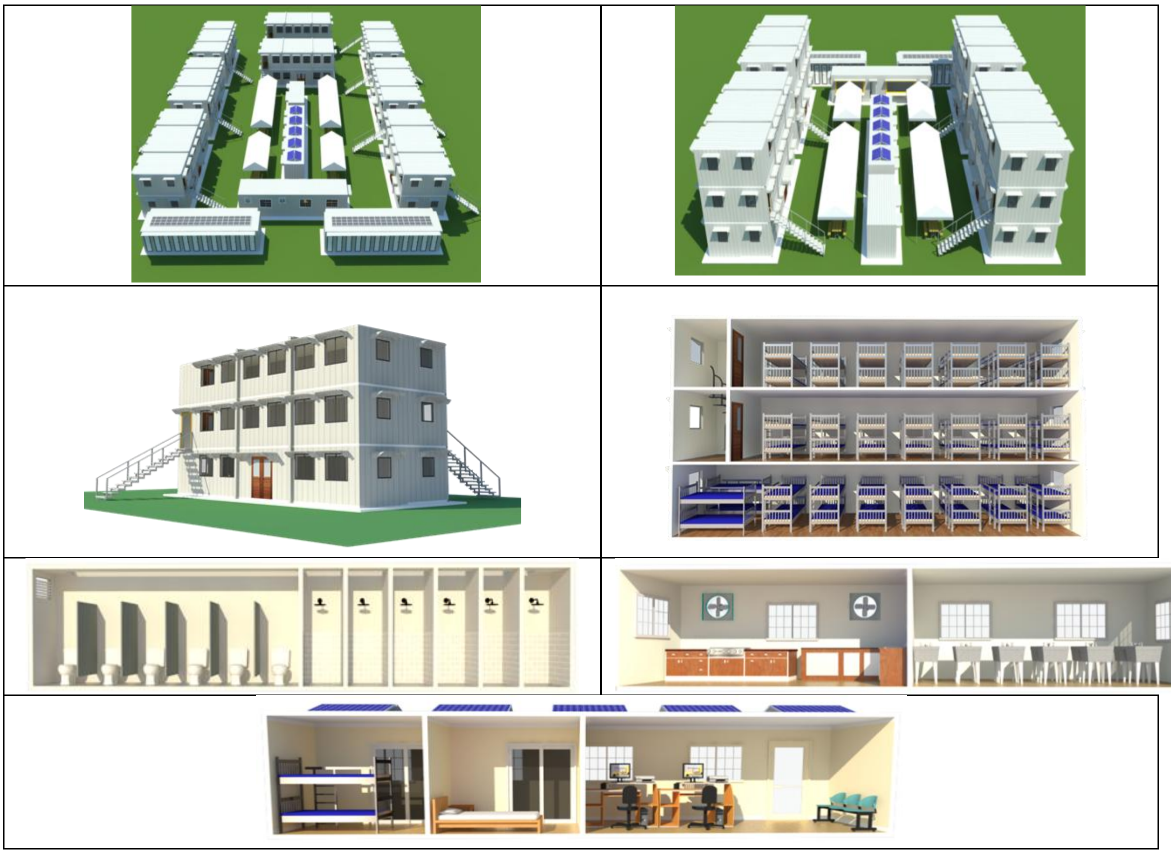

Figure 7 Clockwise from top left: Proposed 2-storey layout; Proposed 3-storey layout; Interior of the 3-storey abode; Common kitchen; admin office; Common toilet and bath area; Exterior of the 3-storey abode.

4 CONCLUSIONS

This study demonstrated a fast, sturdy, and even mobile design of a green emergency housing system for calamity-prone communities using used container vans as evacuation shelter with case studies particular to Marikina and Cagayan de Oro cities. Different layouts were presented and were shown as less expensive than conventional structures. Structural framing that holds the container vans intact was designed using building and structural design codes of the Philippines. It was demonstrated here that advancement in computer technology could aid in the efficient design and production of construction drawings of structures. The study was completed with electrical and water supply and wastewater plans; other pertinent structures such as kitchen, toilet and bathroom, admin office were also included in the plan of the system. There was also an attempt to use alternative source of energy, in this case solar energy which is very important for calamity-stricken communities were the electricity grid is usually shutdown.

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DEVELOPMENT OF A RAPID CONDITION ASSESSMENT TOOL FOR REINFORCED CONCRETE MOMENT-RESISTING FRAME BUILDINGS IN THE PHILIPPINES: STRUCTURAL COMPONENT

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Abstract: This paper describes the development of a pre-earthquake assessment tool that is rapid, visual, and is based on the structural condition of reinforced concrete moment-resisting frame buildings in Metro Manila, Philippines. The Rapid Condition Assessment Tool (RCAsT) uses a basic structural score that is modified based on differences in attributes of the existing building and the base structure. These scores were derived using fragility curves for locally built structures. A near-source score modifier is also incorporated to account for the larger earthquake motion experienced when a building is near a fault line. Moreover, damage modification factors that quantify residual seismic capacity considering the damages observed in columns and beams were established. The tool was used to evaluate several buildings and the results were compared with assessments using the FEMA-154 tool.

Key words: Building assessment, Earthquake, Visual Screening, Fragility, Probability.

1 INTRODUCTION

The 7.2 magnitude earthquake that struck Central Visayas last October 15, 2013 caused extensive damage to existing infrastructures and loss of lives. The types of structures that were damaged and the severity of the damage inflicted make us pause and ask whether similar structures in Metro Manila can survive a similar large magnitude earthquake. PHIVOLCS has been warning Metro Manila of an imminent earthquake that will originate from the West Valley Fault, of equal magnitude with the earthquake in Bohol. An earthquake of the same magnitude caused by the West Valley fault will definitely damage building structures in Metro Manila. It is therefore necessary that existing buildings be assessed for structural integrity and if found lacking be recommended for repair, rehabilitation and/or retrofit in preparation for the large magnitude seismic forces that may be generated by the existing fault.

Past efforts in assessing the vulnerability of structures against earthquakes were conducted in the country. In 2004, a joint collaboration of Japanese researchers from JICA and scientists from PHIVOLCS conducted the Metro Manila Earthquake Impact Reduction Study (MMEIRS). Their work included risk assessment due to scenario earthquakes caused by movement from different active faults in the country. Their results indicate 40% of residential buildings will be damaged in the event of a magnitude 7.2 earthquake occurring in the West Valley Fault, resulting in 34,000 deaths and 110,000 injured (Solidum et al. 2004).

At present, continuous studies on disaster risk mitigation are conducted through programs and projects administered by local agencies. In particular, PHIVOLCS in collaboration with the University of the Philippines Diliman - Institute of Civil Engineering (UPD-ICE) and Geoscience Australia (GA), conducted a project that aims to develop vulnerability curves of key building types in the Greater Metro Manila Area considering earthquake hazard. These vulnerability curves are needed to enhance the risk assessment capability of the Rapid Earthquake Damage Assessment System (REDAS) software, allowing users to estimate the potential level of damage a building will incur for a given ground motion intensity.

The seismic performance of a building is described using fragility and vulnerability curves. Vulnerability curves are functions of the damage ratio and the ground motion intensity, whereas the fragility curves provide the probability of exceedance of a particular damage state (slight, moderate, extensive and complete damage states) due to ground motion intensity. The two curves are interrelated, with the vulnerability curve derived from the fragility curves. Currently, the UPD-ICE is continuously developing and improving these curves for key building types in Metro Manila.

There is a program that is geared towards response to reduce the damage caused by quick-onset events like earthquakes, known as the Earthquake Quick Response Program (EQRP formerly known as DQRP-Disaster Quick Response Program) that utilizes inspection surveys of structures before and after an earthquake. The pre-earthquake inspection survey tool uses the FEMA-154 Rapid Visual Screening of Structures for Potential Seismic Hazards while the post-earthquake inspection survey is based on ATC-20 Post Earthquake Safety Evaluation of Buildings. These instruments were developed in the United States and the conditions of structures considered were not locally based and hence exhibit different seismic capacity compared to the buildings in the Philippines. This was observed when a school building was judged safe using FEMA-154 but was judged otherwise by the local engineers after entering the building based on excessive deflection seen on the beams and large cracks on the interior walls due to settlement.

Therefore, a tool that can be used for rapid condition assessment, applicable to buildings locally constructed and capable of identifying which buildings should be prioritized for detailed investigation should be developed. The Rapid Condition Assessment Tool (RCAsT) Structural Component has two major parts that are used to assess the structural condition of the building. The first part uses basic structural hazard score and score modifiers that were derived using fragility curves for low- and mid-rise reinforced concrete frame buildings in the Philippines. Included in this part is a score modifier for near-source earthquakes which is not used in FEMA-154 but included in the provisions of the NSCP 2010. Thus, this part reflects the initial seismic capacity of the building in its undamaged state. The second part uses a damage modification factor that is based on the quantified residual seismic capacity of the building. The residual seismic capacity is quantified by considering the effect of existing damage observed in the columns and beams of the building. The product of these two parts gives the final structural hazard score. Therefore, the final score is indicative of the true condition of the building before an earthquake.

2 DATA COLLECTION FORM

The data collection form for structural component has two major parts. The first being a quantification of the performance of a building based on the structural configuration, soil condition and other building attributes that might affect its structural integrity through computation of the structural rapid visual screening score. The procedure described in FEMA 155 was used to derive basic structural hazard scores and score modifiers using locally developed fragility curves for buildings found in the Philippines.

The second part, on the other hand, takes into account the damages incurred in the building components through damage modification factors. This portion was patterned after the quantification of post-earthquake damages in RC buildings in Japan using residual seismic capacity. In the paper of Maeda et al. (2004), the ratio of the residual seismic capacity to the initial seismic capacity can be estimated by visually classifying and accounting the damages in columns and walls. This ratio became the basis for the formulation of the procedure in quantifying the damage modification factor (DMF) in this tool. The DMF represents the percentage of the remaining seismic capacity of the building.

Additional information on the structural integrity of the building can be reflected through sketches, photos and commentary boxes that are also provided in the form.

In the succeeding sections, the derivation of the basic structural scores and score modifiers will be explained in detail. Moreover the process by which the quantification of the damage modification factor will also be explained.

2.1 Structural Score

In quantifying the structural score, one needs the basic score, which is generic for one building type, and the score modifiers. Since in this project, the focus is on reinforced concrete moment frames (C1), only one basic score can be seen in the tool. The basic score corresponds to the structural hazard score computed for a base structure. In this study, the base structure used is a regular low-rise building on soil type D designed using post-1992 code and is situated far-field of a fault line. So if the structure is a base structure, the basic score becomes the structural score and no score modifiers are added. On the other hand, if the structure has different attributes or configuration from the base structure, score modifiers corresponding to the varying attributes are added algebraically to the basic score to account for the deviation.

There is a formula being followed in determining the structural hazard score for a given structure. The basic score is just the structural hazard score of a base structure, whereas the score modifier for each variation is the difference between the structural hazard score of a building with that variation and the basic structural hazard score.

In the following sub-sections, detailed discussion on the derivation of these scores will be presented.

2.1.1 Basic Structural Hazard Scores

In the second edition of the FEMA 154 *Handbook,* the Basic Structural Hazard Score is defined, for a particular type or class of building, as the negative of the logarithm (base 10) of the probability of collapse of the building, given the ground motion corresponding to the maximum considered earthquake (MCE). This can be written as follows,

$$BSHScore = -\log_{10}[(P|Collapse\ given\ MCE)] \tag{1}$$

The probability of collapse of a building is the product of the probability of being in the complete damage state (DS), multiplied by the fraction of buildings in the complete damage state that collapsed, written as follows, (FEMA 155)

$$BSHScore = -\log_{10}[P(Collapse|Complete\ DS\ given\ MCE) \times P(Complete\ DS)] \tag{2}$$

Initial Basic Scores were derived using this definition together with the fragility curves developed by the UPD-ICE. However since the fragility curves used in the derivation were different from the ones used in HAZUS, the resulting scores were too small and the score modifiers were not meaningful. This observation caused the group to reexamine the equation.

From the equation, the probability of collapse is calculated by multiplying the probability of complete damage state exceedance and the probability of collapse given complete damage state. Since the product of two small numbers is an even smaller number, the additional step of getting the negative of the logarithm of base 10 of the product of probabilities, is seen as a way to make use of the probability as a convenient measure of the building performance. Hence the group decided to redefine the BSH Score.

The computation of the probability of collapse at the complete damage state was derived from the fragility curves by UPD-ICE. These fragility curves were defined by lognormal cumulative distribution curves. Hence the group decided to rescale the score using the same probability, by using the natural logarithm instead of the $\log_{10}$. In equation form,

$$BSHScore = -\ln[P(Collapse|Complete\ DS\ given\ MCE) \times P(Complete\ DS)] \tag{3}$$

2.1.1.1 Procedure for developing Basic Structural Hazard Scores

To compute for the basic structural hazard score for C1, fragility curve for C1L on soil type D is needed as shown in Figure 1. Before determining the probability of exceeding complete damage state at the given MCE, the peak ground acceleration of the maximum considered earthquake must be calculated first.

The maximum considered earthquake is the largest earthquake event applied in building code design. According to the collective opinion of the Seismic Design Procedure Group (SDPG), the minimum seismic margin contained in the 1997 NEHRP Provisions is about 1.5 times the design earthquake ground motions. (BSSC 1998, Appendix A, Commentary)

Since in the development of the fragility curves utilized in determining scores, the demand spectrum comes from the design response spectra, the maximum considered earthquake will be computed from the same, wherein the seismic coefficient Ca represents the peak ground acceleration in g. Hence to determine the MCE, the design earthquake in terms of the seismic coefficient will be multiplied by 1.5.

In determining the seismic source type it is necessary to determine the maximum moment magnitude for a given site which can be estimated from the nearest fault or seismic source. There are two active valley fault systems dividing Metro Manila namely, the West Valley Fault System and the East Valley Fault System shown in Figure 2. The West Valley Fault is the nearest seismic source capable of producing a maximum credible earthquake of 7 (Nelson et.al. 2000), wherein the seismic source type can be classified as A. Assuming a far-field seismic source type, the near source factor Na, is determined to be equal to 1.0 from Table 208-4 of the NSCP 2010 and consecutively the seismic coefficient Ca for soil type D under seismic zone 4 is computed as 0.44Na as provided in Table 208-7 of the NSCP 2010. MCE of 0.66 g is computed.

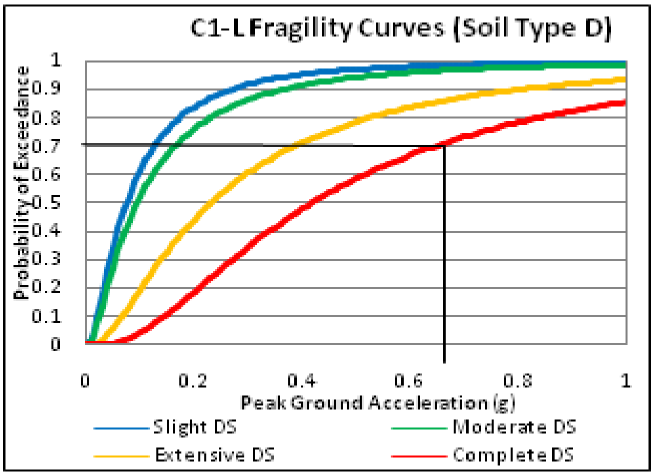


Figure 1 Fragility curves for reinforced concrete moment frame low-rise on soil type D. (SOURCE: UPD-ICE, Development of Vulnerability Curves of Key Building Types in Greater Metro Manila Area, [October, 2013]).

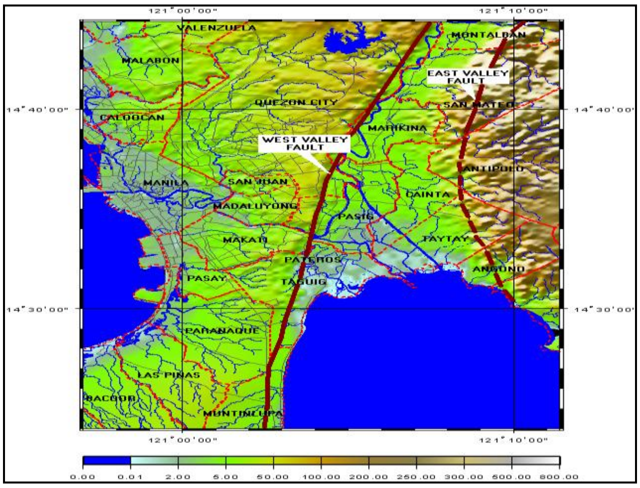


Figure 2 Topographic and Political Boundary Map of Metro Manila showing the existing active fault systems (Bautista, 2001).

The probability of collapse or collapse rates for different structure types may be found in HAZUS-MR4 Table 13.8. The collapse rate for C1-L is equal to 13%.

2.1.1.2 Sample Calculation of a Basic Structural Hazard Score

To determine the probability of exceeding the complete damage state, the MCE is projected to the fragility curve for complete damage state and the corresponding probability is determined. From Figure 1, the corresponding probability, $P|Complete\ DS\ given\ MCE$ is equal to 71% for an MCE of 0.66 g. The collapse rate is determined to be equal to 13%. Therefore, using equation (3), BSH for C1-L is computed as follows,

$$Basic\ Score = -\ln\left[(0.71 * 0.130\right] = 2.40$$

2.1.2 Basic Structural Hazard Score Modifiers

The base structure used is a regular low-rise building on soil type D designed using post-1992 code and is situated far-field from existing faults. If the building differs from the base structure, score modifiers are used to take these variations into account. The parameters that can vary include the following: elevation of the structure that can either be low-rise (1-2 stories) or mid-rise (3-7 stories); the irregularities present in the structural configuration (plan and vertical irregularities); the code used in the design of the structure which can be identified with the vintage of the structure namely pre-code (buildings designed before 1972) , low-code (buildings designed between 1972-1992) or high-code(post-1992 buildings); the soil profile type where the structure is constructed (in Metro Manila only three soil types exist: soil type C, soil type D, and soil type F); and the nearness to a fault line. The score modifiers for each variation are quantified by taking the difference between the structural score for each variation with the basic structural score of the base structure. Summarized in Table 1 are the structural scores computed for each structure with varying attributes.

2.1.2.1 Score Modifier for Mid-rise Buildings

The score modifier for mid-rise buildings was calculated using two sets of structural scores. One for low-rise reinforced concrete buildings and the other is for mid-rise reinforced concrete buildings, both having the same soil type. From Table 1, the basic structural hazard score is 2.4 which was based from low-rise and designed under high code, and the structural score for C1M designed under high code for the same soil type is 3.00. Hence the score modifier is +0.60.

2.1.2.2 Score Modifier for Plan Irregularity

According to FEMA-155, there was no Score Modifier for plan irregularity that is straightforward to calculate, principally because eccentricity is specific to each building. Hence, to approximate the effect of plan irregularity the spectral response values were increased by 50% where the fragility curve will be based and correspondingly the structural score. Employing such increase will yield a structural score of 2.22. Hence the Score Modifier for Plan Irregularities is -0.18. A value of -0.20 was used in the tool as the final score modifier.

Table 1 Summary of Structural Scores.

	MEDIAN	BETA	Ca	Design Earthquake	MCE	Pcomplete	Collapse Rate	BHS
C1-L (D)	0.42	0.82	0.44	0.44	0.66	0.71	0.13	**2.40**
C1-L (C)	0.43	0.82	0.4	0.4	0.6	0.66	0.13	**2.46**
C1-L(E)	0.39	0.89	0.44	0.44	0.66	0.72	0.13	**2.36**
C1-M(PRE)	0.54	0.74	0.44	0.44	0.66	0.61	0.1	**2.80**
C1-M(LOW)	0.54	0.74	0.44	0.44	0.66	0.61	0.1	**2.80**
C1-M(HI)	0.66	0.73	0.44	0.44	0.66	0.50	0.1	**3.00**
Near Source (C)	0.36	0.78	0.4	0.48	0.72	0.81	0.13	**2.25**
Near Source (D)	0.38	0.78	0.44	0.528	0.792	0.83	0.13	**2.23**
Near Source (E)	0.33	0.9	0.44	0.528	0.792	0.83	0.13	**2.22**
Plan	0.3	0.82	0.44	0.44	0.66	0.83	0.13	**2.22**

2.1.2.3 Score Modifier for Vertical Irregularity

The score modifier for vertical irregularity cannot be quantified due to large variation in the configurations and conditions. Hence the value is approximated using engineering judgment. But since this study derived scores applicable to existing moment-frame buildings in Metro Manila, score modifier for vertical irregularity presented in FEMA-154 cannot be utilized directly. To be consistent with that of FEMA 154, an initial value of -1.00 was selected.

2.1.2.4 Score Modifier for Pre-code and Low-code Construction

Design codes are frequently updated and improved over time. Three important vintages were identified based on how drastic a change was made in terms of seismic design philosophy. The years 1972 and 1992 are based on the year of publications of the different editions of the National Structural Code of the Philippines where a paradigm shift in design philosophy occurred. Buildings that were built before 1972 were designated to be under ***Pre Code***, whereas those that were built between 1972 and 1992 were designated to be under ***Low Code*** and Post 1992 were designated under ***High Code***.

The same procedure on how the score modifier for mid-rise was calculated is employed here. However since there is only one vintage used in the development of the fragility curve for C1L, score modifiers for vintages will be based on C1M. Hence three sets of structural scores will be determined with the one in high code as the default score. Again as summarized in Table 1, structural scores for pre and low code is 2.80 while for high code is 3.00. Hence the score modifier for both pre and low code is -0.20.

2.1.2.5 Score Modifier for Soil Type C, D, and F.

Employing the same procedure, structural scores for C1L on soil types, D, C, and E were computed as 2.40, 2.46, and 2.36 respectively. Hence the score modifiers for soil type C and E are +0.06 and -0.04 respectively. Values of +0.10 and -0.10 were adopted in the tool, respectively.

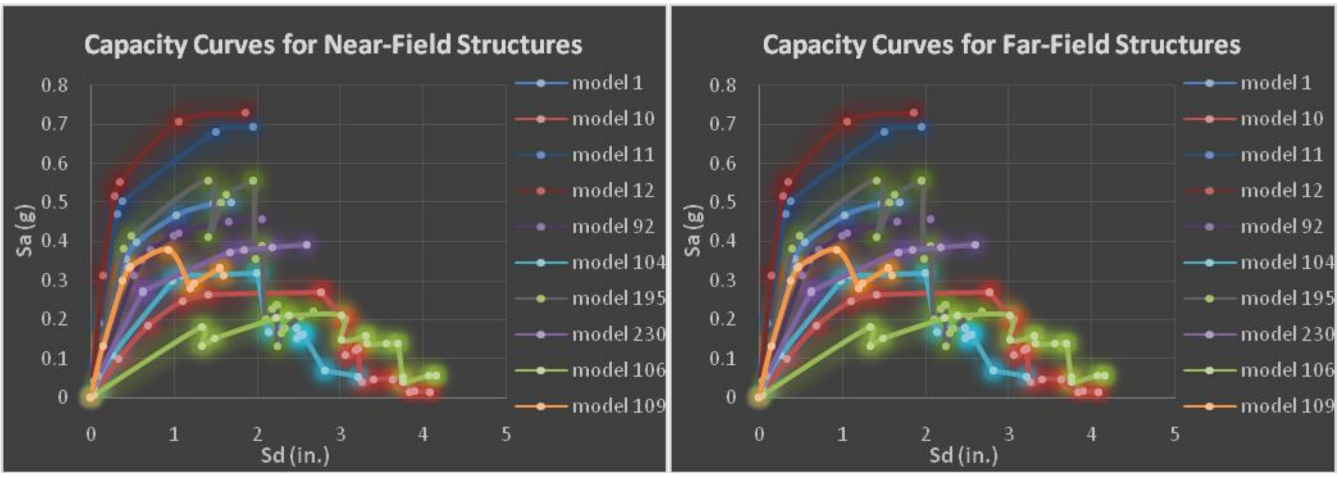
In NSCP 2010, no seismic coefficients were provided for buildings built on soil type F, because a site-specific geotechnical investigation and dynamic site response analysis is suggested to be performed to determine seismic coefficients that are necessary for modeling and developing the fragility curve. Hence buildings built on soil type F would automatically warrant a detailed evaluation.

2.1.2.6 Score Modifier for Nearness to Fault

UPD-ICE is currently improving the fragility curves being developed by incorporating the nearness to fault effect. These are taken into account in the seismic coefficients used as an input in the design of the model structures. The seismic coefficients for the soil types present in Metro Manila are provided in Table 208-7 and 208-8 of the NSCP 2010.

Na and Nv are the near source factors that account for the proximity to the nearest active fault. The values of Na and Nv ranges from 1.6 to 1 and are linearly interpolated depending on the location of the structure under consideration. For simplicity, the location of the structures were lumped as to whether it is located in a near field or far field. Instead of interpolating for every value of the near source factor the group decided to use the upper and the lower limit to represent the two fields. Hence for seismic source type A, the Na and Nv used for structures located less than or equal to 5 km to the nearest fault line are 1.2 and 1.6 respectively, and 1.0 for both Na and Nv for structures located more than 5 km to the nearest fault line. For seismic source type C on the other hand, according to the NSCP the near source factors Na and Nv are both equivalent to 1.0 regardless of the location of the structure relative to an active fault.

The same building databases were used for the model structures in the far field and near-source. Both sets of models were analyzed and its members were designed by software capable of performing a pushover analysis such as ETABS. From the pushover analysis, the capacity curves for both sets of models can be obtained. It was observed that the same capacity curves are obtained for structures in far field and near-source. Figure 3 shows a selection of corresponding models in far field and near-source exhibiting similar capacity curves.



(a) (b)

Figure 3 Capacity Curves for (a) Near-Source Structures and (b) Far-Field Structures.

This suggests that based on the building configurations used there is no significant change in the design of structures in far field and near-source for a low-rise reinforced concrete building. However, the earthquake shaking is considerably higher near a fault than far field. Hence it follows, that the fragility curve developed for near-field structures would appear more vulnerable than far-field structures as illustrated in Figure 4, due to the increase in demand without increase in the capacity of the structure.

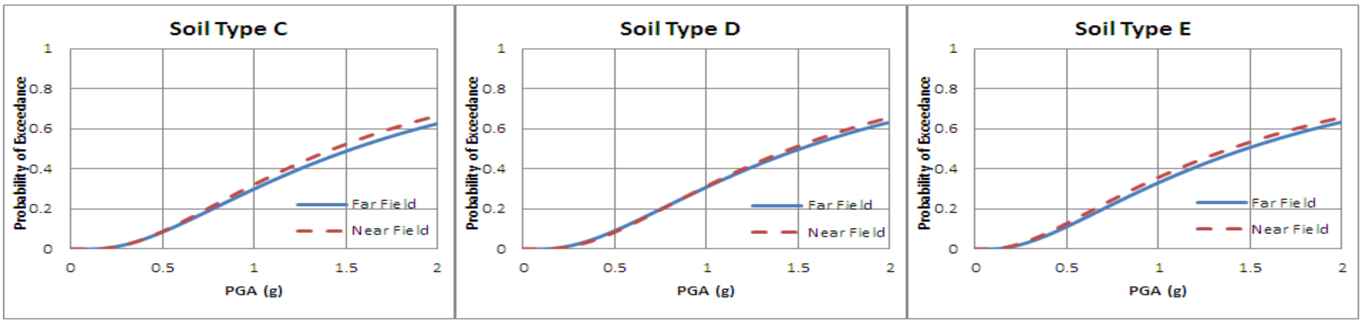


Figure 4 Fragility Curves at the Complete Damage State for Soil Types C, D and E in Far Field and Near-Source.

Since in this study, only the probability of being in or exceeding the complete damage state is used in computing the structural hazard score, comparison is shown in Figure 4for far-field and near-source structures in soil types C, D and E.

As summarized in Table 1, the Basic Hazard Scores (BHS) for structures built on near fault regions of soil types C, D and E are 2.25, 2.22 and 2.22 respectively. It also follows that the score modifiers taken as the difference from the BHS of a regular structure are -0.15, -0.17 and -0.18 respectively. It has been decided to report only one score modifier to represent the nearness to source effect by adopting the value of -0.2.

The score modifiers derived above are summarized in Table 2.

Table 2 Score Modifiers

MID RISE	VERT. IRREG.	PLAN IRREG.	PRE CODE	LOW CODE	SOIL TYPE C	SOIL TYPE E	SOIL TYPE F	NEAR SOURCE
0.6	-1.0	-0.2	-0.2	-0.2	0.1	-0.1	**	-0.2

2.1.3 Damage Modification Factor

Part of the limitations observed in using FEMA-154 as an assessment tool is it evaluates buildings based on exterior observations only. The final score acquired by the building after being assessed using this tool represents the initial seismic capacity of the buildings before earthquake. However it lacks interior damage ratings should they exist.

In the paper entitled, Guideline for Post-Earthquake Damage Evaluation and Rehabilitation of RC Buildings in Japan, the damage rating procedure was based on the residual seismic capacity ratio index ***R***. Utilizing a similar concept, by quantifying the residual seismic capacity and determining its ratio from the initial seismic capacity, the factor can be used to represent a modification factor for the structural scores to account for the damage incurred by the building approximated from visual assessment of interior components such as columns and beams.

With the use of a normalized strength index for each typical member section which often appears in existing RC buildings in Japan considering ultimate shear stress and effective sectional area of each section type, an alternative simplified procedure of calculating the R-index is proposed in the same paper. By classifying and accounting the type of columns and walls with its corresponding damage classification, the R-index can be approximated. (Maeda et al., 2004)

Since this study is focused on low-rise reinforced concrete moment resisting frames, the procedure presented in the paper can be further simplified by considering both columns and beams – since these comprise the major structural components for a moment-resisting frame system – in the evaluation. As an approximation, ductile columns are associated with long columns defined as columns with clear span to smallest depth ratio greater than or equal to 6 and short columns otherwise. Moreover, the beams are classified as long, intermediate and short depending on the length of the clear span (L) as having greater than or equal to 6 m, between 2 m and 6 m, and less than or equal to 2 m, respectively.

Once every structural element is categorized, the state of damage of each structural member is then classified. In the paper by Maeda et al. (2004), where the quantification of the damage modification factor was based, there were originally five (5) damage classes – no damage, slight damage, light damage, heavy damage and collapse. For ease in classifying damages in a rapid visual inspection, this research employs three damage classifications – “no-slight damage”, “light-moderate damage”, and “heavy damage - collapse”. The same reduction factors for Damage Class 0, Damage Class III, and Damage Class V respectively will be adopted from Maeda’s paper.

To aid in accounting the structural element types and their corresponding damages, a table shown in Figure 5 was formulated.

Damages in columns have greater influence in the structural integrity compared to damages in beams. For this reason, damage modification factors for columns $(\boldsymbol{DMF_{col}})$ and beams $(\boldsymbol{DMF_{beam}})$ are computed separately. The equations below show how to compute for the damage modification factor for each structural element.

$$DMF_{col} = \frac{\Sigma\#\ of\ columns\ with\ reduced\ seismic\ capacity}{\Sigma\#\ of\ columns} \tag{4}$$

$$DMF_{beam} = \frac{\Sigma\#\ of\ beams\ with\ reduced\ seismic\ capacity}{\Sigma\#\ of\ beams} \tag{5}$$

The numerator represents the reduced strength and the denominator represents the original strength of the structural elements. To quantify the reduced strength, the number of a certain type of structural element having a certain state of damage is tallied correspondingly in the space provided in the form. The tallied numbers per element type and damage class are multiplied by the corresponding reduction factors before taking their weighted sum horizontally. The weighted sums are combined for all types of columns to obtain the reduced number of columns which corresponds to the numerator of $\boldsymbol{DMF_{col}}$. Similarly, for all types of beams, the numerator of $\boldsymbol{DMF_{beam}}$ is obtained using the same procedure.

The denominator is calculated by counting all the columns and beams inspected regardless of the type and damage class.

DAMAGE MODIFICATION FACTOR (DMF)

	TYPE	NO-SLIGHT DAMAGE	LIGHT- MODERATE DAMAGE	HEAVY DAMAGE - COLLAPSE	TOTAL*** FACTOR
COLUMNS	LONG: h/d>6	x 1	x 0.5	x 0	
	SHORT: h/d≤6	x 1	x 0.3	x 0	
	TOTAL # OF COLUMNS****				DMF_{Col}
BEAMS	LONG: L≥6m	x 1	x 0.7	x 0	
	INTERMEDIATE: 2m<L<6m	x 1	x 0.5	x 0	
	SHORT: L≤2m	x 1	x 0.3	x 0	
	TOTAL # OF BEAMS****				DMF_{Beams}

*** The **Total Factor** is equal to the sum of the products of the number of columns/beams and the corresponding reduction factor per damage state.
**** Total # of Columns/beams is the sum of the number of columns/beams counted on site regardless of damage observed (i.e. no factors incorporated).

DMF= $\frac{1.2\ DMF_{Col} + 1.1\ DMF_{Beams}}{2.3}$

Figure 5 Portion in the data collection form calculating the damage modification factor.

The damage modification factors for each structural type are further weighted by the contribution factors 1.2 and 1.1 for columns and beams respectively (Coronelli 2007). In this way, a damage modification factor for the entire structure can be computed given in the equation below:

$$DMF = \frac{1.2 \times DMF_{col} + 1.1 \times DMF_{beam}}{2.3} \tag{6}$$

2.1.4 Cut-off Score

According to the second edition of FEMA-155 which provides the technical manual for the FEMA-154, the selection of the cut-off score is a prerogative of the community utilizing the inspection tool. The cut-off score of about 2.0 was recommended after fifteen years of experience in the use of FEMA-154 that validated this decision. There are cases wherein users opted to use higher cut-off scores which imply a safer environment, at a correspondingly higher cost. (FEMA-155, 2nd edition).

In order to come up with a rational choice of the cut-off score in this case, DQRP case studies and reports were reviewed. One of the major observations from DQRP case studies and reports is that concrete hollow block (CHB)[1] and wood low-rise structures that were inspected received only either a yellow or a red tag. This implies that these structures may pose a greater threat to the safety of its occupants during and after an earthquake. Thus, it may be rational to say that these existing structures must be evaluated in detail for seismic considerations.

Fragility curves developed by UPD-ICE for CHB is based on a compilation of empirical observations of damage for corresponding ground motion intensities in terms of Modified Mercalli Intensity (MMI) from past earthquakes in the Philippines. Hence this data will be used in calculating the cut-off score. However, the resulting fragility curve is in terms of MMI and needs to be converted to PGA before utilizing it to compute for the probability of being in or exceeding the complete damage state given the MCE.

Using the mean and standard deviation of 7.4 and 0.14 respectively of the fragility curve under complete damage state for CHB as reported in the UPD-ICE report, the probability of exceedance is computed for an arbitrary set of ground motion intensities in MMI. The ground motion intensity in MMI is then converted to Peak Ground Acceleration in (g) using the Gutenberg-Richter MMI to PGA relationship defined in the following equation.

$$\log(a) = \frac{I}{3} - 0.5 \tag{7}$$

where a is acceleration in terms of gals (cm/s^2) and I is the ground motion intensity in terms of MMI.

The probability of exceeding complete damage state is plotted against the peak ground acceleration. These points will be regarded as the data points where a lognormal cumulative distribution curve will be fitted and the corresponding mean and standard deviation will then be used to compute for the probability of being in or exceeding the complete damage state at the given maximum considered earthquake. This is illustrated in Figure 6 wherein the corresponding mean and standard deviation is also presented.

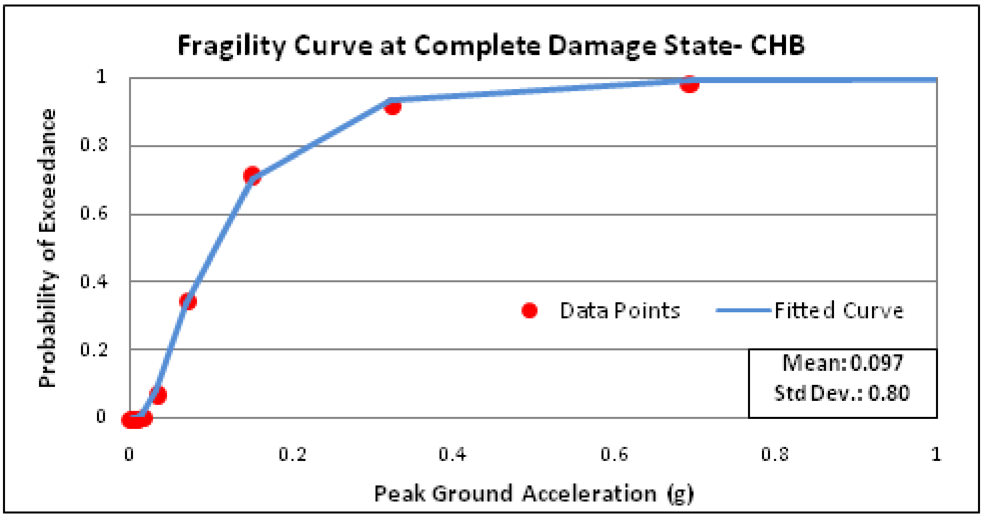


Figure 6. Fragility Curve at Complete Damage State for CHB.

Illustrated below is the computation of basic structural hazard score for CHB.

$$BSH = -\ln(0.99 \times 0.15) = 1.90$$

The probability of being in or exceeding complete damage state with the mean and standard deviation of 0.097 and 0.8, respectively, is 0.99. Since there are no CHB building type in HAZUS the collapse rate used was for Unreinforced Masonry equivalent to 15%. Hence the basic structural hazard score for CHB which will also be used as the cut-off score is 1.90.

[1] These are low-rise structures with walls made of concrete hollow blocks interlocked at the corners, and have no reinforced concrete frame. The floors consist of either plywood or board sheathing, supported by wood subframing. The roofs are corrugated galvanized iron sheets attached to wooden or light metal roof trusses.

3 SAMPLE APPLICATION

The proposed rapid condition assessment tool was applied to several buildings. Two of which were selected to be presented in this paper. These buildings were labeled as Building A and Building B.

3.1 BUILDING A

The structure is made of reinforced concrete and stands 4 storeys high; hence it is categorized as a mid-rise reinforced concrete building or C1-M. The structure has vertical irregularity, because of the presence of a basement at the South-West corner of the building. Building A was built in 1970, hence it was assumed that the design code used is pre code. The structure has an opening at the center, therefore there is plan irregularity. The soil was assumed to be Soil Type D which is stiff soil. The structural score evaluated by the team is 1.40. The damage modification factor (DMF) is equal to 1.0 because no damages were observed in the beams and columns of the building.

Since 1.40 is less than 1.90, a more detailed seismic evaluation is required. **Error! Reference source not found.** shows a filled out RCAsT Structural Form for Building A.

A comparison with FEMA 154 was performed. **Error! Reference source not found.** summarizes the score evaluation of the two rating systems.

The results show that FEMA 154 also suggests that a detailed seismic evaluation is recommended for Building A. The RCAsT Structural Score further reduces the building score due to the nearness to fault effect which is not considered in FEMA 154. Furthermore, the RCAsT structural score will always yield a positive value, whereas FEMA 154 scoring can result to a negative score. Though the score only indicates which building needs to be evaluated in detail, a negative structural score for a building may be understood as a very poor seismic performance in the event of an earthquake.

Table 3. Rating Systems between RCAsT and FEMA 154 for Buildings A and B.

	BUILDING A		BUILDING B	
Criteria	RCAsT	FEMA 154	RCAsT	FEMA 154
Basic Score	2.4	2.5	2.4	2.5
Mid rise	0.6	0.4	0	0
Vertical Irregularity	-1	-1.5	0	0
Plan Irregularity	-0.2	-0.5	-0.2	-0.5
Pre Code	0	0	-0.2	-1.2
Low Code	-0.2	0	0	0
High Code	0	0	0	0
Soil Type C	0	0	0.07	-0.4
Soil Type D	0	-0.6	0	0
Soil Type E	0	0	0	0
Soil Type F	0	0	0	0
Near Source	-0.2	N.A.	-0.2	N.A.
Structural Score	**1.40**	**0.30**	**1.90**	**0.4**
DMF	**1.0**	**N.A.**	**0.98**	**N.A.**
Final Score	**1.40**	**0.30**	**1.87**	**0.4**
Cut off Score	1.90	2.00	1.90	2.00
Detailed Evaluation	YES	YES	YES	YES

3.2 BUILDING B

Building B is a low-rise (2 stories) reinforced concrete moment-resisting-type structure. The plan configuration of the building shows that it has a plan irregularity. It was built on a Type C soil before the 1972 Building Code was enacted. The Structural Score of the building is 1.90.

The total number of columns inspected is 141. Three of these columns have moderate damage – two of which are long columns. Six intermediately long beams of the 141 inspected beams were found to have moderate damage. The total Damage Modification Factor for the Structural Score is 0.98.

The Final Score for the building with DMF considered is 1.87 which is below the cutoff score of 1.9. Therefore Building B is recommended for detailed evaluation. **Error! Reference source not found.** shows a filled out RCAsT Structural Form for Building B.

A comparison with FEMA 154 was performed. Table 3 summarizes the score evaluation of the two rating systems. Similar to Building A, both tools recommend detailed evaluation for Building B. Note further that aside from the inclusion of the nearness to fault effect, the damage modification factor (DMF) for Building B farther reduces its score from 1.90 to 1.87. This particular building demonstrates how the current damages seen on the building is taken into account through the DMF, which is another factor not considered in FEMA 154.

RAPID CONDITION ASSESSMENT TOOL

STRUCTURAL COMPONENT

RCAsT STRUCTURAL SCORE for Low- (1-2 stories) and Mid- (3-7 stories) Rise Reinforced Concrete Frame

BLDG. TYPE	BASIC SCORE	MID-RISE	VERTICAL IRREGULARI	PLAN IRREGULARI	PRE CODE	LOW CODE	SOIL TYPE C	SOIL TYPE E	SOIL TYPE F	NEAR SOURCE	**STRUCTURAL SCORE, S**
C1L,C1M*	**2.40**	0.60	-1.00	-0.20	-0.20	-0.20	0.10	-0.10	**	-0.20	**1.60**

NOTE: *C1 is a reinforced concrete moment resisting frame building type.

** If selected, automatically proceed to detailed analysis.

DAMAGE MODIFICATION FACTOR (DMF)

	TYPE	NO-SLIGHT DAMAGE	LIGHT- MODERATE DAMAGE	HEAVY DAMAGE - COLLAPSE	TOTAL*** FACTOR
COLUMNS	LONG: h/d>6	ALL [ ] x 1	--- [ ] x 0.5	--- [ ] x 0	
COLUMNS	SHORT: h/d≤6	ALL [ ] x 1	--- [ ] x 0.3	--- [ ] x 0	
	TOTAL # OF COLUMNS****	[ ]	[ ]	[ ]	**1**
					DMF col
BEAMS	LONG: L ≥ 6m	ALL [ ] x 1	--- [ ] x 0.7	--- [ ] x 0	
BEAMS	INTERMEDIATE: 2m<L<6m	ALL [ ] x 1	--- [ ] x 0.5	--- [ ] x 0	
BEAMS	SHORT: L≤2m	ALL [ ] x 1	--- [ ] x 0.3	--- [ ] x 0	
	TOTAL # OF BEAMS****	[ ]	[ ]	[ ]	**1**
					DMF beam

*** The **Total Factor** is equal to the sum of the products of the number of columns/beams and the corresponding reduction factor per damage state.

**** Total # of Columns/beams is the sum of the number of columns/beams counted on site regardless of damage observed (i.e. no factors incorporated).

DMF= $\frac{1.2\ DMF_{Col} + 1.1\ DMF_{Beams}}{2.3}$ **1.00**

FINAL SCORE= *(STRUCTURAL SCORE)*(DAMAGE MODIFICATION FACTOR)*

FINAL SCORE= **1.60** *****

SKETCHES:

SCALE:

Comments:

***** If Final Score S ≤ **1.9**, then the structure will be recommended for Detailed Seismic Evaluation

DETAILED EVALUATION RECOMMENDED?

YES	NO

Figure 7 RCAsT Structural Component Filled out form for Buildings A.

RAPID CONDITION ASSESSMENT TOOL

STRUCTURAL COMPONENT

RCAsT STRUCTURAL SCORE for Low- (1-2 stories) and Mid- (3-7 stories) Rise Reinforced Concrete Frame

BLDG. TYPE	BASIC SCORE	MID-RISE	VERTICAL IRREGULARITY	PLAN IRREGULARITY	PRE CODE	LOW CODE	SOIL TYPE C	SOIL TYPE E	SOIL TYPE F	NEAR SOURCE	**STRUCTURAL SCORE, S**
C1L,C1M*	**2.40**	0.60	-1.00	-0.20	-0.20	-0.20	0.10	-0.10	-0.20	**	**1.90**

NOTE: *C1 is a reinforced concrete moment resisting frame building type.
** If selected, automatically proceed to detailed analysis.

DAMAGE MODIFICATION FACTOR (DMF)

	TYPE	NO-SLIGHT DAMAGE		LIGHT- MODERATE DAMAGE		HEAVY DAMAGE - COLLAPSE		TOTAL*** FACTOR
COLUMNS	LONG: h/d>6	**4**	x 1	**2**	x 0.5	**0**	x 0	**5**
COLUMNS	SHORT: h/d≤6	**134**	x 1	**1**	x 0.3	**0**	x 0	**134.3**
	TOTAL # OF COLUMNS****	**138**		**3**		**0**		**0.99**
								DMFcol
BEAMS	LONG: L ≥ 6m	**0**	x 1	**0**	x 0.7	**0**	x 0	**0**
BEAMS	INTERMEDIATE: 2m<L<6m	**135**	x 1	**6**	x 0.5	**0**	x 0	**138**
BEAMS	SHORT: L≤2m	**0**	x 1	**0**	x 0.3	**0**	x 0	**0**
	TOTAL # OF BEAMS****	**135**		**6**		**0**		**0.98**
								DMFbeam

*** The **Total Factor** is equal to the sum of the products of the number of columns/beams and the corresponding reduction factor per damage state.
**** Total # of Columns/beams is the sum of the number of columns/beams counted on site of damage observed (i.e. no factors incorporated).

DMF= $\frac{1.2\ DMF_{Col} + 1.1\ DMF_{Beams}}{2.3}$ **0.98**

FINAL SCORE= *(STRUCTURAL SCORE)*(DAMAGE MODIFICATION FACTOR)*

FINAL SCORE= **1.87** *****

SKETCHES:

SCALE:

Comments:

***** If Final Score S ≤ **1.9**, then the structure will be recommended for Detailed Seismic Evaluation

DETAILED EVALUATION RECOMMENDED?

YES NO

Figure 8 RCAsT Structural Form Filled out for Building B.

4 CONCLUSION

A rapid visual assessment tool was formulated that quantifies the building performance based on the exterior attributes of the building and the interior state of building components. The tool uses structural scores derived from the locally developed fragility curves of moment resisting frame buildings in Metro Manila. Moreover, a score modifier was added, not found in FEMA 154 that takes into account the nearness to fault of a structure. In addition, quantification of the damage modification factor (DMF) was formulated using similar concepts employed in quantifying post-earthquake damage of RC buildings in Japan. The Rapid Condition Assessment Tool (RCAsT) for the Structural Component and FEMA 154 were both applied to two Buildings for comparison. Though both tools have the same recommendation for the two buildings, the Final Score resulting from RCAsT is more indicative of the true condition of the building before an earthquake with consideration to nearness to fault and damages observed in the building.

ACKNOWLEDGEMENT

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DEVELOPMENT OF A RAPID CONDITION ASSESSMENT TOOL FOR REINFORCED CONCRETE MOMENT-RESISTING FRAME BUILDINGS IN THE PHILIPPINES: GEOTECHNICAL COMPONENT

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Abstract : This paper describes the development of a pre-earthquake assessment tool that is rapid, visual, cost effective and reasonably accurate for identifying geotechnical hazards with respect to reinforced concrete structures. In the Rapid Condition Assessment Tool (RCAsT), scores are assigned on the basis of the type and severity of the geotechnical hazard present. The general framework of the tool is based on the MCEER Screening Guide for Rapid Assessment of Liquefaction Hazards of Highway Bridge Site, which was substantially expanded to include seismic and non-seismic hazards. Seismic hazards considered by the tool include effects of local geotechnical conditions on ground motions, liquefaction, and lateral spreading. Non-seismic hazards considered by the tool include presence of expansive or sensitive soils, excessive differential settlements, and lateral movement due to slope instability. Slope stability is separately assessed using the DOST-KAST rapid assessment tool for rainfall induced landslides. The tool was employed to several buildings wherein the results were evaluated in comparison with assessments of engineers.

Key words: *Rapid visual assessment, Condition evaluation, Geotechnical assessment*

1 INTRODUCTION

The geotechnical conditions underlying a structure contribute greatly to the safety and serviceability of an existing structure. The exposure to specific geologic and geotechnical hazards should be taken into consideration when assessing the seismic vulnerability of an existing structure. Such hazards generally include liquefaction, subsidence and settlement, lateral spreading, as well as expansive or sensitive soils. Depending on the foundation system used, exposure to these hazards can result in minimal to severe damage to an existing structure. Identifying the exposure and vulnerability of a structure to these hazards is necessary step when deciding on the need to retrofit an existing structure. This paper describes the of a tool for assessment of the exposure and vulnerability to geotechnical hazards, as well as systematic monitoring of the geotechnical conditions of an existing structure.

The proposed tool is intended for an initial screening existing reinforced concrete structures, with the objective of identifying structures that potentially require further and more detailed investigation. Activities covered in this level include:

- Collection and review of existing data such as foundation plans, geologic maps, hazard maps and previous geotechnical investigation reports.
- Visual inspection of the structural and non-structural components and the geotechnical conditions surrounding the structure.
- Measurement and documentation of observed damage to structure and geotechnical conditions of the site.
- Evaluation of data and formulation of recommendations.

2 DEVELOPMENT OF THE TOOL

The proposed tool was developed based available hazard maps and building codes in the Philippines, as well as integrates specific rapid assessment tools developed for Philippine conditions. The tool is formulated so that it can easily be updated as building codes and hazards are revised. This tool is divided into two types of hazard: seismic hazard and non-seismic hazard. The degree of risk in the area depending on the factors considered will determine the level of hazard the structure will be classified.

2.1 Seismic Hazard

Geotechnical seismic hazards can generally be divided into those that are associated with decrease in soil shear strength and stiffness, seismic ground shaking (i.e. accelerations), and seismic induced lateral ground movements and settlement. (SCDOT, 2010) Liquefaction usually takes place as a result of loss of shear strength due to ground shaking and existing soil conditions. The location and geomorphology of the country also makes it prone to seismic-induced lateral spreading and settlement.

2.1.1 Seismic Zone Classification

Seismic design criteria in building codes are defined by seismic zones location of the structures. In general, seismic zones are categorized into Zone 0 to Zone 4 in which zone 0 denoting the weakest earthquake ground motion and zone 4 as the strongest. (Gosh)

The National Structural Code of the Philippines 2010 (NSCP 2010) divided the Philippines into two seismic zones only: Zone 2 and Zone 4 (Association of Structural Engineers of the Philippines). Areas under Zone 2 have low to moderate probability of damaging ground motion whereas areas under Zone 4 have high probability. NSCP 2010 assigned a seismic factor of 0.2 for Zone 2 areas and 0.4 for areas under Zone 4. Figure 1 shows that Palawan, Sulu and Tawi-tawi are under Zone 2 and the rest of the country is under Zone 4.

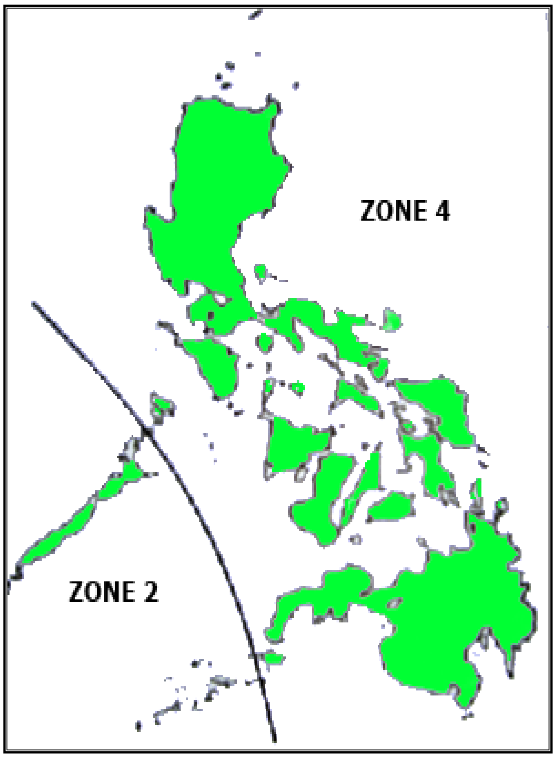

Figure 1 Seismic Zone Map of the Philippines (NSCP 2010-Figure 208-1)

2.1.2 Soil Profile Type

If the area to be considered is under Zone 4 of seismic zone classification, one of the criteria is the underlying soil profile should be stable and strong enough to support the structure in the event of an earthquake. Soil profile type is categorized as S_A, S_B, S_C, S_D, S_E, S_F. Table 1 shows the difference between these soil profile types.

One of the condition of NSCP 2010 for structures under Zone 4 is that the underlying should fall between S_A to S_D soil profile type, otherwise, the structure will be considered unsafe.

Table 1 Soil Profile Types

Soil Profile Type	Soil Profile Name/ Generic Description	Average Soil Properties for Top 30 m of Soil Profile		
		Shear Wave Velocity (m/s)	SPT,N (blows/300 mm)	Undrained Shear Strength (kPa)
S_A	Hard Rock	>1500		
S_B	Rock	760 to 1500		
S_C	Very Dense Soil and Soft Rock	360 to 760	>50	>100
S_D	Stiff Soil Profile	180 to 360	15 to 50	50 to 100
S_E[1]	Soft Soil Profile	<180	<15	<50
S_F	Soil Requiring Site-Specific Evaluation			

[1]Soil Profile Type S_E also includes any soil profile with more than 3.0 m of soft clay defined as a soil with plasticity index, PI > 20, w_{mc} > 40 percent and s_u < 24 kPa. The Plasticity index, PI and the moisture content, w_{mc}, shall be determined in accordance with approved national standards.

NSCP 2010 also defined soil profile falling under soil profile type S_F as follows:

1) Soils vulnerable to potential collapse or collapse under seismic loading, such as liquefiable soils, quick and highly sensitive clay, and collapsible weakly cemented soils.
2) Peats and/or highly organic clay exceeds 3.0 m.
3) Very high plasticity clays with a plasticity index, PI $\geq$ 75, where the depth of clay exceeds 7.5m.
4) Very thick soft/medium stiff clays, where the depth of clay exceeds 35 m.

5.1.3. Types of Foundation

All structures on earth must be supported by an interfacting element called a foundation or substructure (Bowles). Foundation is a part of a structure that transmits the loads it is carrying to the underlying soil or rock. Foundations may be classified based on where the load is carried by the ground: shallow or deep foundations. Shallow foundation, also termed as base or footing, is one in which the ratio of embedment depth to width is D/B $\leq$ 1. Some types would include spread footings and mat foundations. In cases where shallow foundations are inadequate to support the structural loads, deep foundations are employed. Deep foundations, also known as pile foundations, are slender structural members installed on the ground to transfer structural loads to soil at significant depth below the base of the structure. Unlike shallow foundations, deep foundations distribute the load vertically rather that horizontally. Common types of deep foundations are bored and driven pile foundations.

Mat foundations are special used to support several rows of parallel columns and may underlie a portion or the entire building. It can be located at the surface or buried deep into the soil. It is described as raft foundations (Budhu) because they act like rafts when part or all of the loads are compensated by embedment.

A spread footing is a foundation carrying a single column. Its is termed as spread footing because its function is to "spread" the column load literally to the soil so that the stress intensity is reduced to a value that the soil can carry (Bowles). Spread footings with tension reinforcement may be two-way or one-way depending on whether the steel used runs both ways or in one direction. Spread footings may also be reinforced with tie beams for additional support.

Materials for deep foundations may be concrete, steel or timber. Piles can either be driven into the ground (driven piles) or installed in a predrilled hole (bored piles).

5.1.4. Liquefaction Hazard

Static liquefaction is the behavior of a soil as a viscous fluid when seepage reduces the effective stress to zero (Budhu). On the other hand, cyclic liquefaction refers to the response of a soil subjected to dynamic loads or excitation by transient shear waves, which terminates in a complete loss of strength and entry in a liquefied state. Cyclic liquefaction occurs during or after an earthquake (Hunt). Liquefaction-induced ground and foundation displacement has been a major cause of earthquake damage and collapse of structures.

There are several ways of checking for liquefaction susceptibility of an area. The following are the criteria used in this tool:

a) **Liquefaction Maps.** The Philippine Institute of Volcanology and Seismology (PHIVOLCS) is an institute that deals with disaster mitigation fro volcanic eruptions, earthquakes, tsunami, and other related geotectonic phenomena. They released maps showing the Liquefaction Susceptibility Map of the Philippines (Figure 2) and liquefaction hazards in metro manila (Figure 3). These maps can be used if an area is under low, moderate or high risk for liquefaction.

b) **NSCP 303.4.** NSCP 2010 states that a liquefaction evaluation study may be required for a structure during the course of the foundation investigation if the following conditions are discovered:
   a. Area has shallow ground water, 2 m or less.
   b. Area is underlained by unconsolidated saturated sandy allubium (N<15).
   c. Area is under Seismic Zone 4.

5.1.5. Lateral Spreading

Lateral spreading is a form of planar failure occurring in both soil and rock. It is common in river valleys, particularly where erosion removes material from the river banks (Hunt). Tension cracks may occur during the early stages and sudden failure may happen during earthquake loadings. In this tool, structures located within 100 meters from a body of water are considered to be at risk of experiencing lateral spreading. The 100 meter distance is based on the assumption that a 25mm lateral movement will result in severe damage to a structure following Day (2011). Using the empirical relationship of Barlett and Youd (1999), 25mm lateral movements can occur at a distance of 100m from a 10m free face due to a magnitude 7 earthquake with a distance from the nearest fault of 50m or less.

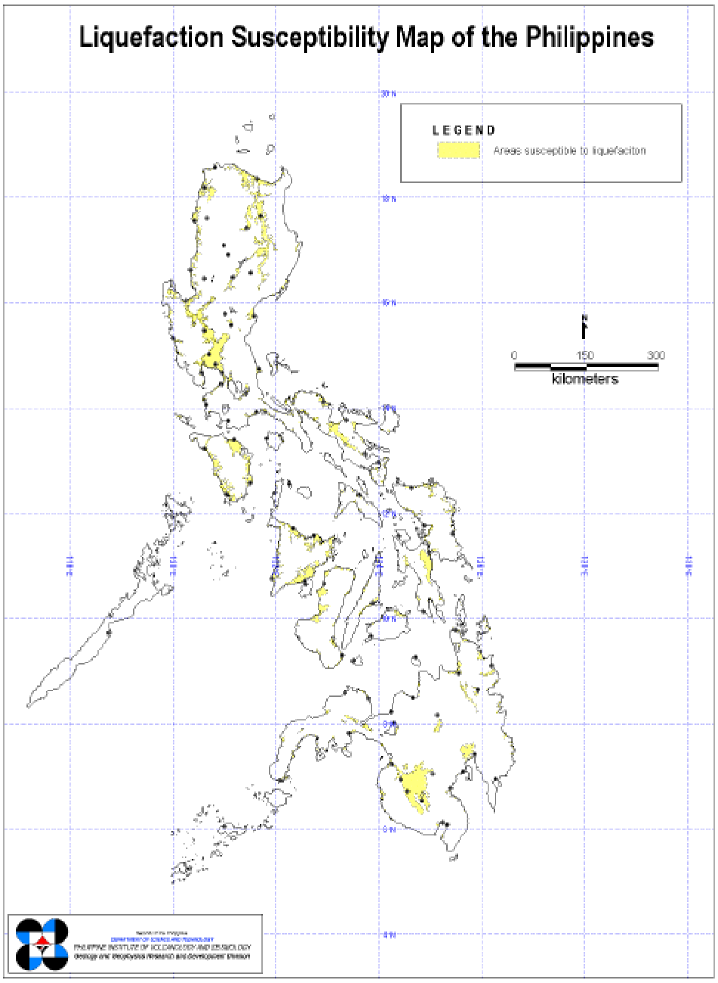

Figure 2 Liquefaction Susceptibility Map of the Philippines (PHIVOLCS, 2010)

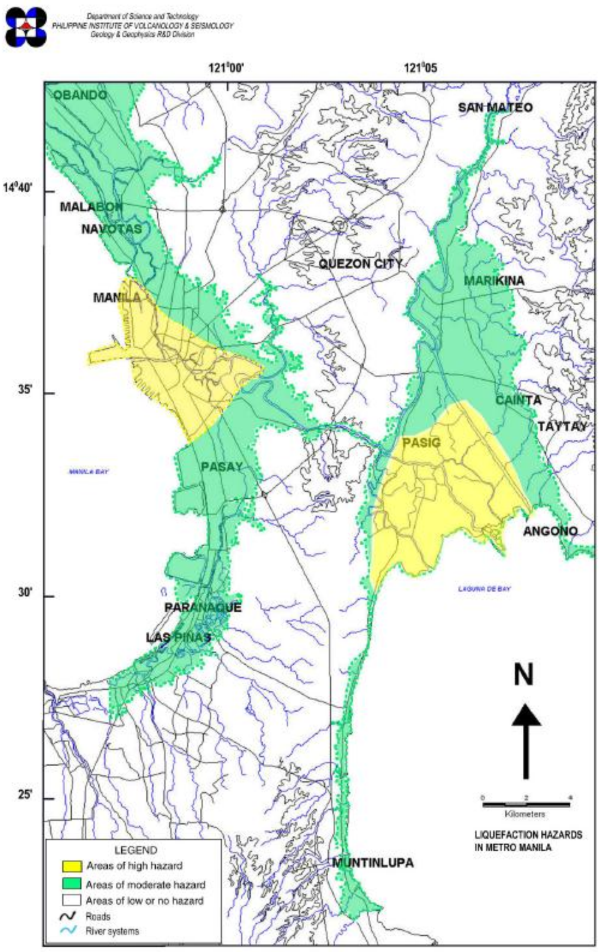

Figure 3 Liquefaction Hazard Map of Metro Manila (PHIVOLCS, 2010)

2.2 Non- Seismic Hazard

Geotechnical hazards not triggered by or related to seismic activity considered in the tool includes settlement, expansive soil, and slope failure. These events are caused by changes in the underlying subsurface conditions resulting to decrease in soil strength, location of structure, and poor construction of foundation.

2.2.1 Settlement

Settlement is defined as vertical or differential movement of the ground supporting a structure due to increase of loading or problems with the bearing soil or rock. Other causes may be due to consolidation of soft soil, settlement of fill, limestone cavitation and earthquake loading. Settlement in structures is manifested by gradual subsidence of structure or wall cracks due to settlement of the foundation. Classic wall crack due to settlement of the foundation are near-vertical that is wider at the top than at the bottom. Table 2 describes the cracks due to settlement and the severity of the damage that it may cause the structure. (Day)

2.2.2 Presence of Expansive Soil

Expansive soils, which are clayey soils also known as swelling soils, are type of soils that increase in volume with the addition of water. There is a significant shrinkage upon drying resulting to cracks on the surface. These are residual soils of high plasticity which are the result of weathering of the parent rock. Moisture changes in these types of soils bring severe movements of the mass and any structure built on top of it experiences recurring cracks and progressive damage (Murthy).

NSCP 2010 included expansive soils in the building code and the following conditions determines the soil to be expansive if all is satisfied:

1) Plasticity index (PI) of 15 or greater, determined in accordance with ASTM D 4318 and liquid limit > 50.
2) More than 10 percent of the soil particles pass a No.200 sieve (.075 mm), determined in accordance with ASTM D 422.
3) More than 10 percent of the soil particles are less than 5 micrometers in size, determined in accordance with ASTM D 422.
4) Expansion index greater than 20, determined in accordance with ASTM D 4829.

Note that tests to show compliance with Items 1, 2, and 3 shall not be required if the test prescribes in Item 4 is conducted (Association of Structural Engineers of the Philippines).

Table 2 Crack damage due to Settlement

Damage Category	Description of typical damage	Approx. Crack width
Very Slight	Very slight damage includes fine cracks that can be easily treated during normal decoration, perhaps an isolated slight fracture in building, and cracks in external brickwork visible on close inspection	1 mm
Slight	Slight damage includes cracks that can be easily filled and redecoration would probably be required; several slight fractures may appear showing on the inside of the building; cracks that are visible externally and some repointing may be required; and doors and windows may stick.	3 mm
Moderate	Moderate damage includes cracks that require some opening up and can be patched by a mason; recurrent cracks that can be masked by suitable linings; repointing of external brickwork and possibly a small amount of brickwork replacement may be required; doors and windows stick; service pipes may fracture; and weathertightnes is often impaired.	5 to 15 mm or a number of cracks> 3mm
Severe	Severe damage includes large cracks requiring extensive repair work involving breaking out and replacing sections of walls (especially over doors and windows); distorted windows and door frames; noticeably sloping floors; leaning or bulging walls; some loss of bearing in beams; and disrupted service pipes.	15 to 25 mm but also depends on number of cracks
Very Severe	Very severe damage often requires a major repair job involving partial or complete rebuilding; beams lose bearing; walls lean and require shoring;windows are broken with distortion; and there is danger of structural instability.	Usually>25mm but also depends on number of cracks

2.2.3 Lateral Movement (Slope Failure)

Lateral movement or slope failure is determines through the proximity of the structure from a nearby slope. For a structure to be safe, it should be built more than 1:H m away from the slope, or the structure is away from the slope at a distance greater than the measure of the height of the slope. If an existing structure is located less than 1:H near a slope, assessment should be made to determine whether the slope is stable or not. For this study, a landslide assessment tool must be used to determine the level of stability of a slope. It is recommended to use another tool developed through a grant from the Philippine Council on Industry and Energy Research (PCIERD) of the Department of Science and Technology (DOST) entitled "Development of a non-expert tool for site specific evaluation of rain-induced landslide susceptibility".

3 SCORING SYSTEM

The proposed scoring system gives separate scores for both seismic hazards, as well as none seismic hazard. Scores of seismic hazards are based on the potential for amplifications of ground shaking, liquefaction and lateral spreading, in relation to the foundation system of the affected structure. Scores of non-seismic hazards are based on the potential for damage due to differential settlement resulting from expansive soils, subsidence, and lateral movements resulting from soil failure.

Structures located in Zone 2 (with estimated peak ground accelerations of 0.2g or less) are considered to have negligible potential for amplification or ground motions, liquefaction and lateral spreading. Based on the 2010 NSCP, soil profile conditions of SD can be assumed if no geotechnical information is available to assess the type of soil profile. The potential for liquefaction is assessed using any of the following three methods: Liquefaction hazard maps as published by PHIVOLCS; Section 303.4 of the 2010 NSCP; previous history of liquefaction induced settlement. The susceptibility of various foundation systems is based on the findings of Ishihara et al (1993) which indicates that structures foundation on isolated spread footings without the use of tie-beams are the most affected by liquefaction induced settlements. Structures founded using rigid shallow foundations such as spread footings with tie-beams and/or mat foundations experience less damage as compared to structures founded solely on isolated spread footing due to the reduced differential settlements although such structures also experience subsidence and tilting. Based on these observations, a 0.75 reduction in the seismic hazard was applied. Although none of the building founded on piles experience any damage due to either differential settlements, subsidence, or tilting, it was noted that driven pile foundation do not offer significant resistance to lateral movements. Recent findings indicate that structures founded on driven piles are vulnerable to lateral spreading . As such, a reduction factor of 0.9 for seismic hazard was assigned to this type of foundation system. As previously mentioned, a distance of 100m from any body of water was set based on the general assumption that lateral spreading resulting in horizontal displacement in excess of 25mm can occur at this distance in the event of a magnitude 7 earthquake.

Settlements due to subsidence that result in damage to the structure were quantified using the scale of described in Day (2011). A maximum score of 20 points was assigned to settlements resulting in very severe effects on the affected structure. Settlements of lesser magnitude were assigned lesser points based on the qualitative description of the effects on the structural integrity of the affected structure. It was assumed that negligible to very slight settlements had no effects on the integrity of the affected structure. It was assumed that the presences of expansive soils had the potential to result in very severe differential movements in the affected structure and were automatically assigned a score of 5 points if present. The presence of expansive soils was identified by either the use of expansion index (if present), Section 303.5 of the 2010 NSCP, or an activity index greater than 1.25 which indicates the swell potential. Lateral movement due to slope failure is quantified through landslide assessment tools. It is recommended to use another tool developed through a grant from the Philippine Council on Industry and Energy Research (PCIERD) of the Department of Science and Technology (DOST) entitled "Development of a non-expert tool for site specific evaluation of rain-induce\d landslide susceptibility". A score of 40 points is assigned to slopes that are highly unstable, 20 points for slopes that are unstable, and 10 points for slopes that are marginally unstable.

Structures obtaining scores of 10 or higher in either the seismic or non-seismic hazard portions of the tool are recommended for level 2 investigation. Structures located adjacent to highly unstable slopes which show visible signs of cracking are considered to be highly unsafe and are recommended for evacuation.

4 THE TOOL

A summary of the flow of the tool is presented in a detailed flow chart in Figure 4, to easily guide the user on how to use the tool efficiently and effectively. A sample geotechnical assessment form is shown in Figure 5.

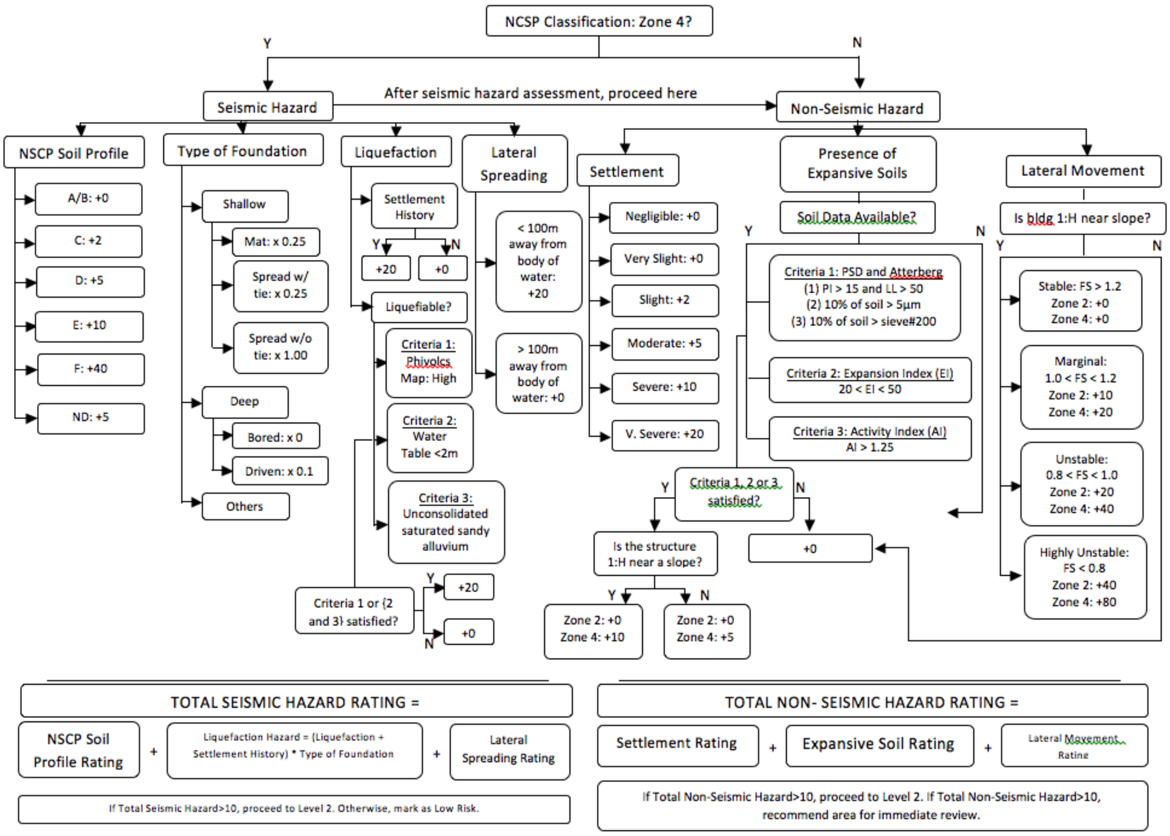

Figure 4 Rapid Condition Assessment Tool For Geotechnical Hazard Flowchart

RAPID CONDITION ASSESSMENT TOOL	GEOTECHNICAL HAZARD LEVEL 1

SEISMIC HAZARD:		Remarks
A.NSCP classification: (Refer to Appendix 1) **Remarks: If area is under Zone 2, proceed to Item F.*	☐ Zone 2 ☐ Zone 4	
B. NSCP Soil Profile: (Refer to Appendix 2)	☐ A/B*(+0)* ☐ C*(+2)* ☐ D*(+5)* ☐ E*(+10)* ☐ F*(+40)* ☐ ND*(+5)*	
C.Type of Foundation: (If footing type is unknown, use spread footing w/o tie beam as default value. If under Others, a Geotechnical engineer must review and be the one to assign multiplier.)	☐ Shallow Foundation: ☐ Mat foundation *(x0.25)*; ☐ Spread footing w tie beam*(x0.25)*; ☐ Spread footing w/o tie beam*(x1.0)*; ☐ Others: (Specify) _______________ ☐ Deep Foundation: ☐ Bored Piles*(x0.0)*; ☐ Driven Piles*(x0.1)*; ☐ Others: (Pls. Specify) _______________	
D.Liquefaction Hazard: (Refer to Appendix 3)	**1. PHIVOLCS MAP**: ☐ High ☐ Moderate ☐ Low **2. NSCP 303.4** (Check if Area is under Low or Moderate Hazard): ☐ Shallow water table < 2m ☐ Seismic Zone 4 ☐ Unconsolidated saturated sandy alluvium **3. Liquefiable?** ☐ Yes*(+20)* (If area is under High Hazard or all criteria under NSCP 303.4 are met) ☐ No*(+0)* **4. History of Settlement?** (Check for previous records) ☐ Yes*(+20)* ☐ No *(+0)*	
E.Lateral Spreading: Location of structure:	☐ < 100m away from closest body of water*(+20)* ☐ > 100m away from closest body of water*(+0)*	
NON-SEISMIC HAZARD:		
F.Settlement: (Refer to Appendix 4)	☐ Negligible (*+0)* ☐ Very Slight*(+0)* ☐ Slight *(+2)* ☐ Moderate *(+5)* ☐ Severe *(+10)* ☐ Very Severe (+20)	
G.Presence of Expansive Soils: Area is expansive if all items under Criteria 1 or 3 are met & EI>20 ; a rating of 20 is added to the score.	**Criteria 1:** ☐ PI>15 & LL>50 ☐ 10% of soil> 5mm in size ☐ 10% of soil > passing No. 200 seive (If no hydrometer analysis is performed, assume soil to be expansive.) **Criteria 2: Expansion Index (EI)** ☐ 0-20;Non-Expansive ☐ 21-50; Expansive*(+5)* **Criteria 3:** ☐ Activity index >1.25	Assume expansive
H.Lateral Movement (Slope Failure)	Is the buliding1:H m near a slope? ☐ Yes ☐ No*(+0)* If yes, what is the state of the slope? (Please refer to Appendix 5 for Landslide Assessment Tool) ☐ Stable; FS>1.2 (+0) ☐ Marginally Stable; 1.0<FS<1.2 *(+10)* ☐ Unstable; 0.8<FS<1.0 *(+20)* ☐ Highly Unstable; FS<0.8 *(+40)*	

RATING TABLE:

SEISMIC HAZARD	Rating
IBC Soil Profile	
Liquefaction Hazard =(Item D.3 + Item D.4)xItem C	
Lateral Spreading	
TOTAL	

*If TOTAL> 10, proceed to Level 2

NON-SEISMIC HAZARD	Rating
Settlement	
Expansive Soils - double score if area is under Zone 4 and near a slope	
Lateral Movement - double score if area is under Zone 4	
TOTAL	

*If TOTAL> 10, proceed to Level 2

*If TOTAL>50, recommend area for immediate review

SIGNATURE OVER PRINTED NAME

EVALUATOR

DESIGNATION

DATE & TIME OF EVALUATION

RECOMMENDATION: ☐ **LOW RISK** ☐ **PROCEED TO LEVEL 2** ☐ **FOR IMMEDIATE REVIEW**

Figure 5 Rapid Condition Assessment Tool For Geotechnical Hazard

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DEVELOPMENT OF A RAPID CONDITION ASSESSMENT TOOL FOR REINFORCEDCONCRETE MOMENT-RESISTING FRAME BUILDINGS IN THE PHILIPPINES: MATERIAL COMPONENT

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Abstract: Many buildings in the Philippines use reinforced concrete, in whole or in part, as the structural system. Proper inspection procedures, based on a visual investigation, can help identify deficiencies in concrete before they become critical to the overall stability of the structure. This paper describes the development of a rapid visual assessment tool for rating the condition of a reinforced concrete moment-resisting frame buildings. The developed tool considers both the structural and nonstructural deficiencies in concrete. It focuses on specific building elements for condition evaluation such as beams, columns, slabs and walls. This Tool provides engineers with background information and a systematic methodology for inspecting reinforced concrete buildings, focusing on deterioration conditions that can be seen and, more importantly, those conditions that can lead to a structural failure. The adopted scoring system is based on the proposed methodology by Coronelli which is a modification of the evaluation procedure by the CEB (1998): Condition Rating. This methodology was proposed for wide variety of structures to identify the most deteriorated cases by a damage index and plan more detailed analyse and repair interventions. Because the procedure of Coronelli considers several factors that are non-existent in the Philippine condition such as freeze thaw, etc it is further modified taking into account local conditions.

Key words: *Building assessment, Condition evaluation, Deterioration, Rapid visual assessment*

1 INTRODUCTION

Various factors adversely affect structural condition and hence the performance of RC structures. These factors may include inadequate material selection, poor workmanship, severe environments, exposure to harmful chemicals, unexpected loadings, fatigue, and catastrophic events (Jain *et al* 2012). Safety management of structures for public and property security must be performed regularly throughout the structure's life cycle. Visual inspection provides important information on performance and durability of structures (ACI 201 2008). In deteriorating structures, several visible distresses may develop with time, of which the commonly detected ones are cracks, leaching/staining, spalling, delamination, and efflorescence. In line with this, inspection activities and condition evaluations are done to assess the current serviceability and structural function of existing structures. Condition assessment and visual inspection are concerned with estimating the likely future safety and performance of an existing structural system. Many buildings in the Philippines use reinforced concrete, in whole or in part, as the structural system. Proper inspection procedures, based on a visual investigation, can help identify deficiencies in concrete before they become critical to the overall stability of the structure. This Tool provides engineers with background information and a systematic methodology for inspecting reinforced concrete buildings, focusing on deterioration conditions that can be seen and, more importantly, those conditions that can lead to a structural failure.

There exist different levels of investigation when it comes to condition survey of reinforced concrete structures. In seismic evaluation of structures, for example, FEMA 310 which is one of the "most advanced seismic evaluation procedure" for buildings categorizes the levels of inspection to a three-tiered process as enumerated by Rai (1998). Tier 1 is the screening phase in which the inspection is mainly visual. In this phase, the engineer looks on potential deficiencies and expected behavior of the structure. This screening helps provide evaluation statements for structural, nonstructural and foundation aspects in the form of checklist. Tier 2 is the evaluation phase where complete analysis of the building is made while Tier 3 is the more detailed evaluation phase.

Building performance can be measured in many ways, the most common being condition. Condition survey is defined as the "examination of concrete for the purpose of identifying and defining areas of distress". (ACI 201) The building's condition gives a measure of the effectiveness of current maintenance programs because it determines the remaining useful life of components or systems and compares it with the full economic life expected, given good maintenance (Abbott, et al, 2007). In terms of condition survey of in-service concrete for the purpose of rehabilitation, the American Concrete Institute (364) classifies condition assessment of concrete structures under two categories: preliminary investigation and detailed investigation.

The preliminary investigation develops an initial assessment of the concrete structure's behavior, condition and existing performance. A preliminary investigation is not intended to be a comprehensive study and is visual in nature. The tasks involved in preliminary survey are:

a. Documents review
b. Site Inspection
c. Preliminary Analysis

A detailed investigation is performed when the initial site visit or preliminary investigation has identified a need for more indepth assessment of concrete structure's behavior. A detailed investigation includes additional filed observation, measurements and field and laboratory testing.

2 DEVELOPMENT OF THE TOOL

The tool was developed from a review of documentation on deterioration conditions in concrete and of accepted industry recommendations and practices. For the development of this tool, review and full consideration of the following were given to:

- American Concrete Institute 201.1: Guide for Making a Condition Survey of Concrete in Service
- American Concrete Institute 364: Guide for Evaluation of Concrete Structures before Rehabilitation
- ASCE 11 Guidelines for Structural Condition Assessment of Existing Buildings
- US Army Corps of Engineers: Guide for Visual Inspection of Structural Concrete Building Components

2.1 Components of the Tool

The tool considers both the structural and nonstructural deficiencies in concrete. It focuses on specific building elements for condition evaluation. These elements primarily include columns, slabs and beams. Walls are also considered but because it is non-load bearing in nature, it is not included in the overall rating of the building. Also, because there are a number of defects in concrete, only the major defects and visible deteriorations are considered. The tool can be divided into six parts: plan frame, critical areas, visible deterioration, building component, condition rating and the recommendations part.

2.1.1 Nonstructural deficiencies

Nonstructural deficiencies in general are surface deficiency resulting from the conditions of the design, construction or service life of the building. These deficiencies are not immediately critical to the structure but they can cause further deterioration, which can eventually lead to structural deficiencies. Examples of nonstructural deficiencies are: abrasion, blistering, chemical reaction cracking, cracking due to construction practice, crazing, discoloration, efflorescence, flaking, honeycombing, pop-out, etc.

2.1.2 Structural deficiencies

Structural deficiencies on the other hand indicate a breakdown of the material to a point that threatens the structural capacity of the members. Common structural deficiencies are chemical deterioration, corrosion cracking, distortion, reinforcement corrosion, scaling, spalling, shear cracking, moment cracking, etc. For a detailed explanation and corresponding photographs for the abovementioned deterioration, please refer to Appendix A

3 SCORING SYSTEM

The adopted scoring system is based on the proposed methodology by Coronelli (2007). This rating system is a modification of the evaluation procedure by the CEB (1998): Condition Rating. This methodology was proposed for wide variety of structures to identify the most deteriorated cases by a damage index and plan more detailed analysis and repair interventions. Because the procedure of Coronelli considers several factors that are non-existent in the Philippine condition such as freeze thaw, *etc* it is further modified taking into account local conditions

The scoring system begins by first examining the structural configuration and its division or components and subsequently judging the relative importance of these components. In general, more importance is given to columns since its failure is brittle and could trigger incremental collapse of more parts of the structure. The failure of the floor however has limited effects with a beam failure. The structural factor, as adopted from the study of Coronelli, which gives the relative importance of each structural element, is shown in Table 1. After examining the structural component, damage of each individual element will be rated.

Table 1 Structural element factor values for framed buildings (adopted from Coronelli, 2007)

Structural Element	**Factor**
Columns	1.2
Beams	1.1
Slabs	0.3
Walls	0.0

3.1 Condition Rating

The condition rating is a numerical score given to the structure relative to its most deteriorated case. The score can range from 0 to 100 % with 100% representing the worst case scenario or the case in which all members are deteriorated. A brief description of each of the deterioration case is sown in Table 2.

Table 2 Condition rating and corresponding deterioration class with description

Deterioration Class	Description of the condition	Rating
I	*No defect*, Only construction deficiencies.	**0-5**
II	*Low degree deterioration,* which only after a long period of time might be the cause for reduced serviceability or durability of the affected structural component, if not repaired in proper time	**3-10**
III	*Medium degree deterioration*, which can be the cause for reduced serviceability and durability of the affected structural component, but still not requiring any limitation of use of the structure	**7-15**
IV	*High degree deterioration*, reducing the serviceability and durability of the structure, but still not requiring serious limitation of use	**15-25**
V	*Very heavy deterioration*, requiring limitation of use, propping of most critical components, or other protective measures	**22-35**
VI	*Critical deterioration*, requiring immediate propping of the structure and strong limitation of use, for example, closing	**>30**

The form includes two condition ratings as follows:

3.1.1 LOCAL Condition Rating (LCR)

The local condition rating or LCR is the rating for each of the building component. This includes individual ratings for beams, columns, floor slabs and walls. The LCR is computed as:

$$LCR = \frac{\Sigma B_1 K_2 K_3 K_4}{72} x\ 100\% \quad \text{Equation (1)}$$

where:

B_1 is the basic value of i[th] damage type, expressing its potential effect on the safety and durability of the structural component under observation; values range 1–4;

K_1 is the structural element factor characterizing its importance for the safety of the whole structure or one of its parts;

K_2 is the intensity factor for the i[th] damage, determined by qualitative visual criteria and experimental measurements in a scale of four degrees, with the corresponding numerical values K_2 = 0.5, 1, 1.5, 2

K_3 is the extension factor for the i[th] damage within the elements under consideration, defined uniquely by descriptive criteria and applied in a scale of K_3 = 0.5–1.0–1.5–2

K_4 is the urgency of intervention factor for the i[th] damage, with values varying from 1 to 5, grouped into four classes on the basis of direct consequences of the deterioration type on the safety of the structure and the users, and related to an indication of time for intervention

3.1.2 GLOBAL Condition Rating (GCR)

The global condition rating gives the condition index of the structure as a whole considering all the structural components. It is the condition rating for the whole building. It is computed as:

$$GCR = \frac{(1.2 * LCR\ Column + 1.1\ LCR\ Beams\ + 0.3\ LCR\ Slabs)}{2.6} \qquad \text{Equation (2)}$$

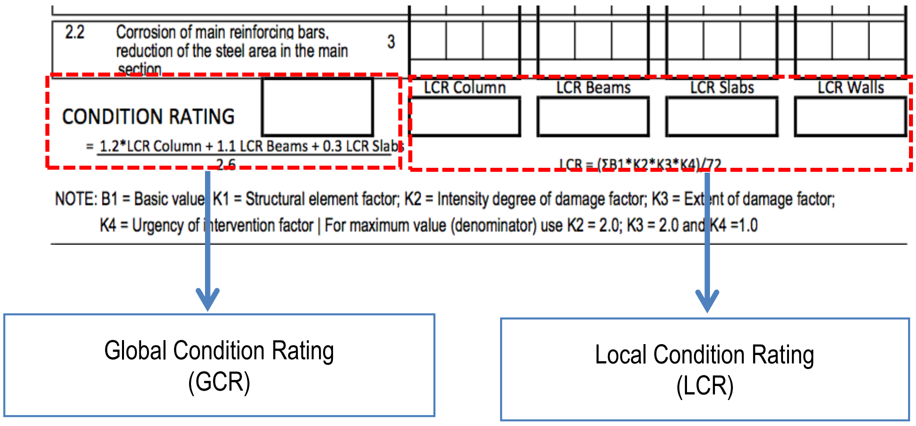

Figure 1 Global and local condition ratings

3.2 Cut-off Score and Making Recommendations

Three recommendations can be made upon computation of the condition rating of the building such as:

a. No further investigation required
b. Detailed local investigation
c. Overall detailed investigation or Level 2 assessment

This recommendation is based on the computed local and global condition rating. If the condition rating is greater than 15% a detailed investigation is recommended. This value is based on the fact that at 15% deterioration condition, a building is already considered medium to high degree deteriorated (Coronelli, 2007).

4 CONCLUSION

A rapid visual condition rating tool that can be used to evaluate the deterioration condition of a moment-resisting reinforced concrete frame building was developed. This tool was developed from review of documentation of deterioration from different standards. A quantitative scoring system from the study of Coronelli (2007) was adopted and localized to be useful in the Philippine setting. This Rapid Condition Assessment Tool (RCAsT): Materials Component can be used as a preliminary tool that will help decision makers if it is necessary to proceed with detailed investigation of the building.

RAPID'CONDITION'ASSESSMENT'TOOL

MATERIAL Component

SKETCH'PLAN'FRAME'OF'THE'BUILDING

CRITICAL MEMBERS*

COLUMNS (% with defect: ____)

BEAMS (% with defect: ____)

FLOORS (% with defect: ____)

WALLS (% with defect: ____)

1.0 CONCRETE

		B1	COLUMNS K2	COLUMNS K3	COLUMNS K4	BEAMS K2	BEAMS K3	BEAMS K4	FLR SLABS K2	FLR SLABS K3	FLR SLABS K4	WALLS K2	WALLS K3	WALLS K4
1.1	Poor workmanship: peeling, stratification, honeycomb, voids	1												
1.2	Cracking cause by direct loading, imposed deformation and restraint	3												
1.3	Efflorescence, exudation and popout	1												
1.4	Mechanical damage: erosion, collision	1												
1.5	Wet surfaces	1												
1.6	Cover defects caused by reinforcement corrosion	2												
1.7	Spalling caused by corrosion of reinforcement	3												
1.8	Open joints between segments	2												
2.0 REINFORCEMENTS														
2.1	Corrosion of stirups	1												
2.2	Corrosion of main reinforcing bars, reduction of the steel area in the main section	3												

CONDITION'RATING	LCR'Column	LCR'Beams	LCR'Slabs	LCR'Walls
0	0.00	0.00	0.00	0.00

$$= \frac{1.2*LCR'Column'+'1.1'LCR'Beams'+'0.3'LCR'Slabs}{2.6}$$

$$LCR'='(\Sigma B1*K2*K3*K4)/72$$

NOTE: B1 = Basic value; K1 = Structural element factor; K2 = Intensity degree of damage factor; K3 = Extent of damage factor; K4 = Urgency of intervention factor | For maximum value (denominator) use K2 = 2.0; K3 = 2.0 and K4 =1.0

RECOMMENDATION

☐ No further actions required

☐ Detailed local investigation required for the following areas

☐ Overall further investigation needed (Level 2 inspection - Condition Rating > 15%)

*Consider the component critical in the presence of the following cracks: (a) Columns - Longitudinal (b) Beams - Transverse at midspan (c) Walls - Diagonal

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APPENDIX A

Table of factors as adopted from Coronelli (2007)

Table A1. List of factors for computation of condition rating and corresponding descriptions`

Factor		Description	Reference Table
B1	Basic value	Expresses its potential effect on the safety and durability of the structural component under observation;	
K1	Structural Element Factor	Characterizes its importance for the safety of the whole structure or one of its parts;	Table A2
K2	Intensity Factor	Intensity factor for the ith damage, determined by qualitative visual criteria and experimental measurements in a scale of four degrees, with the corresponding numerical values K_2 = 0.5, 1, 1.5, 2	Table A3 and Table A4
K3	Extension Factor	Extension factor for the ith damage within the elements under consideration, defined uniquely by descriptive criteria and applied in a scale of K_3 = 0.5–1.0–1.5–2 (Table 3);	Table A5
K4	Urgency of Intervention Factor	Extension factor for the ith damage within the elements under consideration, defined uniquely by descriptive criteria and applied in a scale of K_3 = 0.5–1.0–1.5–2 (Table 3);	Table A6

Table A2. K1 values for framed buildings

Structural Element	K1
Columns	1.2
Beams	1.1
Slabs	0.3
Walls	0.0

Table A3. General criteria for the intensity degree of a damage type

Degree	Criterion	K2
Low - initial	Damage of small size, generally appearing on single localities 0.5 of a member	0.5
Medium–propagating	Damage is of medium size, confined to single localities, 1.0 or damage is of small size appearing on few localities or on a small area of a member (eg< 25%)	1.0
High – active	Damage is of large size, appearing on many localities or 1.5 on a greater area of a member (25 and 75%)	1.5
Very high – critical	Damage is of a very large size, appearing on a major part 2.0 of a member (>50%)	2.0

Table A4. Damage types to be evaluated, associated basic values B_1 and special criteria for the evaluation of the class of types (see Table for corresponding values of K_2)

Item	Damage type	B1	Degree of Damage			
			I (K2=0.5)	II (K2=1.0)	III (K2=1.5)	IV (K2=2.0)
1.0 CONCRETE						
1.1	Poor workmanship: peeling, stratification, honeycomb, voids	1	Single small defect	Several different small defects	Few stronger defects	Several different stronger defects
1.2	Cracking caused by direct loading, imposed deformations and restraint	3	Single < 0.5 mm	Several <0.5mm	Single >0.5mm	Several >0.5mm
1.3	Efflorescence, exudation, popout	1	General criteria (Table 2)			
1.4	Mechanical damage: erosion, collision	1	General criteria (Table 2)			
1.5	Wet surfaces	1	Light	Medium	Heavy	Severe
1.6	Cover defects caused by reinforcement corrosion	2	Rust stains, light	Rust stains, heavy	Cracks over stirrups	Delamination over stirrups
1.7	Spalling caused by corrosion of reinforcement	3	Finer cracks along reinforcing barsin corners	Finer cracks along other reinforcing bars and/or wider longitudinal cracks or exposed reinforcement along corners	Wider cracks along other bars, or exposed reinforcement	Hollow areas and surface spalling
1.8	Open joints between segments	2	1mm	1–3 mm	3-5 mm	>5mm
2.0 REINFORCEMENT						
2.1	Corrosion of stirrups	1	General criteria (Table 2)			
2.2	Corrosion of main reinforcing bars, reduction of steel area in the section (if in critical section, K_4=2)	3	Uniform < 10%	Pitting <10%	Uniform >10%	Pitting >10%

Table A5. General criteria for the extent of a damage type

Criterion	**K3**
Damage is confined to a single unit of the same type of member	0.5
Damage is appearing on several units (eg less than 1/4) of the same type of member	1.0
Damage is appearing on the major part of units (eg 1/4 to 3/4) of the same type of member	1.5
Damage is appearing on the great majority of units (more than 3/4) of the same type of member	2.0

Table A6. Factor to stress the urgency of intervention

Criterion	**K4**
Intervention is not urgent because the damage does not impair either the overall safety and/or durability 1 (service life) of the structure or the durability of the affected member	1
Damage must be repaired within a period not longer than five years, to prevent further impairment of the 2–3 overall safety and/or durability of the structure, or, solely, the durability of the affected member exposed to the aggressive attack	2-3
Immediate repair is required, as the damage is already jeopardizing the overall safety and/or durability of the 3–5 structure (especially in aggressive environment), or, if there is direct danger to people from falling pieces of disintegrated concrete	3-5
Temporary propping or limitation of traffic loads is require	5

Table A7. Deterioration classes

Deterioration Class	Description of the condition	Rating
I	*No defect*, Only construction deficiencies.	**0-5**
II	*Low degree deterioration,* which only after a long period of time might be the cause for reduced serviceability or durability of the affected structural component, if not repaired in proper time	**3-10**
III	*Medium degree deterioration,* which can be the cause for reduced serviceability and durability of the affected structural component, but still not requiring any limitation of use of the structure	**7-15**
IV	*High degree deterioration*, reducing the serviceability and durability of the structure, but still not requiring serious limitation of use	**15-25**
V	*Very heavy deterioration*, requiring limitation of use, propping of most critical components, or other protective measures	**22-35**
VI	*Critical deterioration*, requiring immediate propping of the structure and strong limitation of use, for example, closing	**>30**

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ECOLOGICAL SANITATION, AN APPROACH TO SUSTAINABLE SANITATION

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Abstract: In order to be sustainable, a sanitation system has to be not only economically viable, socially acceptable, and technically and institutionally appropriate, it should also protect the environment and the natural resources (SuSanA, 2008). Achieving sustainable sanitation is very relevant and important in developing and emerging economies. One approach to sustainable sanitation is called Ecological Sanitation. Ecological sanitation, Ecosan for short, is a holistic and sustainable approach to sanitation based on the principles of preventing pollution, sanitizing human excreta and using urine and feces as resources for agriculture. The basic approach is to separate the two fractions of human excreta, i.e., urine and feces, using a urine diverting toilet bowl. Human excreta is rich in Nitrogen, Phosphorous and Potassium (NPK), all important plant nutrients. An Ecosan user in San Fernando, La Union applies his sanitized urine and dried feces in his high value bonzai and ornamental plants; several farmers use urine from a school to irrigate rice, corn and vegetable plots with very good results. In Bauang, La Union, several guapple (giant guava variety) and corn producers have switched from chemical to urine fertilizer. Ecosan has been adopted in other municipalities, i.e, Bayawan in Negros Oriental and Cagayan De Oro in Misamis Oriental, to name a few. Implemented properly, Ecosan facilities can be affordable and safe. It conserves water and advocates recycling of plant nutrients thereby promoting livelihood, sustainable agriculture and food security.

Key words: Sanitation, Ecological Sanitation, Sustainable Agriculture

1 INTRODUCTION

Sanitation is about many things to many people but essentially many will agree that sanitation is about the proper management of human excreta, in terms of clean and safe facilities for human interface, storage, treatment, and disposal. Sanitation is clearly about protecting individual and public health against domestic human waste and water borne diseases.

But sanitation has many sides to it. One very important side of sanitation has to do with the environment. Improper domestic liquid waste management can easily pollute the waterways and water bodies surrounding human settlements, especially in the urban and highly urbanized areas.

Another very important side of sanitation which very few people appreciate has something to do with excreta reuse. It is common to think that human excreta is a waste product of human existence and must be disposed off expeditiously. Thinking of human excreta as a resource is not natural to us. At this point in our development, it is practical for us to “flush and forget” our domestic human waste down the sewer pipe or septic tank.

Treating human excreta as a resource is the main thesis of Ecological Sanitation. Aside from dangerous pathogens, human excreta also contain beneficial plant nutrients, i.e., Nitrogen, Phosphorous and Potassium or NPK. Ecological Sanitation or Ecosan, for short, is all about proper and safe harvesting of human excreta and returning plant nutrients it contain back to the soil.

This paper discusses the science and technology behind Ecological Sanitation, its principle and applications.

2 THE DEFINITION AND PRINCIPLES OF ECOLOGICAL SANITATION

Ecological sanitation systems safely recycle excreta resources (plant nutrients and organic matter) to crop production in such a way that the use of non-renewable resources is minimised.

Three (3) fundamental principles of Ecological Sanitation are (Winblad, et. al. 2004):

1. preventing pollution rather than attempting to control it after we pollute
2. sanitizing the urine and feces
3. using the safe products for agriculture purposes

2.1 Preventing pollution rather than attempting to control it after we pollute
The conventional sanitation wisdom tells us to treat the wastewater we produce. Modern cities of developed countries pride themselves of state-of-the-art wastewater treatment. These cities have capital intensive sewerage pipeline and treatment plant infrastructure that enable them to remove pollutants from wastewater before releasing it to the surrounding water environment. London, for example, has come a long way from its 19th century experience when its Thames River was filthy and obnoxiously odorous receiving untreated sewage. Treating water after it has been polluted has become the order of the day for the modern and aspiring-to-be-modern cities.

In city-state Singapore, they went a step further. Wastewater from sewer pipelines is subjected to various treatment processes including reverse osmosis to produce purified water, said to be “cleaner” than potable water from the tap. This sounds logical for income rich but resource poor country like Singapore. Israel, another resource poor country, is noted to recycle more than 90 percent of its wastewater for reuse in agriculture.

Unfortunately, not all cities are created equal. Most cities, especially those in the developing and emerging countries, can hardly afford to install these highly priced sewerage systems. With ill-planned or unplanned built-up urban areas, these low- to middle-income cities have untreated or semi-treated wastewater that pollute their river systems. In Metro Manila, for example, rivers and esteros are considered biologically dead due to inadequate wastewater treatment systems allowing millions of liters of partially treat wastewater to pollute the water ways every single day, 24/7. In the Philippines, less than 15 percent of the households is served by sewerage system; around 80 percent relies on septic tank system which is the default treatment approach. The rest have no treatment at all. At most, the septic tank system is only 50 percent effective in reducing pollution. Un-serviced septic tanks which comprise the majority perform much less.

Ecosan, on the other hand, starts with preventing the generation of wastewater to begin with. In its basic design, human excreta is not flushed down with water. No water is needed. So it is often called the waterless toilet system. This is beneficial in many ways. First, communities using Ecosan dry sanitation do not produce wastewater and therefore has no pollution loading in its water bodies, both surface water and underground aquifers. They also do not need capital intensive sewerage systems and therefore money can be diverted to other basic necessities of the constituents. Moreover, with dry sanitation, waterless communities can have a sanitary toilet option that is far better than a pit latrine. This solves the long standing issue of government providing pour-flush toilets to poor households without toilets.

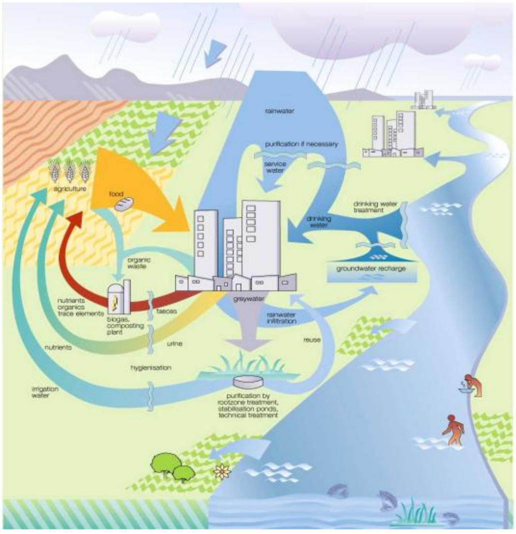

Figure 1 Closing the loop between sanitation and agriculture

2.1 Sanitizing the urine and feces
If sanitation is primarily for health protection, then Ecosan must ensure that human excreta is sanitized for safe handling and reuse. In contrast with conventional wastewater treatment system, Ecosan can render excreta safe at minimal cost and low tech methods.

Human excreta is composed of two fractions: urine, the cleaner fraction, and feces, the dirty fraction. In the conventional water-reliant system, urine and feces are combined and flushed down together. This system renders urine, considered to be sterile and a ready-to-use liquid fertilizer rich in Nitrogen, severely contaminated and useless.

In Ecosan, urine and feces are diverted from one another and are processed and handled separately. The diversion is done through a urine diverting toilet bowl (see Pictures 1 and 22 and Figure 2). Urine is stored for a month, while feces is stored and kept dry for 6 to 12 months, according to WHO guidelines on excreta management. According to some experts, privately produced urine by households with members who are relatively healthy can be used as fertilizer immediately to irrigate their crops. Urine, by natural process, produces urea which has anti bacterial properties. The one-month storage guideline of WHO for urine is designed for multi-source collection, meaning urine collected comes from various generators and the pathogenic quality of the urine is not assured.

Figure 2 A Urine-Diverting Bowl

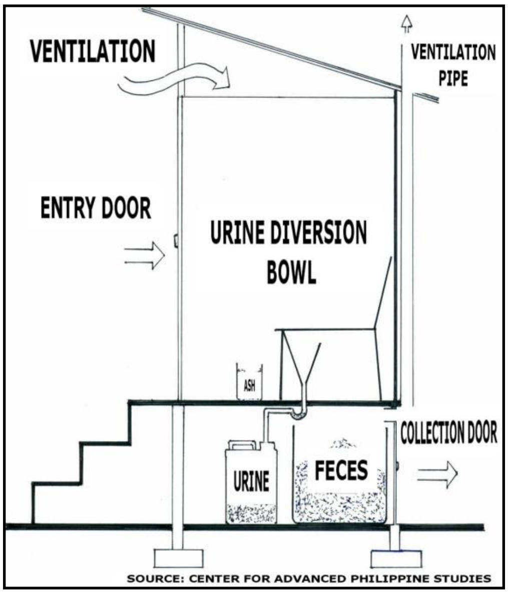

Figure 3 Basic diagram of an Ecosan Urine Diverting Dehydrating Toilet (UDDT)

Figure 4 Typical Ecosan Toilet in La Union Province

Human feces, the dirty fraction, is the most dangerous water pollutant. Feces is host to many pathogens than urine and must be handled with care and treated properly. According to literature, feces can contain at many varieties of disease-causing pathogens. A small amount of feces can contain as much as 10 million virus cells, 1,000,000 bacteria cells and 100-1000 parasite eggs and cysts of intestinal worms.

Table 1 Pathogens in human excreta

	Urine	Feces
Pathogens content	None or very few	High volume
Additional information	Urine from women is prone to fecal pathogens due to female anatomy. Pharmacological residue can be found in urine.	A small amount of feces can contain 10 million viruses 1,000,000 bacteria and 100-1000 parasite eggs and cysts of intestinal worms.

Intestinal pathogens thrive in moist and acidic environment. To kill these pathogens, the feces should be kept dry and, if possible, raise its ph to alkaline level. Applying commonly available absorbent materials, such as wood ash, lime and saw dust, every defecation can promote dehydration and increased ph. Designing the toilet to have adequate ventilation and elevated temperature from heat exposure to sun in the collection chamber can also assist dehydration and odor control. Given the right condition, pathogen die-off occurs rapidly within the first month of storage. In about two to three months, most, if not all the bacteria and viruses are neutralized. The more persistent pathogens are the parasitic eggs. It takes six to twelve months for them to die in hot, dry and alkaline conditions.

Figure 5 Elevated temperature from exposure to the sun promotes dehydration and pathogen die-off

Figure 6 Ecosan Toilet with garden

2.3 Using the safe products for agriculture purposes

Once sanitized, urine can be used as fertilizer because of its high Nitrogen, Phosphorus and Potassium (NPK) content and fecal materials can be buried or composted before reuse as soil conditioner given its high bio-organic content. A person produces around 300 to 500 liters of urine and about 30-50 liter of feces per year. The total nutrient content of this resource is about 4.48 to 7.56 kg of NPK. Most of the NPK (90 %) is in the urine. Only five to ten percent of NPK is in the feces. Of the three nutrients, Nitrogen is the most abundant at 76 percent. Therefore, urine is the more valuable fraction in terms of fertilizer value. Keeping it separated from feces is commonsensical to maximize its potential.

Table 2 NPK content of human excreta per person per year

Nutrients	Urine (300-500 liter)	Feces (30-50 liters)	Total	Percent (%)
Nitrogen	3.1 - 5.6 kg	0.09 kg	3.4 - 5.7 kg	**76.0**
Phosphorous	0.24 - 0.4 kg	0.19 kg	0.36 – 0.6 kg	**8.0**
Potassium	0.6 – 1.0 kg	0.17 kg	0.72 - 1.2 kg	**16.0**
Total NPK	3.94 – 7.0 kg	0.45 kg	4.48 – 7.56 kg	**100**
Percent of Total NPK	**90%**	**10%**	**100%**	

Experiences in Asia, Africa, and Latin America have shown that, with proper management and utilization technique, human urine and feces are effective fertilizers to several crops like, banana, tomato, corn, papaya, eggplant, string beans, guapple (giant guava variety), ornamental plants, and many more. In the Philippines, more than 3,000 Ecosan toilets have been built in several barangays of San Fernando City and Bauang in La Union, Bayawan City in Negros Oriental, Villareal in Samar, Manticao, Initao and Cagayan de Oro in Misamis Oriental (Elmer Sayre, 2010), Panglao in Bohol, among others. Ecosan toilets were also installed in public elementary schools in San Fernando, LU, Sta. Rosa City, Laguna, Cagayan de Oro. Ecosan toilets were also used successfully in emergency evacuation centers in Cagayan de Oro and Iligan during the Sendong Typhoon in December 2011 (CAPS, 2012).

Figure 6 Typical Ecosan Toilet in CDO Evacuation Centers

Figure 7 Ecosan Toilet in CDO Resettlement Site

3 GUIDELINES IN FOR THE SAFE USE OF HUMAN EXCRETA

The World Health Organization is cognizant of the beneficial use of wastewater in agriculture but it cautions everyone that this must be done safely. WHO published in 2006 the guidelines in the proper management and utilization of human excreta in agriculture. In summary, the guidelines put forward the following:

- Application techniques – apply excreta fertilizer on soil, practice caution when using flood and furrow irrigation and spray and sprinkler system
- Crop restrictions – use in non-food crops, food crops that are processed and/or cooked before consumption
- Witholding period – provide adequate interval between final irrigation and consumption
- Procective equipment - use of protective clothing, i.e., boots/shoes and gloves, when applying urine and feces to plants
- Handwashing – rigorous personal and domestic hygiene, frequent handwashing with soap for consumers and field workers; use of separate areas for food preparation; vigorous handwashing after toilet use and fertilizer application
- Health and hygiene promotion – effective hygiene education and promotion required
- Food handling and cooking – vigorous washing of hands and crops during food preparation especially crops and vegetables eaten uncooked for food handlers

4 SUMMARY AND CONCLUSION

Ecological sanitation is a viable sanitation alternative to conventional sanitation. Ecosan has many advantages: it protects and promotes human health; saves water; minimizes environmental degradation by avoiding the generation of wastewater that can pollute water bodies; is affordable and cheaper to build, operate and maintain; and it allows recycling of plant nutrients that help conserve mineral resources like phosphorous. Even the WHO recognizes excreta reuse in agriculture given certain important precautions.

Ecosan is beneficial to rural areas often underserved or un-served by government health and sanitation programs. It provides an alternative to the inappropriate pour-flush toilet system in water scarce areas. It is also applicable during emergency situations. It promotes sustainable agriculture and food security that can alleviate poverty in marginalized areas of the country.

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ENERGY AND RESOURCE EFFICIENCY IN BUILDINGS AND OPERATIONS - SUCCESS STORIES FROM THE PHILIPPINE TOURISM SECTOR

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Abstract:

The Zero Carbon Resorts (ZCR) project has challenged the conventional practices of how tourism establishments operate their buildings and facilities in the Philippines. This paper features a number of practical case studies from tourism SMEs in Palawan. Application of the ZCR method has led to a reduction of up to 63% of costs for energy and water with limited investment. Reasons for these significant improvements were alternative ways to achieve thermal comfort, identification and elimination of energy and resource wastage and a smart realization of energy services.

The required energy services of a hotel can often be supplied from cheaper sources than from electricity, sometime even for free. The building´s envelope can contribute to reducing the cooling load. Hot water can be provided from solar heat and comfortable spaces can be achieved through smart techniques. It is of vital interest for SMEs in the tourism sector to master the challenge of meeting high guest expectations and keeping energy costs affordable at the same time. ZCR provides solutions that target the needed energy services with a corresponding efficient supply system.

The ZCR's 3R (Reduce-Replace-Redesign) intervention ranges from simple measures with low or no investment to efficient high-end technologies depending on the innovation stage the establishments have already reached.

The first 100 members participating in the project reached savings of 142 Million PHP per year for electricity, fuel, water and waste. Currently the project´s 500 members are able reach total savings of half a Billion pesos in operational cost every year. This definitely reduces the environmental pressure and the carbon footprint while at the same time increases the generated value.
The Tourism industry in the Philippines has a high potential for replication of these best practice examples and can become more sustainable by using the ZCR methodology that enables better business in a smart and environmentally conscious way.

Key words : Energy Efficiency; Resource Efficiency; Zero Carbon Resorts; Innovation; Renewable Resources

1 INTRODUCTION

Tourism is receiving increased attention as a development option but with the vulnerability of developing countries to climate change, it is inevitable to take environmental concerns into serious consideration in the tourism business. There is, thus, enough reason for tourism to simultaneously pursue mitigation and adaptation measures. Over the recent decades, Tourism has rapidly grown and represents a large share of the global economy. The total contribution from Travel & Tourism to the world GDP grew by 3.0% in 2012 [WTTC 2012]. This was faster than the growth of the world economy as a whole (2.3%), and also faster than the growth of main industries like manufacturing, financial and business services and retail [WTTC 2013]. In the Philippines, Tourism plays a vital role in its economy, contributing about 6% to the gross domestic product (GDP) and having a 10% share of total employment, directly employing 3.7 million people. The average share of tourism´s direct gross value added in 2010 reached PhP 518.5 billion, that is 13.0 percent higher than 2009's PhP 459.0 billion [NSBC 2011]. As tourism operations rely heavily on the environment, inescapable climate change and global warming have been alarming for the tourism sector. On the other hand shortage of energy and high prices are a main and increasing economic challenge, especially for small and medium sized companies.

Recognizing this critical trend, it is imperative to strengthen sustainable tourism. This is one of the main objectives of the Zero Carbon Resorts (ZCR) project. The ZCR project is funded by the European Union under the Switch-Asia program. The project targets small and medium enterprises (SMEs) such as resorts, hotels and tourism related industries which count for a substantial contribution to energy and water consumption as well as CO_2 emissions and have a high potential for improvement.

As a consequence of the growth of tourism sector in the Philippines, an even larger amount of energy and resource consumption, as well as volumes of waste are observed. The rising demand for comfort, especially for air-conditioned accommodation, is one of the main drivers for the increase on the demand side. A drastic increase in electricity consumption is expected within the next years given the increase of visitors in the Philippines.

The main focus of the project lies therefore on energy and water conservation in SME companies which is systematically addressed by a step by step procedure to significantly reduce consumption and consequently overall pollution and emissions. Tourism enterprises need energy to serve their guests well, high quality energy services are crucial for success in the tourism industry, particularly to meet the increasing demand of users. But it is important to supply this energy in the most efficient and sustainable way. This saves costs and the environment. Due to the poor electricity supply infrastructure and inefficient appliances, energy is one of the highest costs for small tourist businesses. Carbon-neutral energy supply systems, and appropriate local and environmental technology solutions, are required.

2 THE ZERO CARBON RESORTS PROJECT

The Zero Carbon Resorts project (ZCR) started in 2010 in the Philippines, it is led by Gruppe zur Förderung der Angepassten Technologie (GrAT), or Center for Appropriate Technology, which is an Austria-based non for profit organization and R&D center. It is joined by a consortium of implementing partners from Spain, the Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas (PSA-CIEMAT) and from the Philippines, the Palawan Council for Sustainable Development (PCSD) and the Asia Society for Sustainable Transformation (ASSIST). Other associates supporting the project include Department of Tourism (DOT) and Tourism Infrastructure and Enterprise Zone Authority (TIEZA); Department of Environment & Natural Resources (DENR); Department of Energy (DOE);

The project aims to enable better business in the tourism sector and energy services with higher efficiency and lower cost, and to address the growing demand for energy in a smart and environmentally conscious way with its 3-step strategy: Reduce-Replace-Redesign. The project triggers a switch from fossil fuel to the use of renewable energy sources, especially solar energy with the help of a double strategy saving of energy and substitution with renewable sources. Implementation of ZCR by SME members using the 3R methodology (Reduce-Replace-Redesign) reduced up to 63% of their operational costs (energy and water) and therefore created higher value with lower environmental impact.

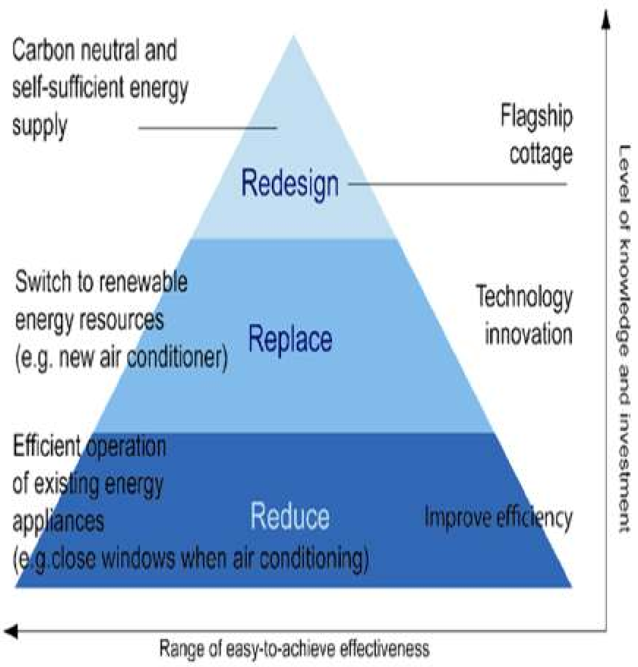


Figure 1 The ZCR Strategy

The progressive "3R" methodology as seen in Figure 1 starts with simple measures with low or no costs that are easy to implement, yet remarkably improve the energy performance (Reduce). To make a change that will both improve energy efficiency and enable a switch to more renewable energy sources, it is crucial to overcome the widespread perception that innovation and change is difficult and expensive. The project therefore adopts a practical step-wise approach. The low-cost

measures in the first step, should give rise to immediate benefits including cost savings and thus strengthen acceptance and continuation.
The next step is to invest the savings gained from the previously implemented solutions in substituting outdated technologies with more efficient ones (Replace) in order to gain further savings. This second step sees technological innovations providing higher levels of efficiency: greener and more efficient alternative technologies replace outdated and fossil fuel-based devices, paid for by the savings made in step one.

For newly established resorts and for expansions of existing businesses the Redesign strategy has been developed suggesting an energy self-sufficient design of the buildings and the supply system. As a tangible showcase, an energy autonomous flagship cottage is designed and constructed that can be replicated elsewhere (Redesign). A corresponding knowledge tool and handbook accompanies each of the three steps for tourism SMEs as a guide to reducing costs.

This multi layered strategy makes it applicable at all stages of development for the targeted companies. Measures range from basic to efficient high-end technologies depending on the innovation stage the establishments have already reached. Innovations are provided at all levels, from an efficient operation of energy-using products, to technical innovations in lighting, ventilation and cooling, up to sustainable architecture strategies.

Table 1 ZCR Project activities overview

<table>
<tr><th colspan="4">ZCR in a Nutshell</th></tr>
<tr><th>Activity Cluster</th><th>Reduce
(1^{st} yr.)</th><th>Replace
(2^{nd} yr.)</th><th>Redesign
(3^{rd} – 4^{th} yr.)</th></tr>
<tr><td rowspan="2">Frontier Group (Case Studies)</td><td>Assessment and Baseline</td><td></td><td>Computation of Benchmarks and Savings</td></tr>
<tr><td></td><td>Monitoring of Performance</td><td></td></tr>
<tr><td rowspan="3">Capacity Building</td><td></td><td>Level 1: Local Promoters</td><td>Level 3: Architects, Planners</td></tr>
<tr><td colspan="2">Level 2: Engineers, Professionals</td><td></td></tr>
<tr><td colspan="3">Frontier Group owners and technicians</td></tr>
<tr><td>Technological Innovation</td><td></td><td>Workshop with local producers (solar water heater, rocket stove, Heat Recovery from Generator's Coolant</td><td>Solar Technology Research and application, Renewable Energy Supply System</td></tr>
<tr><td>Policy Component</td><td></td><td>LGU Resolutions (Palawan)</td><td>Local: SEP (Palawan)
National: DOT Accreditation Standards</td></tr>
<tr><td rowspan="3">Dissemination and Replication</td><td>Conference 1</td><td>Conference 2</td><td>Conference 3</td></tr>
<tr><td></td><td colspan="2">Briefing Sessions (13 Locations all over Philippines)</td></tr>
<tr><td></td><td></td><td>Conference 4</td></tr>
<tr><td>Knowledge Materials and Tools</td><td>-Handbook Vol 1 "Reduce Measures"
-Technical Video Part 1</td><td>-Handbook Vol 2 "Replace: Appropriate Technologies
-Green Technology Catalogue
-Technical Video Part 2</td><td>-Handbook Vol 3 "Redesign: System Solutions"
-ZCR Flagship Cottage
-Technical Video Part 3</td></tr>
</table>

Table 1 shows an overview of the main activities of the project. After the project launched in 2010 it focused on Palawan to create a number of case studies with the so called Frontier Group (FG), which consists of SME representatives of tourism establishments in Palawan. These 30 hotels and resorts serve as model SMEs and have been actively involved from the beginning. All FG members have undertaken energy baseline analysis, a diagnosis of their problems in energy management, and received instructions for improvement as a result. The companies have implemented these recommendations from the ZCR project during the period of the last 4 years. At the same time, addressing the consumption side, campaigns targeted the guests in an effort to trigger their contribution by more environmentally friendly behaviour.

In parallel an intensive capacity building program has been carried out. Engineers, building and facility managers, environmental consultants, as well as hotel and resort owner and staff received knowledge through a series of training courses following the 3R approach. Also, appropriate technology solutions, suitable for local production have been developed and promoted. Such technologies include solar water heaters, improved cooking stove, solar cookers, biogas digesters and heat exchanger. The core strategy is showcasing what is possible and feasible, and displaying the procedures and achievements, should attract more businesses to the step-by-step approach to energy efficiency.

Figure 1 ZCR Appropriate Technologies (left) Solar Water Heater (right) Improved Rocket Stove

With the success of the FGs in achieving efficiency and savings, the project team began its roll out to other areas of the Philippines in 2012 and acquired 500 followers from these examples. The real-life problems and solutions gathered from the FG help other establishments to recognize problems in their own company and to practically follow the instructions, in order to reduce the amount of energy consumption and costs and to improve their energy services.
Their success stories are disseminated to other regions through handbooks and instructional videos. With peer-to peer communication, hotel and resort owners inform each other of their achievements and improvements. These SMEs also function as the main intermediaries between the green technology providers and energy service users (tourists and staff).

Replication and growing community

ZCR constituted a multi-level approach in order to engage a larger number of beneficiaries. It constituted strategic alliances with key communities in order to build synergies with them. It set up the Zero Carbon Resorts virtual platform with two components: one for the public and one for members only. The public site (www.zerocarbonresorts.eu) serves as a platform for information and dissemination. The member site is built on the Zero Carbon Resorts database where the participating SMEs can register, record and monitor their own consumption of resources. The users can discuss topics through the forum. Hotels, resorts, and restaurants who want to improve the quality of their energy services and to reduce operation costs can register through the website to obtain useful information or put their questions to the experts.

The ZCR project conducted briefing sessions together with national agencies like Department of Tourism (DOT) and Tourism Infrastructure and Enterprise Zone Authority (TIEZA) in major touristic areas in order to spread the benefits of the project and to invite SMEs to join the ZCR community. As a consequence more and more new SMEs are signing up as a member. The Project team has successfully conducted briefing session in Bohol, Cagayan de Oro, Batangas, Siargao, Manila, Los Banos (Laguna), Boracay, Aurora-Baler, Legaspi, Hundred Islands, Ilocos, Laoag, Zamboanga, Ilo-ilo and Davao. The briefing sessions have gathered more than 500 participants and more than 200 new members registered to the project as SME or as supporter. In total as of April 2013, the project has reached 910 SMEs through awareness campaigns and acquired 500 members from all over the Philippines.

Tourists and guests of the hotels and resorts are also engaged as a target group in the consumption component of the project, in the form of surveys and campaigns for behaviour change. Tourists and guests are regarded to function as good vectors for dissemination.

Policy adaptation

The projects policy component is aiming at the sustainability of the results and implementing a structural change through the revision of environmental policy by the government. Palawan e.g. has a unique strategic environmental plan (SEP). In order to achieve balance in the plan between development objectives and environmental protection, it set out presents a clearing system for new tourism developments. Each new resort, guest house or hotel, needs official authorization from the Palawan Council of Development (PCSD), a partner in the project which plans to optimize the clearance system. Through this Zero Carbon Resorts practice will become mandatory in future tourism developments.   A temporary solution is already in place, namely to include zero carbon topics in the special terms and conditions issued for individual resorts that apply for approval. Additionally, the project seeks to integrate energy efficiency indicators into the monitoring system that ensures hotels, resorts or other tourism projects are pursuing sustainable development objectives.

3 CASE STUDIES OF ZCR MEMBERS

Is it really necessary to spend as much as you are spending currently, and how can you save? The required energy services of a hotel can often be supplied from cheaper sources than from electricity, sometime even for free. The building´s envelope can contribute to reduce the cooling load. Hot water can be provided from thermal sources and comfortable spaces can be achieved through smart techniques. It is of vital interest for SMEs in the tourism sector to master the challenge of meeting high guest expectations and keeping energy costs affordable at the same time. ZCR provides solutions that target the needed energy services with a corresponding efficient supply system. The following cases show selected examples from a measure database covering 160 implementations to date. The samples are taken from FG members in Palawan who have experienced remarkable savings in their energy and resource consumption through the application of ZCR project tools and solutions.

3.1 Implemented Energy and Resource Saving Measures

<u>REDUCE Strategy:</u>

Figure 2 (before) Comfort room with no door spring (after) Comfort room with door spring

Door springs automatically close the comfort room doors after use. This prevents the loss of cooled air from the sleeping area and thus saves energy from the use of AC.

Figure 3 (before) Candle light as table lamps (after) Used cooking oil as fuel for table lamps

One of the cheapest ways to reduce costs in the hotel or resort is to replace candle light with table lamp fueled by used cooking oil. Used cooking usually ends up as waste in the sewage which contributes to the clogging of piping system and will also require high costs for its treatment.

Figure 4 (before) Dark brown colored roof (after) White Elastomeric Paint coating on top of the existing brown colored

White paint is 23°C cooler than the brown. This proves that white colored roofs help in reducing the heat gain by reflecting sunlight and can consequently save energy cost for cooling.

<u>REPLACE:</u>

Figure 5 (before) Unorganized electrical wiring system may cause danger (after) Organized and labelled electrical wiring system

Unorganized electrical wiring system has been replaced with a new electrical wiring system which is much safer and easier to manage. It has been considered as a worthy investment, since energy wastage could be eliminated with the improved wiring system.

Figure 6 (before) Window type non inverter A/C; (after) Split type inverter A/C

An oversized A/C is actually less effective; it uses more electricity and leaves the air in the room with excess humidity. While, A/C that is too small do not cool the room to a comfortable temperature. A properly sized unit will remove humidity effectively as it cools.

Figure 7 (before) Old and inefficient freezers, (after) New and efficient freezers and refrigerators

For most of island resorts, generators are the usual source of energy supply. In order to cut down on energy demand, old refrigerator and three freezers have been replaced with highly energy efficient ones.

Figure 8 Installation of tubular solar lighting

Daylight systems, such as tubular solar lighting can be used to direct sunlight into the required areas. The main idea of this design is to channel the sunlight, through a cylindrical metal tube, to the desired destination inside the building. Varied methods are available for implementing natural lighting. With the growing awareness and the benefits attached to it, natural lighting has become a very eco-friendly solution and truly zero carbon which has been already opted by many of the ZCR members

<u>REDESIGN:</u>

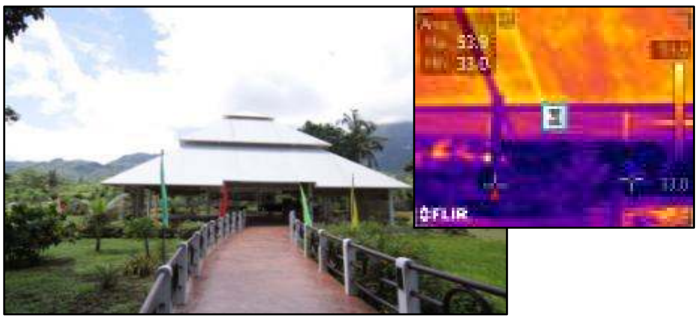


Figure 9 Before: The heat of the sun hits the tent (conference pavilion) roof and the surface temperature of 55 °C

The open pavilion at Daluyon Beach and Mountain Resort in Sabang, Puerto Princesa is a good example how providing comfortable spaces can be achieved through smart techniques.

Before the consulting of the ZCR project team, the conference pavilion did not have any cooling facilities. Due to the material of the membrane, the solar radiation partly penetrated the roof. This increased the inside surface temperature up to 55 °C. As a consequence it was incredibly hot inside!

Figure 10 After: Improved pavilion with installed water sprinkler, insulation at the roof, wooden ceiling and rattan chandelier for better aesthetic effect and as an added insulation

Instead of closing the sides of the entire structure and providing four units of air-conditioners which was quoted at PhP 680,000, Daluyon Beach & Mountain Resort opted for a simpler solutions recommended by the ZCR team, to install a layer of insulation and reflection on the roof of the tent and to utilize a water sprinkler to cool down the roof surface by means of evaporation. The temperature inside the tent has been remarkably reduced by an average of 8 °C on a hot sunny day. This makes it much more comfortable and useable. The sprinkler operates on a closed loop system: it uses rainwater collected from the roof and stored in a cistern from where it is re-circulated. The water pump consumes 350W only when in use. The refurbishment of the conference pavilion is a good example of passive cooling, saving energy as well as investment costs, and increasing the comfort of users at the same time.

OTHER ENVIRONMENTAL MEASURES:

Other implementations of environment conservation include segregation of wastes at source. Upon collection, recyclable materials are brought to a materials recovery facility (MRF) and biodegradable wastes are processed into composts.

Figure 11 Backyard gardening (Locavore)

Composts are used to fertilize vegetables that are grown in the backyard. Backyard gardening also called "Locavore" offers fresh harvest and ensures the guests pesticide free food.

Figure 12 Reed bed system for wastewater treatment

Instead of using energy and cost intensive waste water treatment facilities, a natural way of treating waste water can be implemented. A constructed wetland was installed using reed to treat the waste water and recycle it for watering the plants. Different from conventional treatment systems, no operating energy e.g. for aeration is needed.

4 ZCR PERFORMANCE

Reasons for the significant improvements that have been achieved were alternative ways to create thermal comfort, identification and elimination of energy and resource wastage and a close match of supply and demand.
January 2012, one of the best performing Frontier Group members, Daluyon Beach & Mountain Resort has been chosen as one of the recipients of the 3rd ASEAN Green Hotel Recognition Award. It shows that through ZCR, hotels are not only able to save a lot of energy, emissions and money but can also gain recognition.

The overall environmental and economic performance of Frontier Group members indicates significant figures. Best performers were able to save as much as 63% of the monthly costs for energy and water they had before joining the project.

Table 2 Frontier Group Overall Savings

SAVINGS	TRANSLATION OF SAVINGS
Energy Savings per year = **974,989.01 kWh**	= Equivalent consumption of **2, 300 homes** (as per Approtech Asia, 2005, one home consumes 423 kWh/yr)
Fuel Savings per year = **120,826.07 L**	= Equivalent Fuel consumption of **140 cars** (as per EPA (2008), one car with a fuel economy of 8.2 L per 100 km and driving range of 10,000 km consumes 820 L/yr)
Water Savings per year = **8,910,168.00 L**	= Equivalent Consumption of **70 homes** (as per LWUA Philippines (2005), one low income group consisting of 5 people consumes 122,275 L/yr)
Avoided Emissions per year = **843,516.35 kg CO_2**	= Equivalent Emissions of **400 cars** (as per EPA (2008), one passenger vehicle emits 2,100 kg CO2/yr)

Table 2 shows the annual savings for the 30 Frontier Group members. The translation of these savings indicates the equivalent form of consumption saved. The savings of 974,989.01 kWh is equivalent to the energy consumption of 2300 homes; the 120,826.07 L saved equals the fuel consumption of 140 cars; 8,910,168.00 L saved an equivalent consumption of 70 homes and in total saved 843,516.35 kg CO_2 equivalent to the emissions of 400 cars.

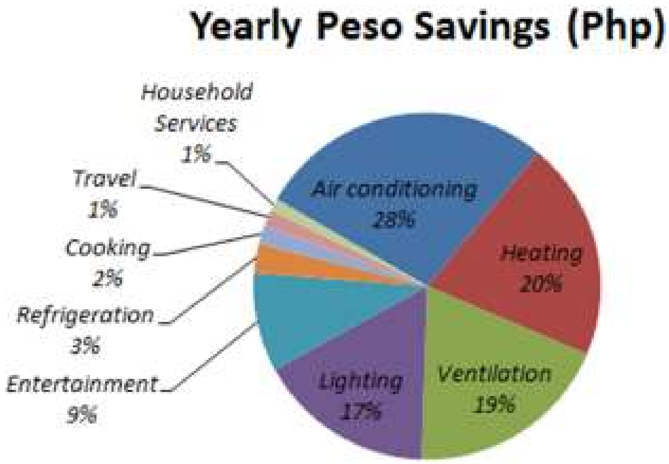
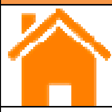
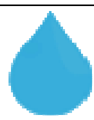


Figure 13 Breakdown of savings according to Energy Services

The breakdown of savings according to energy services of the Frontier Group as shown in Figure 14. Highest annual savings originates from air conditioning which accounts for 28% of the total savings, followed by water heating 20% and ventilation 19%. Lighting accounts for 17% and 16% savings came from other energy services.

Table 3 100 ZCR Members Overall Savings

SAVINGS	TRANSLATION OF SAVINGS
Energy Savings per year = **6,150,021.03 kWh**	 = Equivalent consumption of **14, 500 homes** (as per Approtech Asia, 2005, one home consumes 423 kWh/yr)
Fuel Savings per year = **1,452,834.31 L**	 = Equivalent Fuel consumption of **1,700 cars** (as per EPA (2008), one car with a fuel economy of 8.2 L per 100 km and driving range of 10,000 km consumes 820 L/yr)
Water Savings per year = **43,382,517.39 L**	 = Equivalent Consumption of **350 homes** (as per LWUA Philippines (2005), one low income group consisting of 5 people consumes 122,275 L/yr)
Avoided Emissions per year = **5,892,678.87 kg CO_2**	 = Equivalent Emissions of **2,800 cars** (as per EPA (2010), one passenger vehicle emits 2,100 kg CO2/yr)

In total, the savings per year in only 100 of participating member companies in the ZCR project, that the project has analyzed so far accounts to **142Million Php per year** and CO_2 emission saved per year reached up to **5,892,678.87 kg**. This is an enormous environmental impact and at the same time, economic returns for the members. The monitoring and computation of savings is still ongoing and for all 500 companies, the project will certainly see much higher numbers.

5 CONCLUSIONS

Not only does tourism contribute to climate change, it is affected by it as well. Energy efficiency can lessen the use of fossil fuels and it is an effective way to address climate change. With the decentralized approach and affordable technologies introduced in the "Replace" and "Redesign" strategy of the ZCR project, establishments in remote and urban areas have access to clean energy supply for their energy needs with less dependence on grid connections or generators. The ZCR project provides practical options to save on energy costs through a step by step approach.

Making any business more sustainable is a good economic choice. It goes directly to the bottom line as shown from the figures of savings incurred. The introduction of energy and resource saving measures will translate into both environmental and monetary savings for companies. This makes ZCR project a good business choice for the SME tourism companies, and an

important step forward towards high value low impact tourism. On the other hand, there is a growing market demand for sustainable tourism and guests are willing to pay a little more for efficient services and environment friendly goods.
By increasing energy efficiency, changing peoples' behaviour, implementing green technologies, and using locally available resources, the carbon footprint of tourism can be significantly reduced.

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ENVIRONMENTAL PERFORMANCE ASSESSMENT OF RESIDENTIAL GREEN TECHNOLOGIES USING PHILIPPINE GREEN BUILDING RATING SYSTEMS

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Abstract: The residential sector is one of the main contributors of greenhouse gasses frequently trapped in the atmosphere, causing adverse global effects such as global warming and climate change. Scientists, environmentalists and other professionals constructed green technologies and formulated green strategies to mitigate these said effects. There are a lot of ways in quantifying the environmental benefits presented by these technologies and strategies, from actual observation, computer modelling and through secondary data such as previous published studies and references. The third method was used as the main source of data for compiled green technologies and strategies for this research. With the use of the three most common green building rating systems in the Philippines, Quezon City Green Building Rating System (QCGBRS), BERDE and LEED, the potential scores presented when the technologies are evaluated serve as their environmental performance rating for that respective rating system. Among the 15 green technologies compiled, “Green Roofs” is the best green technology for QCGBRS, “Bamboo Residential Housing” for BERDE and “Thermal Wall Insulation Systems” for LEED. Technology combinations were also formulated for simultaneous integration of technologies according to resident density in a structure. From the overall scores, LDRC1, MDRC3 and HDRC2 are the most desirable green technology combinations for low, medium and high density residential structures respectively. Lastly, three checklists are formulated for each of the three rating systems to evaluate and quantify the environmental performance of future green technologies/strategies not listed on the database. This makes the study open to updates and new information.

Key words: Green technologies; environmental performance; assessment

1 INTRODUCTION

As years progress, the issue of increasing greenhouse gas emissions has been the centre of attention among environmentalists all over the world. One of the largest contributors of greenhouse gasses released in the atmosphere is the residential sector. Studies conducted by the World Resources Institute (WRI) suggested that 9.9% of the world’s greenhouse gasses were attributed to the residential sector (World Resources Institute, 2005).

There are many chemical compounds identified in the Earth’s atmosphere acting as “greenhouse gases.” These greenhouse gases allow sunlight to enter the atmosphere freely. As the sun strikes the Earth’s surface, some of it is reflected back towards space through infrared radiation, or in simple terms heat. The not so beneficial acts of these greenhouse gases then take place as this infrared radiation is absorbed by them, trapping the heat in the atmosphere. This process is the fundamental cause of the so-called “greenhouse effect” where in general terms is a process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases and is re-radiated in all directions.

Most of the greenhouse gas emissions released by the residential sector mainly comes from power consumption. A study on American homes by the United States Energy Information Administration (USEIA) mentioned that the residential sector accounts for 1.2 billion metric tons of energy-related carbon dioxide, 71% of which is produced at power plants providing homes electricity. It was also estimated that residential sector emissions have grown steadily at an average annual rate of about 1.0% since 1990 (USEIA, 2012).

To mitigate the ever-increasing greenhouse gas emissions, particularly those attributed to the residential sector, the field of engineering contributed what we call “green technologies” that are integrated to residential structures. Green technologies in other terminologies may also be called as environmental technologies or clean technologies (OECD, 2011). With sustainable development as its core, these technologies may encompass the aspects of energy conservation, materials recycling, renewable energy production, sewage treatment, solid waste management, air and water purification, environmental remediation, etc. that in turn aim to conserve the natural environment and curb the negative impacts of human involvement.

Green technologies are devices that are integrated either within or outside the residential structure. Some devices require installment during the construction phase while others may take the role of add-ons or those that can be installed even if the structure was built already. Green technologies are also not limited to devices but also planning and strategies to sustainably build the structure. With the integration of these green technologies, the residential structure itself and the household residing in them may already contribute to the lessening of greenhouse gas emissions attributed to the residential sector. It is also possible to simultaneously integrate different green technologies to a structure, though studies must be performed regarding their compatibility to one another.

With green technologies/strategies comes also the use of green building rating systems. Green building rating systems are tools constructed in order to measure and evaluate the environmental performance of a building, whether it may be a residential, commercial or industrial structure. They are constructed to provide building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions. The rating systems cover a broad range of environmental considerations mainly covering the three stages of a buildings life, namely the construction phase, maintenance and operation phase, and the abandonment/demolition phase.

Most common green building rating systems that served as foundations of different national green building systems around the world are LEED and BREEAM green building rating systems (USGBC, 2006). LEED stands for Leadership in Energy and Environmental Design which is created by the U.S. Green Building Council and adapted in the United States while BREEAM stands for British Research Establishment Energy Assessment Matrix which is adapted to the United Kingdom.

In the Philippines, three green building rating systems were adapted and commonly used. These are the Building for Ecologically Responsive Design Excellence (BERDE) rating system, LEED rating system which acts as a third-party rating system and the Quezon City Green Building Rating System (QCGBRS). BERDE is constructed under the Philippine Green Building Council (PhilGBC) having the BREEAM and LEED influence (Mabasa, 2011). The Quezon City Green Building Rating System is constructed under the Quezon City government to suit the city's personal environmental concerns. As of the moment, there are five LEED Certified buildings in the Philippines and these are the Asian Development Bank, Nuvali One Evotech, Shell Shared Services Office, and Texas Instruments in both Baguio and Clark (Malaya, 2012).

2 PROBLEM STATEMENT

The Philippines being an archipelagic country is highly subjected to climate change impacts. With this threat in mind, the country was one of the countries that signed numerous protocols and conventions involving the reduction of greenhouse gas emissions. But the studies at the present suggest that the mitigation of greenhouse gases is still insufficient as human activities and urban development outrun these mitigations. The lack of knowledge and participation of most Filipinos on how to lessen their greenhouse gas emissions impede the steps in the mitigation procedures.

The study focuses on determining what available green technologies are readily implementable to the residential sector and at the same time on how to quantify the effects of green technologies when they are integrated to a residential structure, whether they be individually integrated or simultaneously integrated with other technologies. This quantification process will be based on the three green building rating systems that are most commonly used in the Philippines, which are BERDE, QCGBRS and LEED.

3 SCOPE AND LIMITATIONS

The study is limited on the green technologies implementable to the residential sector. Those which are exclusive to the agricultural, commercial and industrial sectors are not included. Also, the green technologies being considered were not restricted to those technologies currently implemented in the Philippines but those that are implemented around the world. This is to consider new green technologies that may be potentially applied and adapted to the country.

Also the green technologies are not limited to the fully developed technologies that are currently implementable to a structure but those also at the prototype stage or still under development to consider their usefulness in the future since they are still developing. The residential sector under the study includes low density, medium density and high density buildings as defined under Presidential Decree No. 1216 in section 1.1.3.

4 OBJECTIVES

The following are the tabulated objectives of the research:

- To construct a database containing the available green technologies/strategies adapted throughout the world for the residential sector.
- To quantify the environmental performance of residential green technologies based on LEED, BERDE and QCGBRS when integrated individually or in combination with other green technologies to low, medium or high density residential.
- To construct a checklist that will guide others in determining the environmental performance of new green technologies/strategies that will be available in the future.

5 METHODOLOGY

The process that completes the research is divided into six major processes. The methodological framework below identifies these six major activities that were done for the successful completion of the research.

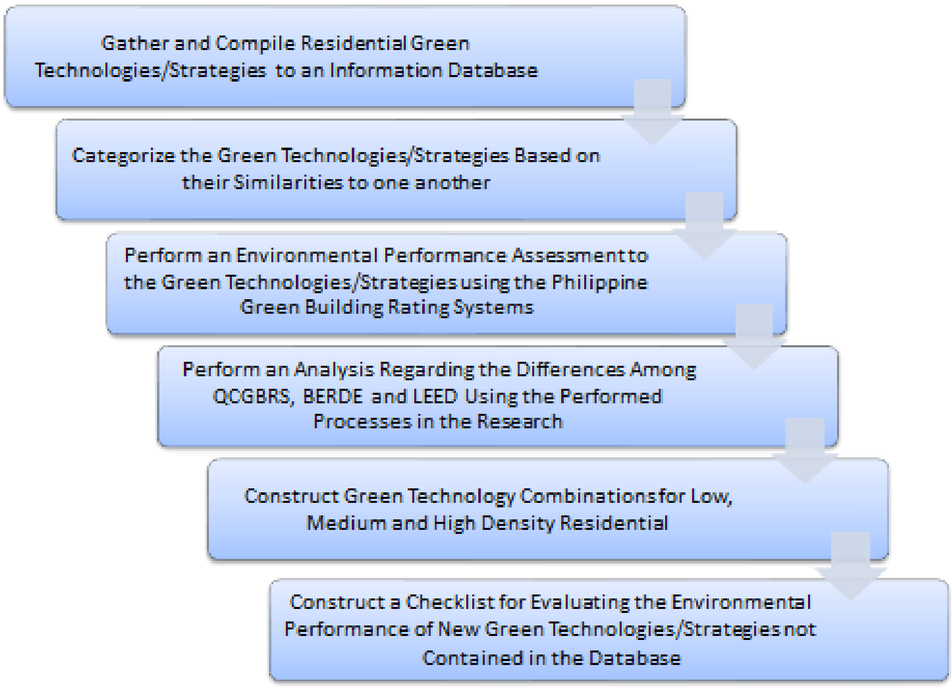

Figure 1 Methodological Framework of the Research

The research will start by first finding literatures pertaining to green residential technologies or strategies. The green technologies/strategies gathered will mostly come out from reliable sources such as books and published journals. Internet sources will be of secondary reference materials. The preliminary gathering of related literature may be conducted first by assessing whether the title of the said literature is more likely related to the research topic. The in-depth analysis of the references is actually performed by thoroughly reading and understanding their contents. Information such as the country of implementation where the green technology/strategy was observed should be considered to conclude whether there is a high chance that it may be implemented to the country.

The green technologies and strategies compiled on the database will be subjected to categorization based on their similarities. The grouping will be based on the information presented on the references and the in-depth analysis conducted among the technologies/strategies. The results of the categorization will be discussed on the results and discussion section.

The environmental performance of the green technologies/strategies is evaluated using Quezon City, BERDE and LEED rating systems. The technologies will be assessed as if they are part of the residential structure. So the technology's role in the structure is to give more potential scores than the default structure alone. The evaluation of the green technologies/strategies will start by outlining the necessary details of the criteria contained in the rating systems. The requirements to give a green technology/strategy potential score will be listed in short statements to easily perform the evaluation process. After the outlining procedure is done, the next step would be the evaluation of each of the green technologies/strategies compiled in the database. The green technologies/strategies will be analyzed per criteria they are subjected to in each of the three green building rating systems. This means that three potential scores will be generated for each technology/strategy, one for Quezon City rating system, one for BERDE and one for LEED. For the ease of analysis of the acquired data, the technologies are ranked based on the amount of score they got from the evaluation. Three rankings will be generated, one for each of the rating system being studied.

When the presented technology/strategy rankings of the three green building rating systems differ, it may be implied that there are also differences existing among the rating systems themselves. Differences may be seen through the amount of points allocated among the criteria reflecting the immediate objectives and priorities they want to achieve. The analysis performed regarding the differences among the rating systems will be shown as statements. The rating systems will be compared with one another implying their immediate priorities and objectives they want to accomplish. The statements will also mention what green technologies/strategies are most suitable to integrate when the structure is evaluated using one of the three rating systems being studied and will explain the reasons why.

After the analysis of the three green building rating systems was finished, the construction of green technology combinations for low, medium and high density residential will take place. From the current trend, studies have shown that there is a decreasing efficiency of green technologies/strategies as they are integrated in high density residential structures such as condominiums compared to low or medium density ones as impacted by different factors such as improper usage and human behavior (Fong, 2012). Therefore, proper selection of technologies/strategies is done based again on the backgrounds and descriptions on their references. Also, some of the journals and references where the technologies are described have been tested to actual or prototype houses and results from this integration may indicate whether they are effective or not to be implemented in low, medium or high density residential structures.

Several combinations will be created which is mainly based on their compatibility with one another. If one technology is incompatible to another technology, then it will be put in another combination of technologies without its incompatible technology on the list. Then, like what was done on the evaluation of the individual technologies earlier, it will also be done in this process where the main difference is evaluating a series of technologies simultaneously instead of one. The assessment will done such that if a technology in a combination already had been given credits for a certain criteria in the rating system, the other technologies that also affect the criteria will be given no credits so that no additional points will be acquired for that combination and the assessment will be more accurate.

After the formulation of combinations was done, checklists will now be created, opening the research for future updates and new green technologies not listed in the database. The checklist will be a set of questions answerable by “yes” or “no”. The questions will most likely represent the questions asked in the green building rating systems where if a technology satisfied all the requirements presented in a criterion, it will be given the maximum points the criterion may offer. Each of the green building rating system will have its own set of questions since some of their criteria differ in requirements to satisfy compared to the other. The evaluator will fill up this checklist with his answers depending on the amount of data he has regarding his new green technology/strategy he wants to assess. Basically, if the evaluator obtained enough information in his technology that may enable him to answer all questions then he may more or less acquire a potential score depending on what green building rating system he wants to use.

6 REVIEW OF RELATED LITERATURE

There are 15 green technologies compiled in the database. The thesis book contains all the necessary information regarding the descriptions and background information for the green technologies contained in the database. Since it is impossible to mention all of them in this summary paper, it is recommended to consult the thesis book itself.

Next would be the Philippine green building rating systems. The two green building rating systems most commonly used and implemented in the Philippines would be LEED and BERDE (Llemit, 2011). As of 2011, Quezon City, the most populous city in the Philippines and one of the cities that make up Metro Manila formulated its own set of rating system that will suite the city’s structures. The Quezon City Green Building Rating System is also a first in terms of giving credits and incentives to those promoting greenness in buildings as they give off tax reductions depending on the rating of the building (DBO, 2011).

These rating systems have their own specific criteria which are mainly formulated by a team of experts. Generally, the criteria of the rating systems centralize on efficient use of energy and water, protection of household health and improvement of employee productivity, and reduction of waste, pollution and environmental degradation (USEPA, 2009). Green building rating systems are most likely the same in terms of their objectives though their differences may be pointed out through their priorities which are seen on the point distribution systems. One group of criteria which addresses a specific problem may have higher potential points than the other in one rating system while the next rating system may have allocated not as high as the previous one. The tables below shows the allocation of points of the three green building rating systems in consideration with their respective building ratings.

Table 1 Quezon City Green Building Rating System Distribution of Points (DBO, 2011)

Distribution of Points	
Group of Criteria	Points
Land/Site Sustainability	19
Energy Efficiency	32
Water Efficiency	30
Materials & Resources	12

Indoor Environment Quality	7
Total	100

Table 2 Quezon City Green Building Rating System Building Classification based on Acquired Green Points (DBO, 2011)

Building Classification		
Green Points	**Rating**	**Tax Credit**
90>	Super Gold	25%
70-89	Gold	20%
50-69	Silver	15%
0-49	Certified	0%

Table 3 BERDE Green Building Rating System Distirbution of Points (PhilGBC, 2010)

Distribution of Points	
Group of Criteria	**Points**
Management	14
Land Use & Ecology	20
Water	7
Energy	9
Transportation	18
Indoor Environment Quality	6
Materials	4
Emissions	11
Waste	7
Heritage Conservation	4
Innovation	10
Total	110

Table 4 BERDE Green Building Rating System Building Classification based on Acquired Green Points (PhilGBC, 2010)

Building Classification	
Green Points	**Rating**
90>	5 Stars
80-89	4 Stars
70-79	3 Stars
60-69	2 Stars
50-59	1 Star

Table 5 LEED Green Building Rating System Distribution of Points (USGBC, 2009)

Distribution of Points	
Group of Criteria	**Points**
Sustainable Sites	26
Water Efficiency	10
Energy and Atmosphere	35
Materials and Resources	14
Indoor Environmental Quality	15

Innovation in Design	6
Regional Priority	4
Total	110

Table 6 LEED Green Building Rating System Building Classification based on Acquired Green Points (USGBC, 2009)

Building Classification	
Green Points	**Rating**
80>	Platinum
60-79	Gold
50-59	Silver
40-49	Certified

7 RESULTS AND DISCUSSION

The study involves 15 residential green technologies which will be subjected into different categorizations in the next sections of the paper. These technologies shall be Cool Roofs, Green Roofs, Solar Roofs, Wind Turbines, Building Integrated Photovoltaic Cells (BIPVs), Solar Power Water Heaters, Earth Cooling Tubes, Thermal Wall Insulation Systems, Anaerobic Fermentation Systems, Insulated Glazed Windows, Efficient Retrofitting of Houses with Air Leaks, Solar Indoor Heating, Strategic Placing of Vegetation and Trees Around Residential Areas, Wood-Intensive Housing and Bamboo Residential Housing.

The categorization of green technologies is spilt into two parts, the first one describes their stage of development as of the present and the other one is their role and beneficial emphasis that they are contributing to the residential structure.

For the first categorization, three technologies are still under development while the other remaining technologies are considered fully-developed. The three belonging on the former group include “Earth Cooling Tubes”, “Anaerobic Fermentation Systems” and “Bamboo Residential Housing.”

For the second categorization, the technologies are split into four distinct groups. These are “Materials Innovation and Efficiency”, “Electricity Generation”, “Water Efficiency and Heating” and “Indoor Cooling and Heating.”

The green technologies belonging to the first group include “Wood-Intensive Housing” and “Bamboo Residential Housing.” For the second group, “Wind Turbines”, “BIPVs”, “Solar Roofs” and “Anaerobic Fermentation Systems.” The third group contains “Solar Power Water Heaters” while the last group contains the largest amount of green technologies such as “Efficient Retrofitting of Houses with Air Leaks”, “Strategic Placing of Vegetation around Residential Areas”, “Cool Roofs”, “Green Roofs”, “Efficient Window Selection”, “Solar Indoor Heating”, “Earth Cooling Tubes” and “Thermal Wall Insulation Systems.”

The potential scores of the green technologies / strategies are summarized through the implementation of the ranking system provided in the upcoming tables. Table 7, 8 and 9 will present the technological rankings for QCGBRS, BERDE and LEED respectively. The number on the right signifies their acquired potential score in that green building rating system. Those technologies with equal potential score are just arranged alphabetically in the table and can be treated with equal ranking status.

Table 7 Green Technology Rankings for QCGBRS

Green Technology Ranking	**Green Technology Name**
1st	Green Roofs (47)
2nd	Strategic Placing of Vegetation and Trees Around Residential Structures (40)
3rd	Anaerobic Fermentation Systems (30)

4th	Cool Roofs (22)
5th	Solar Power Water Heaters (18)
6th	Thermal Wall Insulation Systems (16)
7th	Earth Cooling Tubes (14)
8th	Efficient Window Selection (Double Low-e Glazing) (14)
9th	Efficient Retrofitting of Houses with Air Leaks (12)
10th	Bamboo Residential Housing (11)
11th	BIPVs (11)
12th	Solar Roofs (11)
13th	Wood-Intensive Housing (11)
14th	Solar Indoor Heating (10)
15th	Wind Turbines (8)

Table 8 Green Technology Rankings for BERDE

Green Technology Ranking	**Green Technology Name**
1st	Bamboo Residential Housing (33)
2nd	Strategic Placing of Vegetation and Trees Around Residential Structures (30)
3rd	Wood-Intensive Housing (23)
4th	Anaerobic Fermentation Systems (20)
5th	Green Roofs (14)
6th	Efficient Window Selection (Double Low-e Glazing) (12)
7th	Efficient Retrofitting of Houses with Air Leaks (10)
8th	Thermal Wall Insulation Systems (9)
9th	BIPVs (8)
10th	Earth Cooling Tubes (8)
11th	Cool Roofs (7)
12th	Solar Indoor Heating (6)
13th	Solar Roofs (6)
14th	Solar Power Water Heaters (5)
15th	Wind Turbines (4)

Table 9 Green Technology Rankings for LEED

Green Technology Ranking	Green Technology Name
1st	Thermal Wall Insulation Systems (28)
2nd	Anaerobic Fermentation Systems (26)
3rd	Earth Cooling Tubes (23)
4th	Efficient Retrofitting of Houses with Air Leaks (22)
5th	Strategic Placing of Vegetation and Trees Around Residential Structures (22)
6th	Bamboo Residential Housing (20)
7th	Efficient Window Selection (Double Low-e Glazing) (17)
8th	Wood-Intensive Housing (16)
9th	Green Roofs (14)
10th	Solar Indoor Heating (14)
11th	BIPVs (12)
12th	Solar Roofs (12)
13th	Solar Power Water Heaters (10)
14th	Wind Turbines (9)
15th	Cool Roofs (7)

Next would be the results regarding the formulation of technology combinations. Table 10 shows the green technologies and their applicability status to low, medium and high density residential with x symbolizing as "implementable technology" and o as "not implementable technology."

Table 10 Implementable Green Technologies to Low, Medium and High Density Residential

List of Green Technologies/Strategies	Low Density	Medium Density	High Density
Strategic Placing of Vegetation in Residential Areas	x	x	o
Cool Roofing	x	x	x
Green Roofing	x	x	x
Efficient Window Selection	x	x	x
Wind Turbines	x	x	x
Building Integrated Photovoltaic Cells (BIPVs)	x	x	x
Solar Roofing	x	x	x

Solar Power Water Heaters	x	x	o
Earth Cooling Tubes	x	o	o
Bamboo Residential Housing	x	o	o

There are four green technology combinations created for low density residential, three for medium and three also for high. Looking at the thesis book, LDRC1 is the most beneficial technology for low density, MDRC3 for medium and HDRC2 for high density. For more details, consult the thesis book.

The checklist is constructed in order for the research to be open to updates, especially to new technologies/strategies that may occur in the future and needs evaluation of their environmental performance as done in this study. The three checklists formulated are for QCGBRS, BERDE and LEED respectively and one is created for each since a criterion with the same objectives among all three of them may give different requirements for attaining the desired points allocated to it. They are formulated according to categorization 2 of the research, which is the role of the green technology to the residential structure. For more details, consult Sections 3.6 and 4.6 of the thesis book.

8 CONCLUSIONS

Residential green technologies were compiled to an information database with their backgrounds and information provided by secondary data, particularly through previous published studies, journals and other references. Their environmental performance was quantified by determining their potential scores when subjected to assessments from the three most commonly used green building rating systems in the Philippines, QCGBRS, BERDE and LEED. The green technologies are ranked based on their acquired potential scores from the three rating systems and the technologies with the most points indicate that they are the best to implement when a residential structure is evaluated using one of the three rating systems presented in the research. This together with the point distribution analysis performed on the rating systems pinpointed the differences existing among the three rating systems such as their priorities and objectives. Technology combinations are also formulated in order to simultaneously integrate several green technologies/strategies in a structure, with their compatibility with one another as the basis. Lastly, a checklist for each rating system was created to evaluate future green technologies/strategies not included in the database, making the study open to upcoming updates and new information.

With the rankings presented on the tables above, it was found out that the best technology to implement when the residential structure is evaluated using QCGBRS would be “Green Roofs”. BERDE’s best green strategy would be the use of bamboo in building a residential structure while for LEED, the implementation of “Thermal Wall Insulation Systems.”

When talking about simultaneous integration of technologies in a single structure, for low density residential, the best combination to implement would be LDRC1. For medium density residential the best combination to use would be MDRC3 and for high density residential, HDRC2.

9 RECOMMENDATIONS

The potential scores for each compiled residential green technology generated by the study are numbers to help quantify their environmental performance. But with books and references discussing only the specifics of each criterion for LEED, it is unavoidable to be concerned for the scores presented to QCGBRS and BERDE. Though each criterion presented in LEED may also be in BERDE and QCGBRS, there are some that may require additional requirements which make the giving of points uncertain at some points. Therefore, it is recommended to make further studies for each criterion presented in QCGBRS and BERDE, especially the consultation and verification of each green building rating system representative to the potential scores acquired for each green technology/strategy.

The three checklists created for each rating system are basically summarized and simplified versions of QCGBRS, BERDE and LEED. The questions represent the most influential criteria that gave points to the 15 technologies compiled. With the introduction of new green technologies/strategies in the future and to make the evaluation more accurate, it would be best to consult again the rating system and look for criteria that may give additional points to the new technology and include these criteria in a form of questions to the checklists. Overall, the checklists formulated are still open to updates and revisions.

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FOUR- CHAMBER COCHLEA BOX MODEL: ESTABLISHING ACOUSTIC COMFORT, ILLUSTRATING INJURY AND TOWARDS THERAPY

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Abstract: The unrolled cochlea is modeled using the finite-element software ANSYS, with four inner chambers representing the Scala Vestibuli contiguous with the Scala Tympani thru a rounded helicotrema, the Scala Media, the inner and the outer hair cells. The tectorial membrane is represented as a plate in contact with the hair cells. An improvement to previously presented results is the inclusion of a tapered helicotrema. Various geometries are compared, i.e. with straight sides and with tapered sides, and see the differences in the frequency response of the models. Applying real values for material properties and the human hearing range and using characteristic frequency at certain nodes inside the Scala Media, the tapered model is calibrated to establish the reference comfort. Hearing injury is regarded by subjecting nodes to increased sound pressure levels until the frequency response disappears. This is done at the same time monitoring the change in electrical potential in the inner and outer hair cell regions. The potential change between the normal and the injured conditions is inputted to the Gibbs energy equation for the ATP-ADPase glycolysis to identify a possible route to remedy.

Key words: Cochlea, ANSYS, Hearing Injury, Therapy, Thermodynamics

1 INTRODUCTION

The human cochlea is located in our inner ear region and is responsible for transforming the sounds we hear into electrical signals passing them to the brain for processing and interpretation. The cochlea in vivo is a tapering, spirally coiling, fluid filled, complex organ, however unrolled box models (See Fig 1.) are frequently used in theoretical studies (Neely and Kim, 1986; Steele and Kim, 1999; Nobili and Vetesnik, 2005) or in basic configurations in the development of prototype micromechanical hearing devices.

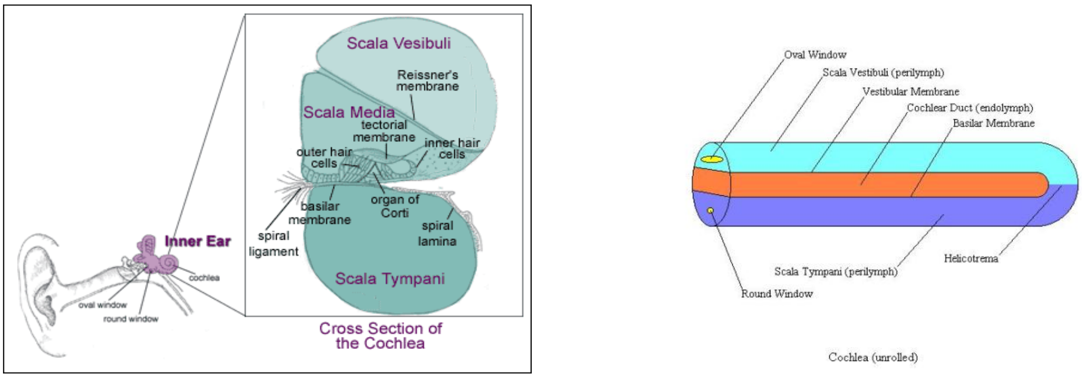

Figure 1 The Cochlea. Upper left is the cochlea's location, natural shape, cross section and main parts; upper right is an example of an unrolled model cochlea showing the compartments. Left image adopted from www.osha.gov; right image from www.etsu.edu .

Sound enters through the oval window, travels along the SM around the helicotrema and excites the SM membranes. In turn inside the SM, the motion of the TM causes the inner and outer hair cells to react by sending electrical signals to the nervous system. Hearing loss can actually be seen as damage to these hair cells. It has been observed that during noise-induced hearing loss, there is a surge of reactive chemical species, e.g. oxygen (Talaska and Schnaht, 2007).

The objective of this study is to provide preliminary insight into cochlear mechanics towards alleviating damage to hearing. We employ thermodynamics to find a rationale in wrestling with the chemical imbalance. The advantage of using thermodynamics is its ability to describe bulk properties (Prausnitz, 2003). The alleviation of the damage can either be by diet therapy metabolism or drug delivery.

2 METHOD

The actual cochlea has a diameter of around 9 mm and a length of about 350 mm, though model dimensions range variably (Gan, et al, 2006; Grivelberg and Bunn, 2002). Below in Fig. 2 is our model with dimensions 4x4x35 mm delineating the SV/ST chambers as joined by the helicotrema, the SM, the IHC and the OHC regions.

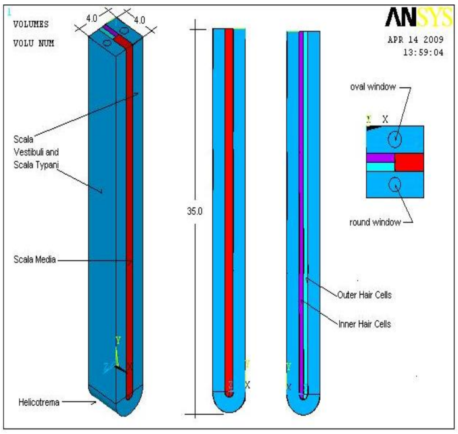

Figure 2 Cochlea Model

Using ANSYS, we assign FLUID30 element to account for the fluid-structure interaction as sound along the SV/ST provides pressures and displacements along the SM. The TM is modeled using SURF154 as a plate attached to the SC having contact with both the OHC and the IHC. The OHC/IHC regions are assigned SOLID98 which has mechanical-electrical coupling properties. We establish the reference comfort level and then illustrate hearing injury while at the same time monitor the change in electrical potential. The potential change is inputted to the Gibbs energy equation for the ATP-ADPase glycolysis (Kondepundi, 2008). Although the ear fluids involve the K^+,Na^+-ATPase process (O'Beirne and Patuzzi, 2007) we observe that most of the studies are qualitative. However, the ADP-ATPase glycolysis underlies all biological processes (Beard and Qian, 2008).

Material properties for the cochlear structures are 1000 kg/m^3 for the SV/ ST fluids while 1100 kg/m^3 for SM/TM and 1200 kg/m^3 for the OHC/IHC, the viscosity of the SV/ST fluid is 0.7 x 10^{-3} Pa-s. We assumed the Young's modulus is 45 MPa for the SM/TM and 7 MPa for the OHC/IHC, the Poisson ratio is 0.3 for the SM/TC and 0.1 for the OHC/IHC. A shear modulus of 0.003 MPa is assigned to the OHC/IHC.

During simulation material properties were transformed to uMKSV system. We only use linear damping to investigate the displacement. The frequency range tested is from 0 to12000 Hz.

3 RESULTS

In order to calibrate the model, responses at the interior of the SM at node 1923 located at X= 3.32, Y=1.28, Z=1.90 mm are shown in Fig.3.

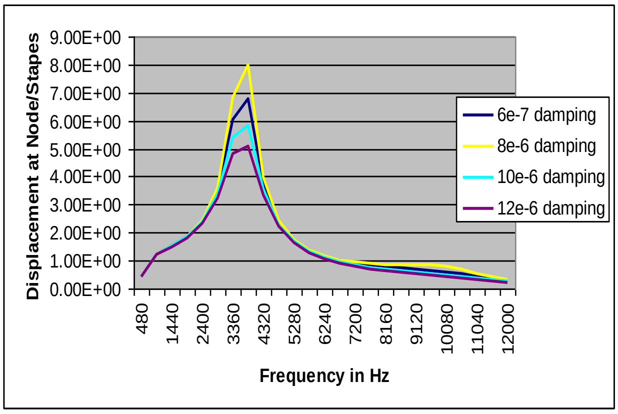

Figure 3 The displacement at node 1923 with respect to oval window at 50.17 dB in the range 0-12000 Hz.

The frequency response of the node is with respect to the displacement of the oval window which can be directly read. The damping variation centers around a characteristic frequency of 4320 Hz. To calculate the equivalent dB we apply from ISO 140-6(E) the equation

$$L = 10 \log n \frac{p_1^2 + p_2^2 + \ldots + p_n^2}{n\ p_0^2} \qquad (1)$$

where p_i are the sound pressure levels at n different position and p_0 is equal to 20 uPa. In this case we take n =8049 which is the total number of nodes of the model. The value obtained is 50.17 dB which is also within the comfortable range of hearing. Next we subject the model to its maximum allowable damping by ANSYS which corresponds to 80.42 dB. However at that hazardous sound level, displacements at a majority of the nodes upon damping variation are already identical flat lines.

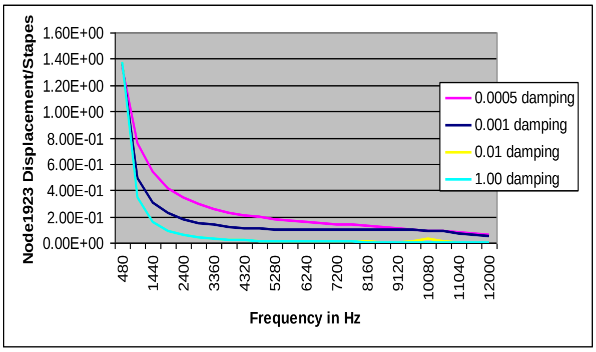

Figure 4 The displacement at node 1923 with respect to the oval window at 80.42 dB in the range 0-12000 Hz.

In Figure 4 we plot the initial flattening of the response, as a sign of injury to hearing at node 1923. Corresponding to the comfort and injury conditions we look at the OHC/IHC regions and investigate the change in electric potential. The OHC and the IHC were respectively assigned initial potentials of -70 mV and -45 mV (Mistrik etal, 2009).

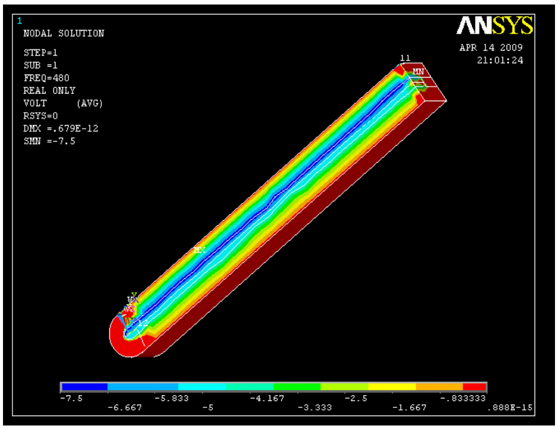

Figure 5 Snapshot of the time-development animation of the potential at node 1923 at 50.17 dB in the range 0-12000 Hz.

A snapshot of the ANSYS animation showing the potential in the OHC/IHC is shown in Fig. 5. We read from the simulation that in comparing with the potentials during the assumed injury there is a discrepancy of -100 mV or of two orders of magnitude. We use this value as the heuristic discrepancy in the Gibbs energy equation describing ATP synthesis during glycolysis. Such a process is present during transport of biomolecules and forms part of the so called K^+-Na^+ pump (Kondepundi, 2008). In addition, electric potential can be related to the Gibbs energy through the equation $\Delta G = \Delta\Psi - T\Delta E - V\Delta Q$, where G is the Gibbs energy, Ψ is the Helmholtz energy, T is the temperature, E is the internal energy, V is the volume and Q is the charge in volts (Deo and Grosh, 2004). We treat all variables constant except Q. In other words what we are putting forward is that an introduction of a chemical reaction which will induce an increase of two orders of electric potential can mediate the chemical imbalance in the cochlea and alleviate hearing injury.

4 DISCUSSION

The subject as presented here can be considered only as an academic exercise ─ as an initial foray through ANSYS and relevant literature into the cochlear mechanics. It is worth mentioning however that the use of thermodynamics in cochlear studies has not been fully exploited especially in the OHC/IHC regions. The plots in Fig 2 are similar to the BM displacement vs. frequency plots (Steele and Kim, 1999; Gan etal, 2005) showing the sharp increase then the sudden drop. Our results however show an extended tail which can be attributed to the fact that the whole regime is linear. Deo and Grosh (2004) used Gibbs energy more to investigate OHC mechanical properties. To the best of the authors' knowledge, modeling of cochlea injury in bulk is lacking in literature. Though the study aims to cover a broad physiological phenomenon, the current state sees much refinement, i.e. geometry and nonlinear effects.

5 CONCLUSION

We consider the entire cochlea and to model using ANSYS basic cochlea phenomena and injury and using thermodynamics hypothesize a basis for therapy.

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MICRO URBAN SCALE COLLABORATIVE INTERACTIONS: CRITERIA FOR ECOSYSTEM INTEGRATION IN ARCHITECTURAL DESIGN

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Abstract: In urban areas, the regeneration of ecosystem functions may be related with community resilience and welfare, as means to reduce vulnerability and external dependency. Looking forward for ecosystem integration development within architectural projects, as part of a regenerative built environment approach, the research focuses on micro urban scale design, relevant to building and immediate site. In the present paper, potential collaborative interactions between local ecology and architecture are identified and systematized, in order to highlight established factors of connection and possible future research areas. A framework, correlating the regeneration of ecosystem services and functions with architectural design quality criteria is also proposed and discussed, supported by case demonstration and literature review, as a step to develop a method of design assistance and assessment of ecosystem integration in micro scale urban architecture projects.

Key words: *Ecosystem integration, Architectural design quality, Ecosystem services and functions, Micro urban scale*

1 BACKGROUND INTRODUCTION

Presently, global human consumption rate of natural resources exceeds Earth's regenerative bio-capacity (WWF: 2010). Such fact, leading to an increased demand and decline of world ecosystems functions and services (MEA: 2003), is challenging environmental design benchmarks to evolve from neutral to regenerative. The concept of regenerative design defines a paradigm shift in built environment sustainability, beyond the mitigation of negative impacts, aiming for a collaborative co-evolution between architecture and nature, as stated by Reed (2007).

In order to improve environmental performance and establish positive synergies, *ecosystem integration* - the integration of site's natural systems and landscape elements within architectural design process -, was referred by Grosskopf & Kibert (2006), as a fundamental characteristic of future ecological architecture. Through collaboration with on-site resources, ecosystem integration presents several potential cost-benefit advantages towards comfort passive processes, water cycle management, local amenities, food production, resource distribution, cultural functions and biodiversity, providing combined assistance to material systems closed loops, optimization of passive design, hydrologic cycles and environmental quality (Kibert: 2007).

In the notion of ecosystem integration is also implicit the possibility of a more holistic, symbiotic cooperation between ecosystem and architecture, as interconnected complex systems with mutual benefits, contributing to local ecology regeneration and improving other architecture quality parameters, beyond environmental performance. However, the conditions and strategies for a collaborative integration of local ecology within architectural design entail further systematization and design development. The identification of a knowledge gap in this topic was stated by Grosskopf & Kibert (2006), as a need for innovation, both as methods and design tools, and of fully developed examples, in practice, of local ecosystem integration in architecture. Concurrently, the terms in which local ecosystem integration may be accomplished and assessed are not sufficiently systematized, and the whole range of potential collaborative interactions is not suitably explored.

The need for research development in this area is particularly noticeable for micro urban scale interventions, within the boundaries of building and immediate site. Collaborative design with natural systems has been developed predominantly in the fields of landscape design and planning, as in *Design with Nature* (McHarg: 1969), *Design for Human Ecosystems* (Lyle: 1985), and *Regenerative Design* (Lyle: 1994), related to interventions at regional and macro scales. Theories and methodologies for ecosystem site analysis and planning design were also acknowledged - including the Sustainable SITES Initiative (2009), but an adequate transposition of those methods to micro scale interventions is not yet consolidated (Vitorino: 2012).

In the available design assistance and assessment tools, impacts towards local ecology, either positive or negative, are partially included and frequently fragmented through diverse parameters, or addressed by prescriptive topics, not favoring a structured and holistic comprehension of ecosystem relations. Under these circumstances, design practice is not encouraged towards ecosystem integration or regenerative standards. In order to invert that, the resource to systematized ecosystem functions and services (widely adopted as a decision making tool towards development strategies), has been analyzed as a possible basis to green building assessment and regenerative built environments, by Olgyay and Herdt (2004), and Zari (2012), presenting relevant potential to promote local ecosystem integration within architectural projects.

In the present paper, collaborative interactions between local ecology and architecture, at micro urban scale, are identified and systematized, with the resource to study case references, with the aim to provide comprehensive design assistance and further research development in the field. In order to develop the basis of a methodology of assessment and design assistance for ecosystem integration within architecture projects, the present paper examines possible correlations between ecology (functions and services) promotion and design quality parameters, and discusses its influence and possible application in urban areas. The term collaborative interactions is used to express the potential symbiotic relation established between ecosystem regeneration and architectural design quality promotion.

2 ADDRESSING ECOLOGICAL FACTORS IN URBAN AREAS

In urban areas, the regeneration of ecosystem's services and functions directly addresses local environmental quality and impact on surrounding ecosystems, reducing urban vulnerability and external dependency, and contributing to increase community resilience and well-being, lower ecological footprint, and positively influence the perception of resource use limits and ecosystem inter-dependency. This perspective is supported by the concepts of design for eco-services and positive development, advocating the increase of ecological base in cities, as suggested by Birkeland (2008).

Although an integrated perspective of ecosystem regeneration requires bio-region macro-scale adequacy, urban transformations occur frequently within individual property. As result, design options incorporated in architectural projects of micro urban scale (building, building envelope and immediate site) present relevance potential to contribute positively to local ecology, in a bottom-up approach, that values the impact of small functional interventions in city's socio-ecological system.

For ecosystem integration in micro urban scale projects is fundamental the awareness and respect of the particular local underlying characteristics of each urban area and project site - referred as *deep local structure* by Spirn (2003), to orient site specific indicators, synergies, and conceptual solutions within architectural design. By the same grounds, one of the fundamental methodologies of regenerative design consists in tracing back the local ecosystem history, as part of what Reed (2007) identifies as understanding the *master pattern of place*. In urban settings, also the factors of ecological disturbance demonstrate local variation, and might constitute regeneration priority areas to orient the focus of micro scale collaborative design. A set of common factors of disturbance in urban ecosystems, and of ecosystem functions loss relative to deep original ecosystems, were identified by Gilbert (1991) and Mendiondo (2008), and are illustrated in Table 1.

Table 1 Urban ecosystems common factors of disturbance

Area		Factors of disturbance
1	Biodiversity	Habitat loss, habitat fragmentation and small scale habitat mosaics, introduced (non-native) and invasive species, reduction of specialized habitats, increase of adaptive opportunistic species, and severe reduction of plant biomass
2	Land and soil	Agricultural land take, alterations in soil composition [soil contamination, structure and loss of fertility], soil impermeability and storm water run-off, erosion vectors [soil movements and steep slopes], alterations in topographic structure
3	Water cycle	Alterations in hydrographic structure [channelization, damming], alterations in water cycle and storage, water pollution [effluents, and storm water pollutants]
4	Microclimate	Micro-climate changes [urban heat island, decreased solar radiation exposure, alteration of wind patterns]
5	Pollution	Air pollution [sulfur, nitrogen, carbon, VOC's, particles], noise pollution, light pollution, human and motor traffic disturbance vectors, pesticides and herbicides, radioactive and electromagnetic pollution, organic, bacterial and pathogen pollution, salinity, acidification, heavy metal pollution and eutrophication
6	Other ecosystems	Relations with external and bordering ecosystems [impacts related with material resources, transport, waste disposal, and others]

Even though deep ecological system are inherently different from city to city, due to the imposed alterations the generality of urban ecosystem services are nowadays quasi confined to the functions performed by parks and garden areas: air quality, water and local climate regulation, as well as cultural, recreational and educational roles. The integration and cooperation with local ecological systems within architectural design may contribute to the reversion of disturbance patterns and the increase of ecosystem functions, in urban areas. The integration of local ecosystems within architectural design is then two-folded, as it aims to intervene within the immediate ecosystem, by means of restoration and regeneration, with macro-scale repercussions to global ecosystem.

3 FRAMEWORK FOR ECOSYSTEM AND ARCHITECTURAL DESIGN CRITERIA

The motivation to create a framework linking ecosystem and architectural criteria derives fundamentally of the need to: a) detect, systematize and value mutual positive contributions between the natural and the built systems, generating synergies and beneficial impacts; and b) reinforce the connection of ecological building with design research and intrinsic architectural values. A preliminary correlation framework for ecology and architectural design was previously proposed deriving from criteria relative to: 1. ecosystem assessment and 2. architecture quality parameters (cf. Vitorino: 2012), and it is updated and developed in the present paper. The current criteria selection, methodology and results are briefly exposed in the following sections.

3.1 Ecosystem Criteria

The selection of ecosystem assessment criteria was based on ecosystem functions and services, and partially adapted and selected from Costanza *et al* (1997), De Groot *et al* (2002), MEA (2003) and TEEB (2011). The resulting indicators are organized, in Table 2, through 4 key ecosystem regeneration areas: Provisioning, Regulating, Cultural and Supporting.

Table 2 Ecosystem assessment criteria

Ecosystem functions and services	Indicator description
❶ Provisioning	
1. Food supply	Provision of edible habitats: crops, fisheries, wild food
2. Fresh water supply	Contribution to fresh water filtering and storage
3. Fibers and raw materials	Provision and renewability of materials: wood, hemp
4. Fuel and energy sources	Provision of renewable energy sources: wood, biofuel
5. Ornamental and medicinal resources	Provision of habitats for medicinal and ornamental sources
❷ Regulating	
6. Air quality regulation	Bio-chemical balance and particle filter by vegetation
7. Climatic regulation	Land cover and vegetation influence on local climate
8. Water purification	Filter of compounds in inland and marine waters
9. Erosion control and hazard protection	Soil retention and landslide prevention, moderation of extreme events
10. Biological control & pollination	Biological control of pests, diseases and disease vectors
11. Environment modulation	Perceptual moderation and modulation: light, noise
❸ Cultural	
12. Sense of place and identity	Identity features, significant species and historical cultural landscapes
13. Cultural, artistic & scientific resources	Inspirational sources for art expression, education and science
14. Landscape aesthetic fruition	Scenery valuation, and nature observation points
15. Leisure, recreation and health	Landscapes with recreational use, outdoor sports and health settings
❹ Supporting	
16. Soil formation and fertility	Weathering of rock and accumulation of organic matter
17. Photosynthesis and primary production	Production of oxygen, and assimilation of energy and nutrients by biota
18. Nutrient cycling and waste treatment	Storage, breakdown and cycling by organisms in air, soil and water
19. Water cycling and regulation	Water cycling, concentration and flow regulation through ecosystem
20. Biodiversity and nursery habitats	Habitats and breeding ground for native and endangered species

3.2 Architectural Design Criteria

Architecture design criteria were determined, recurring to existing design assistance tools and indicators, attempting to reflect the concepts in force associated with design quality and performance, including environmental sustainability. The resulting criteria were partially adapted, selected and added from SPEAR, REGEN, LENSES, CASBEE, BREEAM, LEED, DGNB, and LIVING BUILDING CHALLENGE, and indicators were rearranged into a customized set of topic areas.

The addition and arrangement of architectural criteria derived from cross-comparison analysis of the referred assistance tools, and intends to provide a comprehensive and balanced representation of the different architectural quality areas and respective topics of analysis, either quantitative or qualitative, and only partially overlaps the objectives of environmental and sustainability methods. Qualitative criteria are often not addressed in environmental assessment methods due to accountability and measurability matters. As a result, relevant architectural qualitative criteria is only secondarily included in design assistance tools and indicators, and frequently escapes the focus of sustainability assessment methods.

The resultant architectural design criteria, is organized into 6 main areas, in Table 3 (the first 3 corresponding to extrinsic quality indicators factors and the last 3 to intrinsic quality indicators factors): Macro local relations, Environmental balance, Socio-economic relevance, Conceptual and perceptive quality, Comfort and Functionality, and Building construction.

Table 2 Architecture design parameters

Design quality area	Indicator description
❶ Macro local relations	
1. Adaption to eco-physical context	Site selection, hydrography and topography
2. Sense of place and cultural identity	Socio-cultural references, landscape marks, system of views
3. Transports and functional articulation	Relations with functions, infrastructures, volumes, and local mobility
❷ Environmental balance	
4. Biodiversity and ecosystem	Soil, water, and site biodiversity
5. Energy [and atmospheric emissions]	Passive design, energy consumption and production, emissions
6. Water [and effluents]	Water consumption, harvest, and treatment
7. Materials [and solid waste]	Local, renewable, low intensity materials, waste management
8. Other sources of local pollution	Light pollution, noise, heat island effect, glare
9. Sustainable life-style support systems	Kitchen gardens, compost, laundry natural dry, and other daily uses
❸ Socio-economic relevance	
10. Customization possibilities and operation	Comfort operation systems, space and envelope control & alteration
11. Community participation & user satisfaction	Local communities & stakeholders, user targeting and assessment
12. Social responsible construction practices	Multifunctional and intersocial use, security, employment, sourcing
13. Economic dynamics and lifecycle costs	Economic impact and distribution, operation and end use costs
14. Human health and well being	Human well-being, socio-psychological comfort
❹ Conceptual and perceptive quality	
15. Concept originality, innovation & creativity	Artistic and conceptual valuation, contemporaneity, innovation
16. Visual	Light/shadow, contrast, scale, rhythm, form, framing and views
17. Acoustics	Acoustic properties, propagation and materials sounds
18. Tactility and motion perception	Surfaces temperature, colors, texture, height levels and steepness
19. Olfactory	Scents from materials, uses
❺ Comfort and functionality	
20. Acoustics	Internal and external sound control and propagation
21. Lighting	Natural and artificial light comfort and balance
22. Indoor air quality	Air renovation, elimination of particles and VOC's
23. Humidity and temperature	Hygrothermal comfort in daily and annual cycles
24. Exterior areas	Amenities, landscape, wind, shadows, safety
25. Ergonomy, accessibility & universal design	Adequacy to human dimensions, access by reduced mobility users
26. Adequacy to function, use & circulation	Space, volume, and organization fitness to program and occupancy
❻ Building construction	
27. Details and finishes	Durability, coherence, and rigor of finishing materials
28. Execution quality and process management	Rigor, quality of construction, on-site management, quality control
29. Structure stability and quality	Resistance to loads, use and structure design quality
30. Durability and maintenance	Life cycle loops, resilience of systems and materials, ease of repair
31. Safety and emergency systems	Fire, earthquake, flood, intrusion and hazard preparedness

3.3 Methodology

The possible positive interactions between the criteria established for ecosystem and architecture quality were referenced in a matrix diagram, or correlation framework. In the resulting diagram, each of the architectural design quality parameters is related to each of ecosystem functions and services, in order to identify existing or possible collaborative interactions. The diagram analyses potential symbiotic interactions between ecosystem regeneration and their prospective contribution to architectural quality. The entries on the diagram identify different possible interactions between criteria, signaling: a) positive influence on ecosystem regeneration, b) positive influence on architectural design criteria, c) mutual positive influence, and d) unidentified positive correlation.

A case of potential positive interaction of natural system towards architectural quality might be expressed by the relation between the climatic regulation with humidity and temperature comfort, in architecture. An example of this relation is a trellis of native deciduous plants (cucumber, morning glory, loofah and gourd) installed in the outside of a building, by user's initiative, in Tokyo. The same passive design solution presents other positive correlations, benefiting either architectural parameters (biodiversity and ecosystem, energy, other sources of local pollution, sustainable life-style support systems, buildability and deconstruction, acoustics, lighting, exterior areas, and customization possibilities) and ecosystem functions (food supply, ornamental resources, air quality regulation, sense of place and local identity, environmental perceptive modulation, and several supporting functions).

The correlations entries are cumulative of best practice, reflecting the analysis of 130 selected study cases and documenting literature. Thus, the correlation framework doesn't represent frequency but a single possibility. To each positive correlation identified in the diagram corresponds a design solution or strategy, found in one or more references.

3.4 Results

From the correlation framework, resulted a matrix of 620 possible correlations, from which 415 presented possible positive collaborative interactions, at micro urban scale (a, b, c), and only 205 non indentified positive correlations (d).
Through the analysis of the correlation framework, it was possible to evidence criteria, within ecosystem functions and services and architecture design parameters with greater potential to promote ecosystem integration, represented in Figure 1 and Figure 2. (The differentiation between positive influence on ecosystem regeneration, positive influence on architectural design criteria, and mutual influence are not expressed in the graphics).

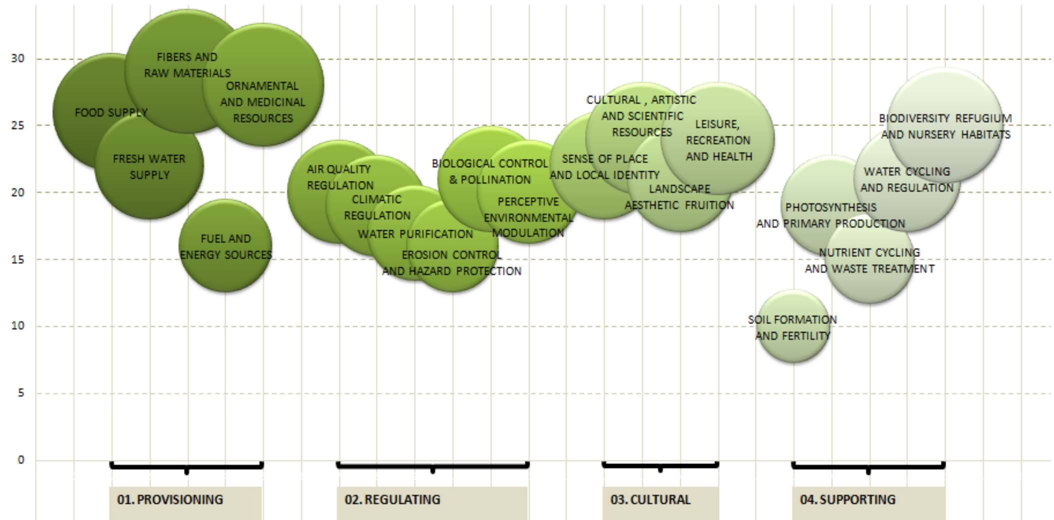

Figure 1 Collaborative interactions with ecosystem assessment criteria [the number of correlations with architecture parameters, for each ecosystem criteria is indicated by the vertical axis and respective diameter]

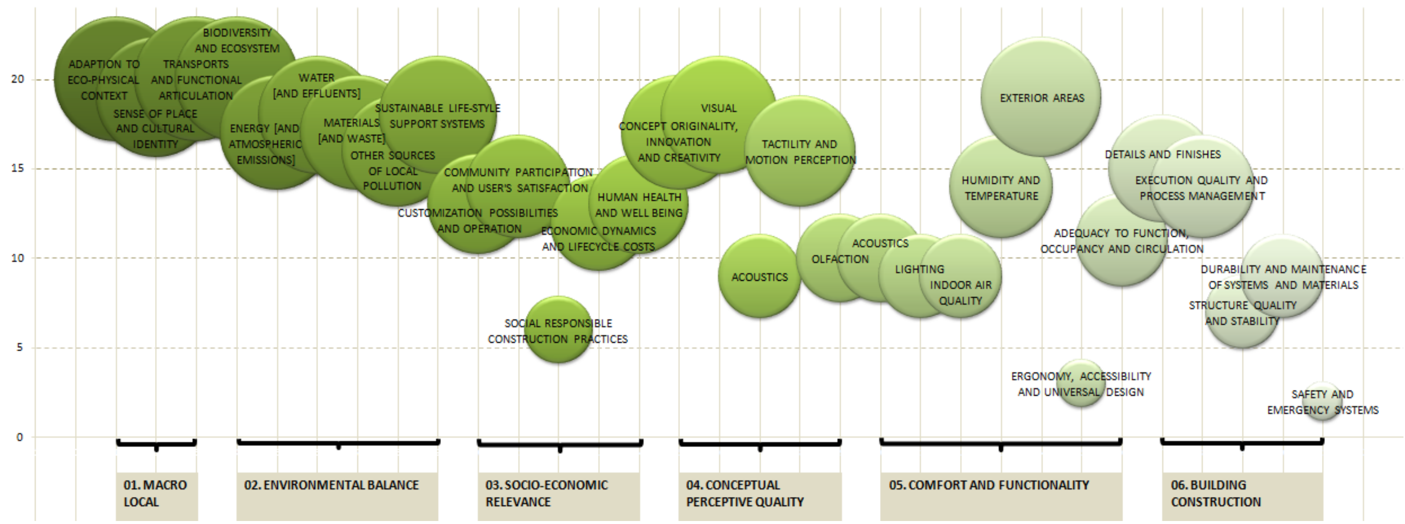

Figure 2 Collaborative interactions with architecture design parameters [the number of correlations with ecosystem criteria, for each architectural parameter is indicated by the vertical axis and respective diameter]

4 DISCUSSION OF THE RESULTS AND APPLICATION OF THE FRAMEWORK

In the correlation framework, it was attempted to identify and systematize potential collaboration synergies, through the selection of built and non built projects where local ecosystem integration were identified. The majority of the sample projects evidenced specific positive interactions with local ecology but few combine multiple synergies for overall ecosystem regeneration.

The cumulative results of the study case references indicate however that ecosystem functions and services present a considerable correlation rate with architecture design parameters. Most of the indicators can be related with more than half of the architecture quality parameters. An emphasis is noticed on provisioning services, denoting possibly not only the capacity of several architecture design parameters to increase their production, but also their fundamental importance into architectural criteria at diverse levels. Cultural services are understandably more promoted through architecture criteria than the inverse, in urban areas. Denoting possible constraints of micro urban scale and inherent land uptake in urban ecosystems, diverse functions associated with soil formation and fertility, erosion control and nutrient cycling score the lowest collaborative interactions with design parameters.

Regarding architecture quality parameters, relevant correlations are found in the ones related to macro local relations, environmental balance, and perceptive and conceptual quality. Socio-economic relevance, comfort and functionality and building construction areas present a higher fluctuation, through individual indicator. Environmental sustainability and comfort parameters present a high degree of potential cooperation, either in ecosystem and architectural assistance directions. Simultaneously, the design strategies of building envelope surface and form, usage of materials, and community involvement assume relevance to provide and restore additional ecosystem functions, by water and greenery surfaces, habitat provision, and collaboration with provisioning and regulating processes.

The low number of collaborative interactions in certain architecture design parameters may be attributed to a diverse set of reasons: intrinsic lack of applicability, or reduced sources of information (as in the case of ergonomy, accessibility & universal design and of social responsible construction practices); preponderance of macro scale influence (safety and emergency systems); and uneven distribution of quality parameters, as in the duplication of acoustics indicators, double considered in comfort and perceptive quality areas.

With the resource to additional data collection, the tentative outcomes of the correlation framework might be further assessed and rectified, reducing the degree of inaccuracy. As a result from this analysis a more coherent set of criteria is possible, regrouping and selecting the pertinent criteria to assess ecosystem integration in individual projects. The framework may then provide a backdrop comparison to enhance ecosystem integration during design process.

The proposed correlation framework of ecosystem and architectural criteria may assume diverse purposes for ecosystem integration in architectural design design, namely: a) to provide support for study case identification and systematization of existing or prospective synergies; b) to constitute an analysis model for an individual project or specific design solution; and c) to comprise assistance during design stages, as a tool for thinking and decision making. Regarding the use of the framework as a decision making or analysis tool for a specific project or design solution, the greater diversity and range of achieved positive interactions, would suggest more successful collaborative options. In this case, the results of the diagram would vary according to the cultural and natural aspects of a specific context and project, and not be compared outside its site-specific range.

4 CONCLUSIONS

Local ecosystem collaboration within architectural design presents several possibilities of implementation in urban environments, even at micro scale. Although urban and global ecology issues cannot be tackled without the resource to macro scale and even social transformations, micro scale strategies constitute complementary bottom-up strategy potential to contribute positively and cooperate with local natural systems. Moreover, the enhancement of local ecosystem functions and services, through architectural design options, offers additional design research challenges and architectural quality promotion possibilities.

The presented correlation framework, linking ecosystem and architectural design criteria, revealed several possible collaborative interactions towards local ecology, and highlighted possibilities of ecosystem cooperation within architectural design. The identified collaborative interactions between ecosystem functions promotion and architecture present in fact a potential positive influence to the most common disturbance vectors that affect biodiversity, microclimate, pollution, and ecosystem exchange, in urban areas. The further development of the proposed correlation framework, with additional criteria and data revision, may derive into a decision making tool for design assistance and assessment of ecosystem integration, within architectural projects, with prospective fruitful results at micro urban scale.

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MODIFIED DOST-KASC METHOD: A SIMPLE, RAPID, COST-EFFECTIVE AND SEMI EMPIRICAL LANDSLIDE ASSESSMENT TOOL

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Abstract : A modified version of the Department of Science and Technology-Kalinga Apayao State College (DOST-KASC) landslide rating system is presented. The proposed method involves a more refined procedure for assessing the slope angle as well as non-expert method for incorporating effects of uniaxial strength and Rock Quality Designation (RQD) into the strength of the slope material. Forty five rock slopes along the Halsema Highway were assessed using the modified DOST-KASC procedure together with Limit Equilibrium Methods. A statistical comparison of the results obtained from the forty five slopes using the DOST-KASC and Limit Equilibrium Analyses was performed. Results of these analyses show that incorporating the proposed modifications into the DOST-KASC increases the coefficient of correlation from 0.176 to 0.599. In comparison, the coefficient of correlation between the SMR method and Limit Equilibrium Methods for the forty five slopes assessed was 0.355. The results of this study demonstrate the potential of the modified DOST-KASC method as a landslide rating scheme that gives results that are comparable in accuracy to the widely used SMR method when assessing rock slopes, while being simpler and faster to use than the SMR method.

Key words: Landslide, Slope Stability, Rapid condition assessment

1 INTRODUCTION

The Philippines is one of the most disaster-prone countries in the world because of its geographic location and geologically active environment. It is characterized by high seismicity and active volcanism. An average of 30 typhoons visit the country every year. All these factors combine to make the country highly susceptible to landslides. In recent years, landslide hazards have become an increasingly serious threat to life and property. Recent landslide occurrences that have claimed hundreds of lives and caused significant property damage include: Cherry Hills-Antipolo (Morales et al., 2001), Panaon Island-Surigao (Zarco, et al., 2007), Aurora-Quezon (Zarco, et al., 2007), St. Bernard, Southern Leyte (Catane et al., 2006), and more recently on 1 December 2006, mudflows triggered by tropical storm Reming (Durian) devastated the communities around Mayon Volcano, killing 753 people and destroying P1.7 billions worth of property. Due to the increasing number of extreme climate events and earthquakes that trigger widespread landslides, as well as the need for a method for quickly assessing and identifying susceptible slopes, a number of landslide rating systems have been developed. Examples of these include the Japan Road Association system (1988), and the method proposed by the Japan Ministry of Construction in 1987. For rock slopes, the most widely accepted method is the Slope Mass Rating system proposed by Romana (1995). In the Philippines, the Department of Science and Technology together with the Kalinga-Apayao State College (Peckley et al., 2010) developed a local landslide rating system that is rapid, low cost, requires minimum expertise and training, and can be used to assess both rock and soil slopes.

In this study, the authors compare the accuracy of the DOST-KASC method for evaluating the stability of rock slopes with other rating systems which include the JRS, JMC, SMR methods together with Limit Equilibrium Analyses. Forty five slopes along the Halsema Highway were selected for the purpose of this study. Comparison of the results obtained between the four rating systems with the Limit Equilibrium Analysis indicated the accuracy of the DOST-KASC is much higher than the JRS and JMC methods, but lower than SMR system. Further study indicates that the accuracy of DOST-KASC method can be substantially increased by refining the method in which the slope angle and strength of the slope material are measured. The proposed refinements in the DOST-KASC method are simple enough for a non-expert to perform, yet increase the accuracy to a level that is comparable if not better than the SMR method.

2 THEORETICAL FRAMEWORK OF THE DOST-KASC METHOD

2.1 Factor of Safety

In the DOST-KASC method, the overall factor of safety against failure of a slope is assessed according to the following expression

$$FS = \frac{\left[vFactor \times fFactor \times \ sRating - sRed - dRed \ \right]}{\alpha Rating \times lFactor} \quad (1)$$

Where *sRating* is a numerical index from 1 to 100 representing the strength of the slope material, and *αRating* is also a numerical index from 1 to 100 and is proportional to the tangent of the slope angle α. The modification factors are *vFactor* representing the contribution of vegetation, *fFactor* representing the contribution of previous slope failures, and *lFactor* representing the effect of land use. The reduction factors are sRed corresponding to the presence of springs, and dRed corresponding to the presence of drainage.

2.2 sRating system

The value of *sRating* is assigned by using the following guidelines as summarized in Table 1. For rock slopes, the material classification can be performed in situ using a Schmidt rebound hammer, or through unconfined compressive tests performed on core samples. Fur such cases, the following scheme may be used for purposes of determine the material type for rock slopes.

Table 1 *sRating* for various slope angles

Material	Slope Material	*SRating*
HR-1	Massive and intact hard rock	100.0
HR-2	Block, well-interlocked, hard rock, rok mas consisting mostly of cubical blocks	45.0
HR-3	Very blocky, disturbed, hard rock with multi-faceted angular blocks formed by 4 or more discontinuity sets.	25.0
HR-4	Disintegrated, unstable rocks and boulders protruding rock fragments	13.0
SR-1	Massive and intact soft rock	30
SR-2	Very block and fractured soft rock	15

The *sRating* can be estimated by driving a 4-inch wire nail into the outcrop. For hard rocks (HR-1 through HR-4), it is not possible to penetrate the rock mass given that the material has a shear strength in excess of that of concrete (21 MPa). In the case of soft rocks, a 4-inch nail can be driven into the rock mass because the shear strength is less than that of concrete.

2.3 *αRating* system

The value for the slope angle factor *αRating* is obtained by grouping the slope angle into one of the categories as shown in Table 2, representing the tangent of the mean of the range of the group, and normalized such that the values range from 1 to 100. It this procedure it is assumed that the slope under consideration has only one slope angle *α* and a predominant slope material. If the slope angle varies, but the variation is within the range of angles corresponding to a single *αRating*, and if the predominant material is uniform within the area, then the area is treated as a single area. If the slope angle varies, and the variation is outside the range corresponding to a single *αRating* value, then the area should be subdivided into smaller areas with widths 10m or longer.

Table 2 *αRating* for various slope angles

Slope Angle *α*	*αRating*
75°	100.0
60° ≤ α < 75°	32.0
45° ≤ α < 60°	17.0
30° ≤ α < 45°	10.0
15° ≤ α < 30°	5.0
α < 15°	2.0

2.4 Modification and Reduction Factors

In addition to the slope angle and strength factor, the following factors influencing the stability of the slope are taken into consideration

Vegetation Cover

The effect of vegetation cover on the shear strength of slope is taken into consideration by multiplying vegetation factor *vFactor* to the modified *sRating* of the slope. Table 3 summarizes the numerical value for *vFactor* for different vegetation types.

Table 3 Types of vegetation and corresponding numerical values for *vFactor*

Type	*vFactor*
No Vegetation	1.0
Predominantly grass or vegetation with shallow roots	1.1
Coconut, bamboo, or vegetation with moderately deep roots	1.3
Trees with age less than or equal 20 years	1.5
Tress with age more than 20 years	2.5

Frequency of failure and deformation

The presence and frequency of previous failures and visible signs of ground deformation is used to reduce the modified *SRating* multiplying with the factor *fFactor* together with the *vFactor* previously described. Table 4 summarizes the numerical value for *fFactor* corresponding to different types and occurrences of slope failure and deformation.

Table 4 Frequency of failure or presence of deformation and corresponding numerical values for *fFactor*

Type	*fFactor*
Once a year or more than once a year	0.5
Presence of past failure, but occurrence not yearly	0.7
Presence of tensile cracks in ground	0.7
If a retaining wall is present, wall is deformed	0.7
None	1.2

Presence of springs and Drainage conditions

The effect drainage conditions on the stability of the slope is incorporated into the rating system through the factor *dRed* which is subtracted from the *sRating* . Table 5 summarize the numerical values for different spring conditions *sRed*, while Table 6 summarizes the numerical values of *dRed* different drainage conditions. The spring *sRed* and drainage condition *dRed* factors are subtracted from the unmodified *SRating* to obtain the modified *SRating* . It is then further modified by multiplying by *vFactor* and *fFactor* .

Table 5 Presence of springs and corresponding numerical values for *sRed*

Type	*sRed*
Yearlong	2.0
Only during rainy season	1.0
No flow or spring	0.0

Table 6 Drainage conditions and corresponding numerical values for *dRed*

Type	*dRed*
No drainage system	2.0
Totally clogged, filled with debris	2.0
Partially clogged or overflows during heavy rains	1.0
Water leaks into the slope	1.0
Good working conditions	0.0

Land use

The effect of land use on the stability of the slope is incorporated multiplying the *αRating* with *lFactor*. Table 7 summarizes the numerical value for *lFactor* for different land use types.

Table 7 Land use categories and corresponding numerical values for *lFactor*

Type	*lFactor*
Dense residential area with closely spaced structures < 5m part	1.4
Commercial buildings having 2 stories or more	1.4
Residential area with buildings having 2 stories or less spaced at ≥ 5m apart	1.25
Road or highway with heavy traffic (1 truck or more every 10 minutes)	1.4
Road or highway with light traffic (less than 1 truck every 10 minutes)	1.25
Agricultural area, grasslands and bush lands	1.0
Uninhabited or no vegetation	1.0

The level of stability or susceptibility is then assessed as follows: $FS > 1.2$, the slope is considered stable; $1 \leq FS < 1.2$, the slope is considered marginally stable; $0.7 \leq FS < 1.0$ is considered susceptible; and $0.7 < FS$ is considered highly susceptible.

3 MODIFIED DOST-KASC METHOD

The DOST-KASC is a very simple method that requires minimum expertise and training, and is applicable to both soil and rock slopes. Furthermore, it can be applied to all types of rock slopes regardless of the presence of discontinuities. However, some results obtained from using this method underestimate the stability of the slope based on the range of the slope angle and the rock strength of the slope material. Therefore, to further improve results using this rating system, modification of these parameters need to be applied. In this study, two modifications are proposed to the rating system. These include: (1) refinement in the measurement of the slope angle; and (2) refinement in the estimation of the rock strength using the uniaxial rock strength and RQD.

3.1 Modified s*Rating* system

In the modified system being proposed, the *sRating* is the function of uniaxial strength of the slope material σ_u and the discontinuities present on the slope which is which is indirectly quantified using the *Rock Quality Designation* (*RQD*) as shown in equation (2)

$$sRating = \sigma_u \times RQD \tag{2}$$

The uniaxial strength of the slope material σ_u is estimated in the field based on the Rock Mass Rating (RMR) system by Bieniawski (1989) as summarized in Table

Table 8 Uniaxial strength score of SMR

Rock description	Range of Score	Field identification	
		Pocket knife	Geological hammer
Ext. strong	100	No peeling	Only chips after impact
Very strong	70	No peeling	Many blow to fracture
Strong	30	No peeling	Several blow to fracture
Med. Strong	15	No peeling	A firm blow to fracture
Weak	6	Difficult peeling	Can indent
Very weak	1	Easy peeling	Can crumble

Calculation of this parameter is shown in Table. The RQD is estimated based on the spatial distribution of discontinuities using the method from the SMR (Romana, 1993) Formula to calculate the RQD value is shown on formula

$$RQD = 100\times \left(\frac{0.1}{s}+1\right) \times \exp\left(\frac{0.1}{s}\right) \tag{3}$$

where *s* is the discontinuity spacing in meters.

4 EVALUATION OF MODIFIED DOST-KASC METHOD

The accuracy of the proposed landslide rating system was assessed using 45 slopes along the Halsema highway randomly selected, and evaluated using the Original and modified DOST-KASC methods together with SMR, Japan Ministry of Construction, and Japan Railway Association rating systems (Orense, 2003). The stability of the slope was estimated using limit equilibrium analyses consisting of a combination rotational, planar and wedge failure mechanisms. In performing the limit equilibrium analyses, unconfined compression tests performed on intact rock samples obtained from lithological unit were used to estimate the strength of the rock material.

In order to compare quantitatively the agreement between the modified DOST-KASC with the Limit Equilibrium Analyses, a Pearson's chi-squared tests using cross tabulation analyses were used to independence of the different rating schemes with the limit equilibrium analyses. Based on the crosstab analysis, application of modification on the DOST-KASC for some slope site giving the improvement which giving similar stability result with the other slope stability analyses, but some slopes make the result vary. Comparison of the modified DOST-KASC and the limit equilibrium method using the Pearson's chi-square test, the value of the index is 49.384, which is significantly until less 0.1% confidence interval. Table 9 shows the cross tabulation analysis between the Modified DOST-KASC and the Limit Equilibrium Methods

Table 9 Crosstab analysis of limit equilibrium method versus modified DOST-KASC

	Stability Category	Modified DOST-KASC				Total
		1.0	2.0	3.0	4.0	
LEM	1.0	12	0	1	0	13
	2.0	2	4	0	3	9
	3.0	1	0	1	5	7
	4.0	1	0	0	15	16
	Total	16	4	2	23	45

Linear regression was also done to compare the result of each rating system with the limit equilibrium analysis. From the regression analysis, it can be seen also that there is an improvement of the R-square value of the original DOST-KASC from 0.176 to 0.599 in the modified DOST-KASC. It is shown also that the Modified DOST-KASC has a higher coefficient of correlation as compared to the SMR. Table shows the R-square value of the rating systems compared with limit equilibrium method. It should be qualified that the abovementioned results are valid only for shallow slopes failures and for the lithology of the study site. The same results may not be true for sites with different lithology, or where slopes failures are deep seated or involve toppling.

Table 10 R^2 value of regression analysis of limit equilibrium method with various landslide rating system.

Rating system	R^2	Adjusted R^2
JMC	0.0820	0.0610
JRA	0.0150	-0.008
SMR	0.3700	0.3550
Original DOST-KASC	0.1950	0.1760
Modified DOST-KASC	0.6080	0.5990

5 CONCLUSIONS

The DOST-KASC has several advantages over the SMR which make it suitable for performing preliminary slope stability assessment. The DOST-KASC method is more suited for use by non-experts as compared to the SMR since it requires less knowledge of geology and geotechnical engineering. Furthermore, the SMR is limited to rock slopes with discontinuities. In comparison, the DOST-KASC can be used for both soil and rock slopes. However for rock slopes, it is observed that the DOST-KASC is not as accurate as the SMR and Limit Equilibrium Method. Based on the observations, the original DOST-KASC when compared to the Limit Equilibrium Method often underestimates the factor of safety against slope failure. It was determined from the sensitivity analysis that the two factors that have the greatest effect on the factor of safety are the slope angle and the material strength of the slope. Consequently, modifications to the DOST KASC method are suggested to make it comparable with SMR and Limit Equilibrium Methods when assessing the stability of rock slopes. Based on the study, it was observed that by introducing modifications in the procedure for assessing the slope angle, and incorporating the effects of uniaxial strength and Rock Quality Designation (RQD) to the material strength of the slope, the accuracy of the DOST-KASC method in assessing the stability of rock slopes can be increased significantly when compared to limit equilibrium methods. In this study, this was demonstrated using cross tabulation chi-square tests and linear regression analyses. Based on the results of these analyses, it was observed also that the coefficient of correlation of the DOST-KASC method with limit equilibrium method increases from 0.176 to 0.599 when the proposed modification are incorporated into the DOST-KASC method, which is higher to the coefficient of correlation of 0.35 between the SMR method and limit equilibrium method. The proposed modifications to the DOST-KAST method are summarized as follows. The slope angle is measured using a compass or range finder, and the corresponding weight is obtained using the tangent of the measured angle. The effects of uniaxial strength of the slope material based on the RMR method from Bieniawski and the effects of RQD on the slope material based on the SMR of Romana are used to estimate the strength of the slope material. Incorporating these modifications into the DOST-KASC method was shown proven to improve the accuracy of the original DOST-KASC method in assessing the stability of rock slopes to a level comparable to the SMR if not better. The results of this study demonstrate the potential of the modified DOST-KASC method as landslide rating scheme that gives results that are comparable in accuracy to the widely used SMR method when assessing rock slopes for shallow failures, while being simpler and faster than the SMR method.

The DOST-KASC is recognized as a simple method that can be used by non-experts as a method for assessing the stability of slopes within an observed area. Objective of this study is to focus on rock slopes. This is can be used for shallow or deep seated type of landslide. Parameters used in this study are limited to those used in the rating system. A parameter not included in this study is the effect of the earthquake on the resulting slope stability, since earthquakes are important trigger for landslides. For future study, it is recommended to have parallel study for soil type of the slopes in order to compare the accuracy of the DOST-KASC method versus limit equilibrium methods. This would also provide a more rational method for arriving at the weights of the other parameters that control slope stability.

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RATED PG: PRACTICAL GREEN

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1 INTRODUCTION

Is green visible or invisible? Is living sustainably a set of metrics or is it in one's heart? It is clear that going green and sustainable is getting to be mainstream. Fun runs, triathlons and health food are quite popular these days. These are answers to the human desire of longer life, of quality of life. Alongside with these is a growing awareness of the effects of the environment on the lifestyle of humanity. We are starting to look at the holistic approach to human survival and its reliance on the sustainability of the world.

This paper shall focus on sustainability of the built environment in a hot humid country of the Philippines, subjected to natural disasters such as typhoons, earthquakes and volcanic eruptions. It shall approach sustainability in a simple way, an approach that most will understand and be encouraged to implement.

2 WHAT IS GREEN ARCHITECTURE

In its most basic concept, Green Architecture is "Designing WITH Nature". In conceptualizing a sustainable built environment, the designer must assess what are the available resources and climatic conditions. The designer must first work with nature to create a comfortable and sustainable environment for people. Should the existing conditions of nature be harsh to the users, creative measures may be undertaken to assist the resources of nature to achieve the desired results.

In an expanded version, Green Architecture is a component of sustainable design that is concerned with the aesthetic and ecological harmony between the building and the built environment around, and between the building and the natural environment around. It must perpetuate a symbiotic relationship between the building and its environment.

3 REALITY CHECK FOR GREEN ARCHITECTURE

Since the built environment creates the greatest impact on sustainability, advocates of green buildings are working harder on raising this awareness in each and every person on the planet. Green building rating systems have been set up in most countries, as it is the building industry answer to the band wagon of going sustainable. After about a decade of green building rating systems, only a few buildings have been rated. What about the rest of the structures? Have these rating systems and their "certified" specialists created an image that a green building is complicated and expensive? Besides, since the environment varies from country to country, a global green building rating system does not seem likely to be practical.

In the Philippines, advocacy for a sustainable built environment is hampered by three barriers. These are cost, complexity and resistance to change.

COST: There is a general perception that going green and sustainable is expensive. This is compounded by images of high-tech solutions such as solar panels, wind turbines, etc. Since initial cost of buildings is one of the main concerns in the Philippines, the precieved cost of going green has hampered its acceptance.

COMPLEXITY: There is a general perception that going green and sustainable is complicated. Through the various metrics and specialists of green buildings, it appears that going green is beyond simple notions for most people. However, in the Philippines, many have forgotten that simple sustainability concepts have been practiced for generations. This misconception has hampered green and sustainable design from being implemented.

CHANGE: The players of the building industry, as most others, have a certain resistance to change. Green and sustainable buildings need a changed mindset to incorporate Integrated Design Process, energy efficiency and reduce wastage. Likewise, this resistance to change has hampered green and sustainable buildings from being implemented.

If greening the built environment is to make a big contribution to sustainability in our planet, then most buildings must be sustainable. It must be demonstrated that going green and sustainable is and can be practical.

4 MARKETING PRACTICAL GREEN

In the Philipines, with our abundant resources and the people's resiliency to natural disasters, the global media thrust of global warming does not seem to affect most. I experienced this realization in a small town in the rural area, where I was talking to the town officials about the idea of capturing rainwater and water efficiency. Shortly after the talk, the officials walked me through the town and showed me their “unlimited” and free fresh water resource – making water efficiency a hard sell.

How then would you convince our people to accept and practice green architecture and sustainability? Rather than present the global warming issue and scarcity of resources, it may be more attractive to present green architecture and sustainability in terms of the benefits for individuals … and should be as simple as possible.

Practical Green may be marketed to benefit the individual through comfort, cost and continuity as they design, build and live in a sustainable built environment.

COMFORT: The main objective of putting up structures is to protect the individual from the potentially harsh exterior environment. In the Philippines, this would mean protection from the heat and rain. Practical Green would need to address that comfort can be achieved in simple and practical ways.

COST: As mentioned earlier, cost is one of the hindrances for accepting green architecture and sustainable design. Practical Green would need to demonstrate that having a sustainable built environment does not necessarily need to be expensive – both in its initial cost and in its operational cost.

CONTINUITY: Once comfort is achieved at a reasonable cost, maintaining that lifestyle needs a certain degree of contunuity. Practical Green needs to incorporate ideas of perpetuating sustainability especially in the use and disposal of resources and materials.

Achieving comfort, cost and continuity in a simple, easy-to-understand checklist is the objective of Practical Green.

5 RATED PG: PRACTICAL GREEN

Each country is unique with its resources, climate, environment and purchasing capacity. Going green has to match these conditions in order to be successfully implemented. Rated PG: Practical Green shall explore these green and sustainable practices that match the Philippine environment and purchasing capacity. It all starts with maximizing nature given resources or passive solutions before utilizing the technology driven or active solutions.

Rated PG: Practical Green consists of two blocks of ideas – working with nature and assisting nature.

5.1 Working with Nature

Nature is sustainable, and man's intervention has somehow affected these sustainability cycles. Designing with nature to achieve a comfort level at a reasonable cost, while understanding the forces and resources available with minimal intervention are the strategies in this section. These strategies are sometimes called “passive” strategies. Working with nature consists of strategies for the building envelope, water and materials.

- **Building Envelope**: The purpose of the building envelope is to insure the comfort of the users in collaboration with the external environment. To achieve this comfort for the building envelope, there is an interplay of the building form and the building fabric. The building form marks the barrier between the outside and the inside. The building fabric allows natural light to enter the building, blocks the heat and allows for natural ventilation through the use of windows, walls and insulation. The following can be a checklist for the building envelope:

  - **Reduce the heat**: The Philippines is a hot and humid country and any strategy that keeps the heat out of the building contributes to the comfort of the occupants.
    - Smaller building exposure to the east and west
    - Insulate the roof
    - Insulate the east and west walls
    - Use of double walls and double roof
    - Provide a hot air exit at the highest point in the interiors

- **Let natural light in**: Maximizing daylighting will help reduce the need for artificial light (that will equate to savings) and create a bright and cheerful interiors. Daylighting is best harvested from the north. Since the Philippines is above the equator, daylight can be harvested from the south, but with appropriate sunshading devices.
  - Provide large windows on the north.
  - Provide windows with horizontal sun shade on the south.
  - If more natural lighting is needed, provide clearer story windows.

- **Catch the breeze**: In general, the Philippine wind patterns run northeast and southwest. However, it is best to check the micro-climate in each specific case, as large bodies of water, mountains and other structures may affect these wind patterns.
  - Provide for cross ventilation
  - Position windows to catch the prevailing breeze

- **Water**: A vital resource for life, the Philippines is blessed with abundant rainfall. The rainwater is a rich source of potable water. However, with the reduction of rainwater allowed to seep into the ground because of our built environment, measures to address this must be in place.
  - Harvest rainwater in elevated tanks, allowing gravity to help dispense the water.
  - Recycle wastewater through septic tanks, reed beds or sewage treatment plants.
  - Provide a dual-pipe system of potable and non-potable water in the building.
  - Insure that most rainwater and surface runoff seep down into the ground.

- **Materials**: The Philippines is a rich source of building materials such as stone, lime, clay, sand, bamboo, wood, etc. The main consideration for materials is the total life cycle of extraction, processing, use and disposal. At the end of its regular life-cycle, the material, if it is to be green, can be reused, recycled or is biodegradable if disposed back into the earth.
  - Use local materials as a priority material for the building
  - Chose materials that are durable and need minimal maintenance
  - Reuse or recycle as much as possible
  - Reduce waste by designing on the material module size

5.2 Assisting Nature

At times, the environmental resources are too harsh to provide comfort for the building users. In this situation, green and sustainable strategies may apply technology to insure the comfort level and livability of the built environment. These strategies are sometimes called “active” strategies that use generated power, mechanical forces, and other technologies. Assisting nature consists of strategies for cooling, artificial lighting and renewable energy.

- **Cooling**: A hot and humid climate will need at times a technology that keeps the temperature and humidity at a comfortable level. However, the choice of technology for cooling must be carefully chosen as air conditioning may use up to half of the total electricity cost of a building
- Consider high volume, low speed (HVLS) ceiling fans
- Use energy efficient air conditioning systems

- **Artificial Lighting**: It is inevitable that artificial lighing will be needed at night, and sometimes during the day. On the average, lighting may use twenty percent of the total electricity of the building.
- Use energy efficient lighting fixtures, like CFL or LED
- Plan light switching in accordance to the proximity to a source of natural light.
- Consider motion-activated lights

- **Renewable Energy**: The Philippines has one of the highest cost for electricity. Although current renewable energy such as photovoltaics, hydro and wind are quite expensive, it would be good to prepare for them.
- Photovoltaics should generally face south at an inclination equivalent to the degrees the location is above the equator.
- A photovoltaic system will need storage batteries and an inverter to convert DC to AC.
- Wind turbines need about 4 meters per second (20kph) winds to be viable.

6 CONCLUSION

Rated PG: Practical Green is a simple checklist divided into (1) Working with Nature and (2) Assisting Nature. This checklist can be expanded as resources and technology improve. It is imperative that priority be given to "Working with Nature" or passive strategies, as these simple strategies are cost effective.

Sustainability is nothing new. Sustainable development is a survival skill that our forefathers used to design the built environment and we can look back and learn those skills. They had a sensitivity to nature, what it provided and what they needed to assist it. As technology grew, humanity became less sensitive to nature and its built-in sustainability. We need to bring back these time-tested notions of sustainability.

Through this simple checklist of green and sustainable strategies, more buildings can be green. When more buildings are sustainable, then the sustainability effort starts making a real impact of the survival of our country.

Going Practical Green will pave the way for a more sustainable Philippines!

Green Architecture Advocacy Philippines, a civic organization, advocates that sustainability can and should be practiced by all. Its advocacies are carried out through regular lectures open to the public.

Sustainability for ALL … because that's when sustainability counts!

SAFE HOSPITALS E-TOOL: A COMPARATIVE ANALYSIS OF THE DISASTER-READINESS OF PRIVATE TERTIARY HOSPITALS USING A COMPUTER-BASED ASSESSMENT TOOL

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1 INTRODUCTION AND BACKGROUND

1.1 Background of the Problem

When disaster strikes, a community‟ s critical services must be able to protect the lives and well-being of the affected population, particularly immediately following impact. The ability of health services to function without interruption in these situations is a matter of life and death. It is imperative that all health services are housed in structures that can resist the force of natural disasters, that equipment and furnishings are not damaged, that vital connections (such as water, electricity, medical gases, etc.) continue to function, and that health personnel are able to provide medical assistance when they are most needed.

The countries of the Americas, along with more than 160 countries around the world at the 2005 World Conference on Disaster Reduction, adopted "Hospitals Safe from Disasters" as a national risk reduction policy in order to ensure that all new hospitals are built to a level of safety that will allow them to function in disaster situations. „Safe hospitals‟ initiatives also call for the use of mitigation measures to reinforce existing health facilities, particularly those providing primary health care. (Pan American Health Organization, 2008)

Hospitals are safe from disasters when health services are accessible and functioning, at maximum capacity, immediately after a disaster or an emergency. But what are "Safe Hospitals?" A safe hospital will not collapse in disasters; can continue to function and provide its services as a critical community facility when it is most needed; and is organized, with contingency plans in place and health workforce trained to keep the network operational. (Pan American Health Organization, 2008) According to the PAHO Disaster Mitigation Advisory Group (DiMAG), a safe hospital is a facility whose services remain accessible and functioning at maximum capacity and in the same infrastructure, during and immediately following the impact of a natural hazard.

1.2 Statement of the Problem

The Pan American Health Organization (PAHO), a regional office of the World Health Organization (WHO) developed the Hospital Safety Index which is a rapid and low-cost diagnostic tool used to assess the probability of a hospital or health facility remaining operational in emergency situations. From this initiative, the Department of Health (DOH) developed its own localized hospital disaster-readiness assessment tool and applied it to hospitals here in the Philippines. However, these existing tools can still be improved to make them more concise, localized, quantifiable, user-friendly, customizable, scalable, and easily integrated to existing hospital systems.

This thesis recognizes the need for such improvements with the current assessment tools and thus the development of the Hospitals Safe From Disasters Computer-Based Assessment Tool (HSFDCBAT). In order to establish the applicability and effectiveness of this tool, this study carries out a comparative analysis on selected private tertiary hospitals here in the Philippines. From the methodology, the thesis also documents the disaster-readiness of the health facilities as well as the "user-satisfaction" aspect which can be a basis for further advancements of the tool.

1.3. Objectives of the Study

In order to establish the disaster-readiness of the selected hospitals and to attain the goals set for this research study, the following objectives were set:

1.3.1. To develop a concise and quantifiable localized hospital safety index here in the Philippines.

1.3.2. To design and develop a computer-based assessment tool to make this localized hospital safety index more user-friendly, more scalable, customizable, flexible and easily integrated within the hospital system as well as with the built environment.

1.3.3. To use this tool in determining the disaster-readiness of the selected hospitals and to carry out a comparative analysis on the data gathered from this study.

1.3.4. To assess the applicability and effectiveness of this tool as a way to check the hospital‟ s disaster-readiness based on the context of the user for each respective health facility.

This study aimed to develop a tool from an existing concept, then to the advancement and improvement of this concept, then its application and testing, and finally to its evaluation as an effective tool.

This research was done not to criticize, undermine, supersede or claim superiority over another but rather to help improve, simplify, localize and synthesize existing assessment tools.

1.4. Significance of the Study

When health services and hospitals fail due to disaster, people die and suffer needlessly both during the disaster and long into the future. Those who were injured need urgent medical attention but those who escaped injury have not escaped the long term need for medical care and public health after the disaster is forgotten. Deaths of the sick, elderly and children in hospitals during disasters and the failure of emergency services when they are most needed can have a crippling effect on public morale and can ignite political dissatisfaction. (National Center for Health Promotion - DOH, 2009).

The study showed that it may be of value to the practice and to the advocacy on safe hospitals as set by the Department of Health under the wing of the World Health Organization. The body of knowledge that was created in this study will benefit many sectors such as the Department of Health, hospital systems, both private and public, professionals of the built environment specializing on safe hospitals and schools, medical practitioners and most importantly, the patients and the public who will use these hospitals especially in the occurrence of disasters.

1.5. Expected Output

This study is expected to provide an efficient, scalable, customizable, flexible and integrated disaster–readiness evaluation tool which is applicable in the local context, based on the Hospital Safety Index from Pan American Health Organization (PAHO) and the Safe Hospitals in Emergencies and Disasters: Philippine Indicators from the Health Emergency Management Staff of the Department of Health (DOH-HEMS). Its applicability in the private hospitals may then be modified to make it applicable in government hospitals and maybe in the future, as it is designed to be scalable, make the tool web-based for better coordination among hospitals as well as ease of use.

This study showed a comparative analysis of selected private hospitals using the developed computer-based assessment tool, as well as an evaluation of the tool on its relevance to the users. The results gathered from the research work may lead to possible dissemination of findings in a conference or journal and with it as an output, a prototype of the desktop-based application which can then be subsequently modified into a web-based solution which has the potential to benefit more users.

1.6. Scope and Delimitation of the Study

Four (4) private, tertiary level health facilities were identified for this study. The four hospitals were pre-selected according to the following criteria set as study focus/limitations:

1.6.1. Geographic Location. Hospitals selected in this study are located in Luzon, specifically in Central Luzon and Metro Manila. (See Figure 1)

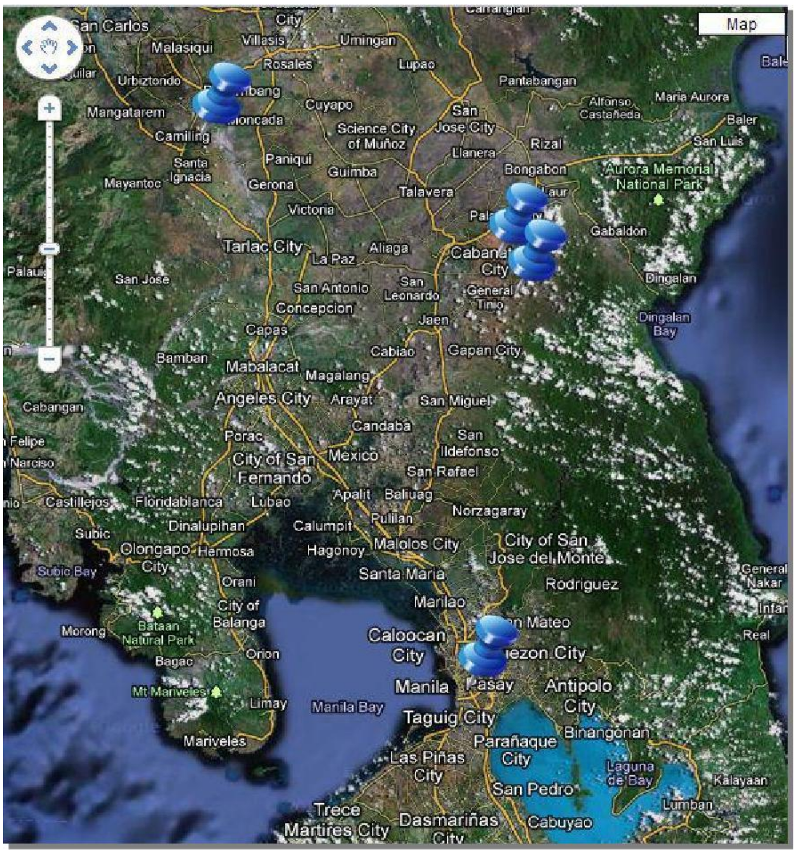


Figure 1 Geographical Location of Selected Hospitals (Source: Google Maps)

1.6.2. Hospital Level.

The DOH classifies hospitals into four (4) levels depending on service capability, as detailed in DOH Administrative Order no. 2005-0029. Each hospital level is briefly described below (Lavado, 2011):

- Level 1, Primary: An emergency hospital that provides initial clinical care and management patients requiring immediate care. Clinical services include general medicine, pediatrics, obstetrics, non-surgical gynecology, primary clinical laboratory, first level radiology and pharmacy.
- Level 2, Secondary: A non-departmentalized hospital that provides clinical services such as general medicine, pediatrics, obstetrics, surgical gynecology, secondary clinical laboratory, first level radiology and pharmacy.
- Level 3, Tertiary: A departmentalized hospital that provides particular forms of treatment, surgical procedure and intensive care. Clinical services provided include general medicine, pediatrics, obstetrics, surgical gynecology, tertiary clinical laboratory, secondary level radiology and pharmacy.
- Level 4, Teaching & Training: A teaching or training hospital that provides clinical care similar to Level 3 as well as sub-special forms of treatment. Clinical care is also similar to level 3 as well as sub-specialty clinical care as well as third level radiology.

1.6.3.Hospital Type.

Hospitals can also be classified as either Government or Public Hospitals such as Provincial Hospitals and Rural Health Units (RHU‟ s); and Private Hospitals which are categorized as either DOH-retained or locally-owned and controlled. Private hospitals are classified as single proprietorship, partnership, corporation, missionary / religious / civic organization or foundation and cooperative.

1.6.4. Development Time Frame of Hospital. Historical development of the hospitals was also considered with respect to National Structural Code of the Philippines (NSCP) code changes.

1.6.5. Development Size of the Hospital.

Hospital size in terms of its estimated floor area (FA) as well as in terms of its patient bed capacity.

1.6.6. Access to Available Data.
Because of the confidentiality and proprietary nature of certain information, the hospital administration was hesitant to release pertinent information and materials on the project. Certain information was sourced from the hospitals‟ website.

1.6.7. Weighting System.
Due to the considerable effort involved in gathering experts in their respective fields and then assessing which checkpoints are important based on their perception, this was not made part of the scope of this research anymore. Instead, a baseline weight of 1.0 was used for all the checkpoints in the tool (i.e. all checkpoints in suitable sites, structural, non-structural and functional all have equal weights and relevance, at least for this version of the tool). Weighting system can also be based on existing studies if available.

1.6.8. Insurance Companies.
Data from insurance companies which are also concerned with the disaster-readiness of hospital facilities were not collected because of confidentiality and proprietary concerns and thus, no comparison whatsoever with the functionality of the HSFDCBAT was made in this research.

1.6.9. ISO-Certified Hospitals.
Same with the previous limitation and for the same reasons, data from ISO Certifications and ISO-certified hospitals which are concerned with the disaster-readiness of hospital facilities were not collected and thus, no comparison whatsoever with the functionality of the HSFDCBAT was made in this research.

1.7. Definition and Terms

1.7.1. Safe Hospitals

1.7.1.1 A safe hospital will not collapse in disasters; can continue to function and provide its services as a critical community facility when it is most needed; and is organized, with contingency plans in place and health workforce trained to keep the network operational;

1.7.1.2 A safe hospital is a facility whose services remain accessible and functioning at maximum capacity and in the same infrastructure, during and immediately following the impact of a natural hazard.

1.7.1.3 Can also be referred to as "Hospitals Safe From Disasters (HSFD)"

1.7.2 Hospital Safety Index (HSI)
A rapid, reliable and low-cost diagnostic tool which is easy to apply by a trained team of engineers, architects and health professionals. Scores are entered into an Excel spreadsheet (the Index Calculator), and automated formulas tabulate the results. The results take into account the safety level of structural, nonstructural and functional components. There are 145 items or areas assessed and health facilities fall into one of three safety categories: High, Average and Low. It was developed by the Pan American Health Organization (PAHO).

HSI provides a snapshot of the probability that a hospital or health facility will continue to function in emergency situations, based on structural, nonstructural and functional factors, including the environment and the health services network to which it belongs.

1.7.3 Safe Hospitals in Emergencies and Disasters: Philippine Indicators
- this Manual emanated from a research concept by the Department of Health-Health Emergency Management Staff (DOH-HEMS) to assess hospitals‟ structural, non-structural and functional elements in times of emergencies and disasters. This eventually became a project entitled, Capacity Assessment of Metro Manila Tertiary Hospitals in Responding to Emergencies and Disasters," which was funded by the Health Policy Development and Planning Bureau (HPDPB), coursed to the National Capital Region, and started in October 2008. An Assessment Team was organized to oversee the implementation of the research project in 25 hospitals in the National Capital Region.

1.7.4 Pan American Health Organization (PAHO) - is an international public health agency with over 100 years of experience working to improve health and living standards of the people of the Americas. It enjoys international recognition as part of the United Nations system, serving as the Regional Office for the Americas of the World Health Organization, and as the health organization of the Inter-American System. PAHO is based in Washington, D.C., and has scientific and technical experts at its headquarters, in its 27 country offices, and its nine scientific centers, all working with the countries of Latin America and the Caribbean in dealing with priority health issues. PAHO Member States include all

35 countries in the Americas.

1.7.5 World Health Organization (WHO) - is a specialized agency of the United Nations (UN) that acts as a coordinating authority on international public health. WHO is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries and monitoring and assessing health trends.

1.7.6 Department of Health (DOH) - is the principal health agency in the Philippines. It is the executive department of the Philippine Government responsible for ensuring access to basic public health services to all Filipinos through the provision of quality health care and the regulation of providers of health goods and services. The DOH is composed of about 17 central offices, 16 Centers for Health Development located in various regions, 70 hospitals and 4 attached agencies.

1.7.7 Disaster - defined as an occurrence where normal conditions of existence are disrupted and the level of suffering exceeds the capacity of the hazard-affected community to respond to it. (Department of Health Western Pacific Region, 2010)

1.7.8 Emergency - defined as a state in which normal procedures are suspended and extra-ordinary measures are taken in order to avert the impact of a hazard on the community. Authorities should be prepared to effectively respond to an emergency. If not properly managed, some emergencies will become disasters. (Department of Health Western Pacific Region, 2010)

1.7.9 Hazard - any phenomenon that has the potential to cause disruption or damage to the community, e.g. earthquake, flood, typhoon, and cyclone. Some hazards may cause emergencies; not all become disasters. (Department of Health Western Pacific Region, 2010)

1.7.10 Computer-Based Assessment (CBA) - also known as Computer-Based Testing (CBT), e-assessment, computerized testing and computer-administered testing, is a method of administering tests in which the responses are electronically recorded, assessed, or both. As the name implies, Computer-Based Assessment makes use of a computer or an equivalent electronic device such as a cell phone or PDA. CBA systems enable educators and trainers to author, schedule, deliver, and report on surveys, quizzes, tests and exams. Computer-Based Assessment may be a stand-alone system or a part of a virtual learning environment, possibly accessed via the World Wide Web.

1.7.11 Computer-Based Assessment Tool (CBAT) - shall mean a tool whose main function is to execute a Computer-Based Assessment (CBA).

1.7.12 Health Emergency Management Staff (HEMS) - is an organization created under the Department of Health to ensure a comprehensive and integrated health sector emergency management system

1.7.13 Scalability - in information technology, (including hardware, communication and software), is the ability of a system, network, or process, to handle growing amounts of work in a graceful manner or its ability to be enlarged to accommodate that growth.. For example, it can refer to the capability of a system to increase total throughput under an increased load when resources are added.

1.7.14 Hospital Bed Capacity - the number of beds which a hospital has been designed and constructed to contain. It may also refer to the number of beds set up and staffed for use.

1.7.15 Database - is an organized collection of data for one or more purposes, usually in digital form

1.7.16 Graphic User Interface (GUI) - is a type of user interface that allows users to interact with electronic devices with images rather than text commands. GUIs can be used in computers, hand-held devices such as, portable media players or gaming devices, household appliances and office equipment.

1.7.17 Database Query – a piece of code (a query) that is sent to a database in order to get information back from the database. It is used as the way of retrieving the information from database. A database "query" is basically a "question" that you ask the database. The result of the query is the information that is returned by the database management system.

1.7.18 Infographic - Information graphics or infographics are graphic visual representations of information, data or knowledge. These graphics present complex information quickly and clearly, such as in signs, maps, journalism, technical writing, and education.

1.7.19 Disaster Management Advisory Group (DiMAG) - a group which provides advice to the Pan American Health Organization (PAHO) and its members in a variety of themes related to disaster mitigation and risk reduction in the health sector. The group was set up in 2003 as a way of dealing with three important facts: new hospitals are being built in the region without taking risks and natural hazards into consideration; many existing hospitals show unsatisfactory performance in emergency and disaster situations; and countries and health facilities need to be able to ensure access to independent, technical advice.

1.7.20 Disaster Management Committee (DMC) – a committee formed from an interdisciplinary field dealing with the strategic organizational management processes used to protect critical assets of an organization from hazard risks that can cause disasters or catastrophes, and to ensure the continuance of the organization within their planned lifetime

1.7.21 Emergency Operations Center (EOC) - is a central command and control facility responsible for carrying out the principles of emergency preparedness and emergency management, or disaster management functions at a strategic level in an emergency situation, and ensuring the continuity of operation of a company, political subdivision or other organization.

1.7.22 Hospitals Safe From Disasters Computer-Based Assessment Tool (HSFDCBAT) – refers to a computer-based assessment tool designed and developed by the researcher to carry-out the assessment of the disaster-readiness of health facilities similar to the Hospital Safety Index. For this research, it may also be referred to as an e-Tool or an e-Index.

1.8 Historical Background

In 2005, the Hyogo Framework for Action (HFA) was endorsed by 168 countries on the World Conference on Disaster Reduction in Kobe, Japan. This provides a global footprint for disaster risk reduction and calls on nations to promote the goal of risk reduction.

Three years later, in 2008, actions on hospital disaster preparedness became more extensive here in the Philippines. The conceptualization of research on hospital preparedness in emergencies was pioneered by the Department of Health – Health Emergency Management Staff (DOH-HEMS) and the Health Policy Department and Planning Bureau (HPDBD) but there were no available tools yet early on. As the development went on, a steering committee was created and hospital assessment tools were drafted. On August 2008, the launch of the World Safe Hospitals Campaign and discussion of tools was held at the Pan Pacific Hotel in Makati City, Philippines.

The manual "Safe Hospitals in Emergencies and Disasters: Philippine Indicators" from the DOH-HEMS to assess Philippine hospitals‟ structural, non-structural and functional elements in times of emergencies and disasters was then developed. On October 2008, the research project called "Capacity Assessment of Metro Manila Tertiary Hospitals in responding to Emergencies and Disasters" was started. It was funded by the HPDPB, coursed to the Center for Health Development-National Capital Region (CHD-NCR). An assessment team was organized to oversee the implementation of the project in 25 hospitals in the National Capital Region. (Banatin, 2009) The set of indicators in the manual have since been revisited and revised through several write-shops and with the Technical Working Groups. National codes, policies and guidelines were also included in this manual as resource material. (Department of Health - Health Emergency Management Staff (DOH-HEMS), 2009)

January 2009 kicked off the start of the assessments for other hospitals and three months later in April, World Health Day was celebrated with the theme, "Save Lives: Make Hospitals Safe in Emergencies" which was marked by the launch of the displaying of lanterns in all hospitals as symbols of "Safe Hospitals". The Manual on Safe Hospitals was also officially launched during this month at the Traders Hotel in Manila. Trainings on Safe Hospitals continued and the presentation of Capacity Assessment of Metro Manila Hospitals, which was done on sixteen (16) DOH hospitals, two (2) Local Government Unit (LGU) Hospitals and seven (7) private hospitals by six teams of experts was held. The year was capped off by the "International Conference on Safe Hospitals" - Philippine Convention on Health Emergency Management held at the Shangri-La Hotel, Mandaluyong, Philippines on December 2 and 3.

Up to the present, there are still continuing workshops on addressing critical issues on Safe Hospitals where concerned groups review gaps, explore solutions, document and consolidate these gaps and solutions and then identify next steps for action.

2 REVIEW OF RELATED STUDIES AND LITERATURE

2.1 UN International Strategy for Disaster Reduction (UN/ISDR)

The WHO Western Pacific Region states that the following publications were made from 2008 to 2009 specifically for the Safe Hospitals Campaign: Assessment Tools for Hospital Safety; Indicators for Safe Hospitals; Guidance on Conducting Hospital Drills/Exercises; Guidance on Hospital Disaster Management Planning; Guidance on Designing Disaster Resilient Health Facilities; Structural and Functional Indicators for Safe Hospitals; and Guidance on Advocacy and Awareness Raising. (WHO Western Pacific Region, 2009)

The UN International Strategy for Disaster Reduction (UN/ISDR) and WHO have embarked on the 2008-2009 World Campaign on Hospitals Safe from Disasters. This reflects one of the five priorities of the Hyogo Framework of Action 2005-2015. A bi-regional launch was conducted in January of 2008 in Bangkok and the regional launch for the Western Pacific was organized August 2008 in Manila.

The Safe Hospitals Project aims to provide tools that enable government, communities and institutions to reduce their hospitals' and health facilities‟ risks from natural hazards and disasters. It aims to develop, test and publish tools and resources for the health sector to assess and address risks arising from natural hazards. Specifically, it aims to accomplish the following:

- Publish tools for mapping the vulnerabilities of health sector's infrastructure
- Tools and guidelines of health sector disaster management
- Enhance capacity for disaster preparedness and response
- Assess structural and functional integrity of selected health facilities
- Raise awareness of the campaign for community leaders, private sector health staff, planners, decision makers, policy makers, and the general public.

Several gaps have been identified. Local health managers, hospitals and other health facilities identified that natural hazard-prone areas around the countries in the region lack the capacity to respond to emergencies and are vulnerable to the negative impact of disasters themselves. Essential health services are usually disrupted after a disaster when health facilities are damaged or destroyed. Impact on the people is great when lack of knowledge, skills, and tools on disaster preparedness and emergency management is combined with safe hospital and hospital preparedness was developed in early part of 2009.

As a component for capacity development, a training course was developed which is a take-off from the Public Health and Emergency Management for Asia and the Pacific (PHEMAP) training courses offered at the international and national levels. This is a "special" training course on safe hospitals. (UN International Strategy for Disaster Reduction (UN/ISDR), 2009)

2.2 Applicability of the Hospital Safety Index by PAHO in the Philippine Context

This researcher studied the applicability of the Hospital Safety Index by PAHO in the Philippine context by applying the index to a private tertiary hospital in Tarlac and then comparing it to the locally-used Philippine Indicators. After applying the Hospital Safety Index on a local tertiary hospital and then getting trusty and reliable results, it was concluded that the Hospital Safety Index, which is specifically made for Latin America and the Caribbean, is also applicable in the Philippine context. Most if not all of the elements in the checklist are applicable, except for hazards like hurricanes which are not evident here in our country.

Comparing the Hospital Safety Index to its local counterpart, The Philippine Indicators for Safe Hospitals in Emergencies and Disasters, it can be seen that most of the indicators are just specific and locally-customized versions of the checklist points in the former. It should be noted, though, that the structural indicators in the Philippine Indicators are more complete and are more pertinent for local use. Also, the additional non-structural and functional indicators for hospitals with highly infectious diseases are present in the local hospital disaster readiness tool and absent in the PAHO evaluation tool. This may have a definite use in the local context but these additional indicators should be condensed to have a more relevant approach as far as safe hospitals are concerned. (See Figure 19)

2.3 Personal Accounts of Hospital Disaster Victims in the Philippines (from DOH-Hospitals Safe From Disasters Video

Presentation)

Hospitals have become victims of disasters of the past. Some examples are the super typhoon that battered Bicol Regional Training and Teaching Hospital (BRTTH) in the Bicol Region, Fire at Lung Center of the Philippines, Earthquake causing cracks on hospital walls, floods on hospital floors and more. These were some personal accounts of the people from hospitals directly affected by these disasters (National Center for Health Promotion - DOH, 2009):

2.3.1 Dr. Noel Roy Gigare (Chief of Hospital, Federico Ramon Tirador, Sr. Memorial Hospital, FRTSMH in Iloilo) on typhoon Frank hitting Iloilo in 2008 – "like a tsunami…waist deep to neck deep floods almost 6 ft.

…after less than 3 hours, it subsided…it was just a flash flood. All equipment were damaged and only the ceiling was left. Most patients and staff evacuated as fast as they can to save their own lives…they escaped by passing through ceiling."

2.3.2 Dr. Michael I. Terrencio (Chief of Clinics, Dr. Rafael S. Tumbokon Memorial Hospital, DRSTMH in Aklan) on typhoon Frank hitting Aklan.

"first time water reached the inside of the hospital. More than 2 ft of flood water crept into the hospital. Mudflow came with flood…Immediately ordered evacuation of the patients at ground floor…they were not able to have 2nd round of evacuation because in 30 min, the water level rose another foot. Equipment were not saved because people were rescued first. New CT-scan (less than a year of usage) was submerged in water…Aklan was worst damaged in province…Immediately sent a team of doctors and nurses to augment…to operate, admit patients."

Figure 2 Emergency Room of DRSTMH in Aklan (Source: Screen Capture from DOH Video)

2.3.3 Mr. Rudel M. Jaranilla (Nurse VI, Western Visayas Medical Center) –

"In dialysis, you need water. Not only ordinary water but treated water.

What will happen to patients that will be dialyzed if we don‟ t have water? So there are contingency stocks of water as well as stock of diesel fuel for generator to supply electricity to the hospital. The machines should be taken cared of. In that aspect, we have anticipated all those things. Many parts of ceiling were damaged (like waterfalls); Some of the windows were broken; With regards to facilities, computers were saved. X-ray machine was damaged due to water from ceiling."

2.3.4 Dr. Mary Jean A. Gelito (OIC, Ibajay District Hospital) – "waist deep floodwater, patients were brought literally to the ceilings, providing airways by punching holes through the roof. 16 patients, 49 people in the hospital during typhoon Frank. Unprecedented flood water level in the hospital. Damage of equipment and documents were aplenty. Beds, mattresses, tables and chairs, cabinets, furniture and fixtures were all damaged."

2.3.5 Dr. Antonio S Ludovice, Jr. (Chief of Hospital Josefina Belmonte Duran Memorial District Hospital, Tuburan, Ligao City) –

"Consecutive typhoons, Typhoon Milenyo and Typhoon Reming. During typhoon Milenyo, the Operating Room was already detached. During typhoon Reming, 80% of hospital facility and building was destroyed. Two tents were set-up, one from AFP and the other from United Nations Children‟ s Fund (UNICEF). One used as Out Patient Department (OPD) Emergency Room (ER) and the other one for Surgery. The staff was on a 24-hour on-call touring duty."

Figure 3. JBDMDH in Ligao City without a roof because of Typhoon Reming and Milenyo (Source: Screen Capture from DOH Video)

2.3.6 Dr. Edgardo Esplana (Chief of Hospital, Bicol Medical Center, BMC) "Initally, we assess our own facility regarding the damages that were wrought by the typhoon. Upon assessment, and seeing that there was not much damage, we dispatched our Health Emergency Management Team to roam the different areas in the nearby towns if they can extend any help…There was 15-M worth of damage."

2.3.7 Dr. Rogelio Rivera (Chief of Hospital Bicol Regional Training and Teaching Hospital) - "250-bed tertiary hospital located in Legazpi City, Province of Albay. Nov 30, 2006, Typhoon Reming brought havoc to region…Nov 29 weather update said typhoon will not hit Albay province, however Code White was raised and HEMS was mobilized. The next day, the typhoon changed its course and directly hit Albay province thus Code Red was raised and HEICS, Hospital Emergency Incidence Command System was put in place. More than 50 % of facilities were damaged including the ER. Electrical and water system were cut off, aggravating the situation. Because personnel were limited because of impassable roads, and they themselves were victims, the hospital had a very limited staff. On first two days of operation after disaster, hospital was limited only to emergency situations only. After typhoon, influx of more than 200 patients was treated at our damaged ER. Succeeding days became difficult because of depletion of supplies."

Figure 4 Aftermath of Typhoon Frank in a Bicol hospital. (Source: Screen Capture from DOH Video)

2.3.8 A personal account of a hospital patient - “Saddest, most disheartening experience during typhoon Reming, two of my kids got injured from the landslide, but when we rushed them to the hospital, we lost hope.
Because even the hospitals are victims to the disaster. It‟ s dysfunctional, it couldn‟ t treat patients. If there was any functioning hospital that time, my kids could have been revived.”

2.3.9 Another personal account of a hospital patient - “When I got injured during the typhoon Milenyo (typhoon Xangsane), I was confined in a hospital. I thought being in a hospital was safe. But one morning, I woke up, I saw the roofs of the hospital being blown away. It was a stressful, traumatic even. And it didn‟ t help in my recovery. It‟ s just so sad and so frustrating that what you thought could be the safest place can actually be dangerous too.”

Figure 5 Typhoon Ondoy's effect on hospitals (Luis, 2009)

Figure 6 UERMMMC hospital during Typhoon Ondoy (Luis, 2009)

Figure 7 Ondoy's effect on Mission Hospital in Rosario, Pasig (Luis, 2009)

Figure 8 Effect of floods and landslides on hospital supplies and equipment (Luis, 2009)

Figure 9 Effect typhoons on transportation and logistics. (Luis, 2009)

2.4 Recent Developments on the Hospitals Safe From Disasters (HSFD) Initiative

2.4.1 The Emergency and Humanitarian Action (EHA) unit of the WHO Regional Office for the Western Pacific (WPRO), in partnership with the University of the Philippines Open University (UPOU), conducted the midterm review of the second phase of the Hospitals Safe from Disasters (HSFD) campaign on 2-4 March 2011 in Manila. The second phase of the project aims to expand mapping and assessment of different levels of hospitals in small and medium sized cities, integrate HSFD concepts in national development plans and policies, and support further development and adaptation of tools and resources. This will mainstream disaster risk reduction in the health sector within the framework of the global campaign for safer cities in 2010-2011.

Through several workshops and group discussions, the review team evaluated the accomplishments of the past seven months against the proposed program of activities in terms of outputs, target dates and budget. Issues, experiences and views from different perspectives were shared between participants. From these in-depth discussions, recommendations and strategies for the effective continuation of the project were then developed.

“The project has achieved a lot of progress,” said Dr. Arturo.

Pesigan, EHA Technical Officer. “But we must continue to work together as we move toward the achievement of goals that go beyond the project. Eventually, countries should be able to implement and integrate safe hospitals concepts in and through their own initiatives and national disaster preparedness plans.” (WHO Western Pacific Region Emergency and Humanitarian Action, 2011)

During one of the WHO workshops, an Association of Structural Engineers in the Philippines (ASEP) structural engineer discussed the analogy that new building costs PHP 20,000 to PHP 25,000 per square meter to build and the structural cost of this alone is around 50% or PHP 10,000 to PHP 12,500 per square meter already. If the structure requires rehabilitation, the rehabilitation cost is around 15% for the structure only. This amounts to 3,000 to 3,750 PHP per square meter. Soft cost can be estimated at about one third of the rehabilitation cost or around 1,000 to 1,200 PHP per square meter, with a minimum of 500 PHP per square meter. This includes soil tests, X-rays, project management, consumables and overhead costs. He suggested that if you will exceed 30% of the total cost for a new hospital for rehabilitation, better build a new hospital. This just goes to show how costly compliance to structural requirements could be, especially for health facilities.

2.4.3 To emphasize how serious one of the health facilities is in complying with the functional capacity requirements, a hospital representative shared that a week ago from the interview, seven of their team members attended a disaster preparedness summit and that several days later they attended a Metro Manila Earthquake Impact Reduction Study (MMEIRS) seminar. During the interview, their team was undergoing training for safety preparedness which was according to him, a weekly routine for them as safety and fire brigade volunteers of the hospital. He said that security is also one of the main concerns of the team as well as terrorism, not only earthquake, fire, etc.

For a change, one of the interviewees for the research study, who was involved with the One Million Safe Schools and Hospitals Project of the DOH and the WHO, was more concerned with functional aspects of the HSFDCBAT. He further discussed that these functional requirements are community-based, community-wide and has a tie up with the Local Government Units (LGU‟ s), the Red Cross, other hospitals and other networks, but the main problem is funding. The concern of private hospitals, according to him is that they generate their own funds while government hospitals can wait for budget (continuous funding). He also stressed that it is difficult to ask for budget because of the value of money, and the immediate needs of hospitals weighed against the cost implications of having a disaster-safe health facility.

As with any other institution, he said, when it comes to responses, the main concern is still funding. People in the response community will always think of “saving lives”, but saving lives incur costs. One of solutions he mentioned is what he and his team are doing. They volunteer. He said that in convincing others to volunteer, one way to look at it is to “don‟ t think of it as another job but think of it as protecting your job” since volunteering in making health facilities safe from disasters is in effect, also protecting their own livelihood.

3 METHODOLOGY

3.1 Flow of Study

The data collection was done by first acquiring the Hospital Safety Index from PAHO (Pan-American Health Organization) and the local version which is the Philippine Indicators on Safe Hospitals in Emergencies and Disasters. These assessment tools were then evaluated on what are applicable in the local context and what should be added or modified from the existing checkpoints. These are then applied to the localized version of the tool which is currently more qualitative than quantitative.

From the data gathered, a computer-based assessment tool was developed and used to assess disaster-readiness of selected private hospitals here in the Philippines. This in turn will produce data, this time, quantifiable, which will be a better gauge in determining whether a hospital is indeed disaster-ready based on its structural, non-structural (including architectural) and functional characteristics. Limitation of this computer-based assessment tool, though, is that it will first be desktop-based (i.e not yet web-based) for computers within the hospital network system. But further development can convert this into a web-based application which will make it more accessible and interactive among participating hospitals and organizations through the web.

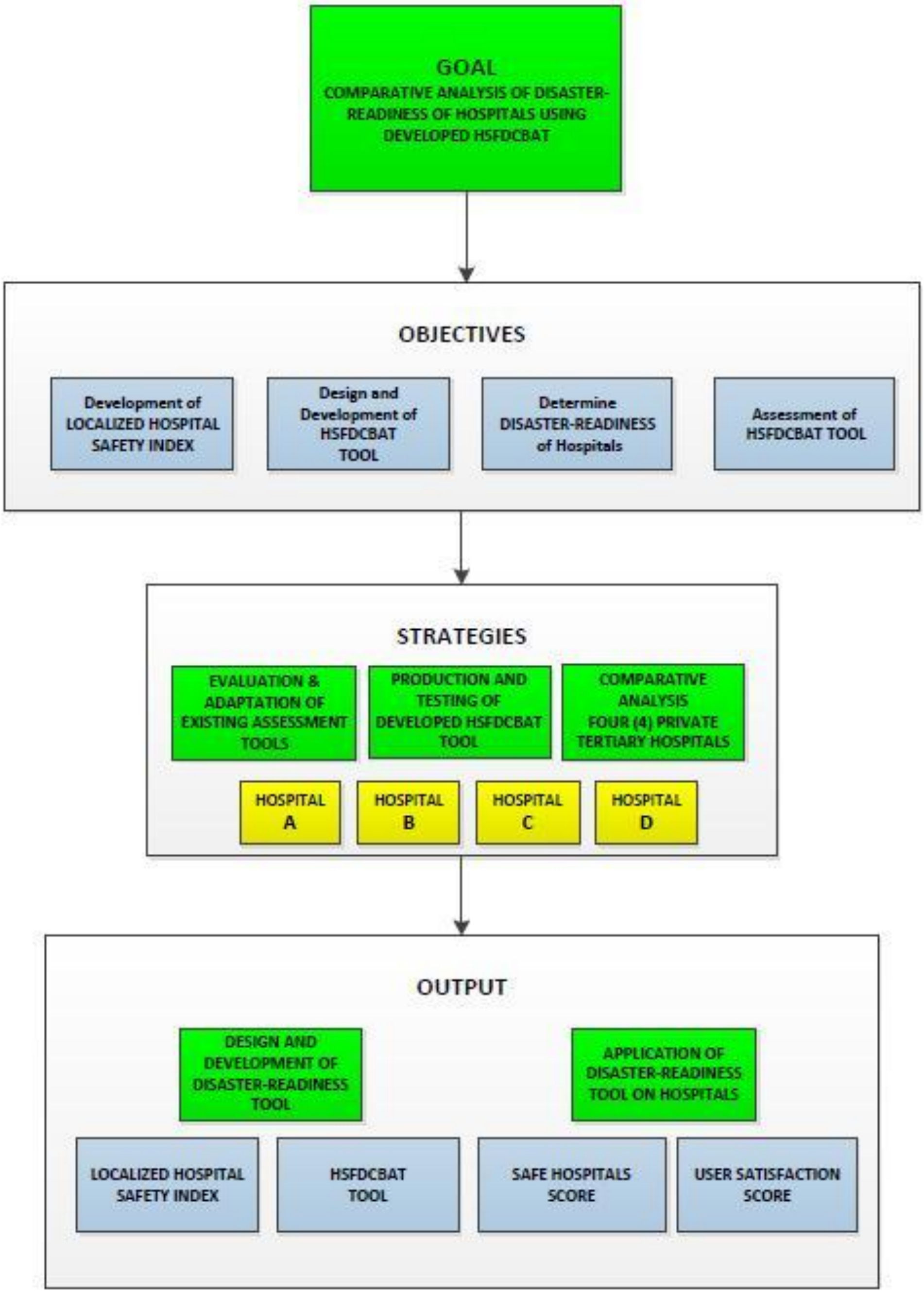


Figure 10 Flow of Study

The disaster-readiness of the sample hospitals will be established from the comparative analysis, documentation and interpretation of the HSFDCBAT results. Surveys and interviews were also conducted on those who used the software for recommendation or disapproval of the developed tool. (See Figure 10)

3.2 Data Collection

Primary references for the research work were acquired through electronic files from the website of the Pan-American Health Organization (PAHO) including the Hospital Safety Index Evaluation Form and the Hospital Safety Index Guide for Evaluators. The Hospital Safety Index Calculator, though, was acquired through direct communication via email with the Regional Adviser for Emergency Preparedness and Disaster Relief of PAHO and the World Health Organization (WHO). This calculator was supposed to be given only to those who attended seminars and workshops on Safe Hospitals in the Americas in data discs but the Director was kind enough to send this researcher a copy given the condition that it will be for academic purposes only and that it will remain confidential.

For the Department of Health (DOH) documents, hard copies of the research materials were acquired from the DOH themselves through the help of individuals who were involved with the Safe Hospitals initiative of the said government agency. Also, references from PowerPoint presentations, videos and lectures in workshops as well as advertisement campaigns organized and produced by the DOH and the WHO were also vital in the data gathering process.

For the comparative analysis, all of the pertinent data were acquired from the HSFDCBAT tool, generated reports from the system and interviews with the respective individuals from the hospital who are knowledgeable in the subject matter and the actual participants who used the system. First hand data were also gathered from site photography and direct inspection of the hospitals. These four (4) health facilities were selected as areas for study based on the scope and delimitations earlier mentioned. It should be noted that purposive, convenient, non-probability sampling was used to get the sample hospitals.

3.3 Plan of Analysis

In line with the study's objective of primarily developing a simple, concise and efficient localized hospital safety index based on mathematical models, the existing assessment tools (PAHO HSI and DOH-HEMS Philippine Indicators) were reviewed and compared, then the relevant and locally-appropriate checkpoints were analyzed and consolidated. These checkpoints were then used as the basis for the development of the HSFDCBAT, which subsequently, would be the basis for the analysis of the disaster-readiness of the hospitals.

Due to the agreed upon confidentiality of the hospital data that were gathered, the hospital names were neither divulged nor mentioned in this paper but instead, represented as Hospitals A, B, C and D. Each health facility was analyzed individually in terms of their *site location*, *structural safety*, *non-structural safety* and *functional capacity*. Their strengths and weaknesses were also assessed based on the HSFDCBAT tool report. The health facilities were compared with each other on which common areas or checkpoints are susceptible to high risks during disasters. From this analysis, recommendations were also given for each hospital for the next steps to be done. After each assessment, a survey, which is also a part of the tool, is carried out to evaluate the usability and relevance of the tool. (See Figure 11a & 11b)

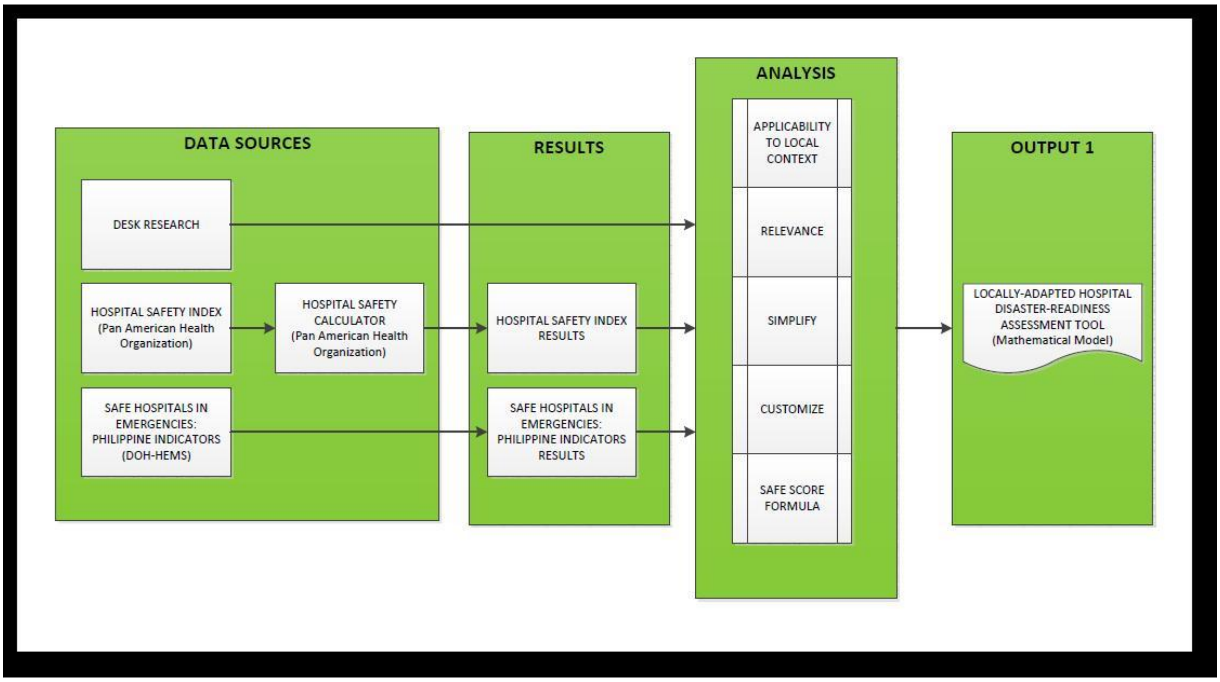


Figure 11a Data Collection

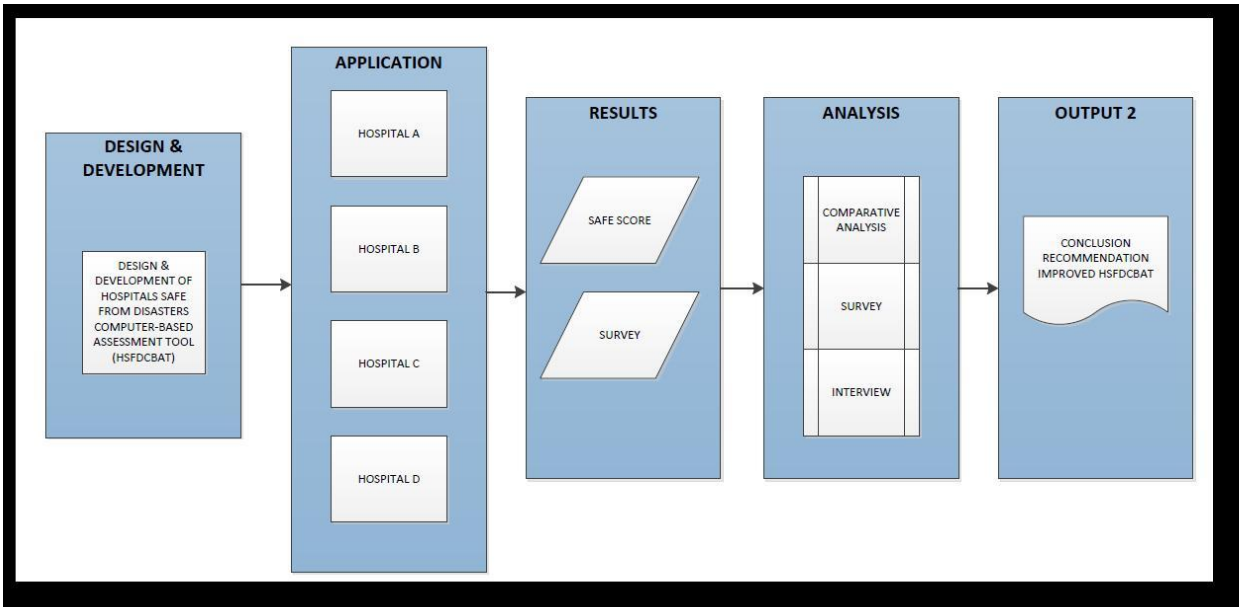


Figure 11b Data Collection

4 DISCUSSION OF "SAFE HOSPITALS"

4.1. Discussion of Hospitals Safe from Disasters (HSFD)

The factors that put hospitals and health facilities at risk are the buildings, equipment, health workforce and basic lifelines and services. Upon construction, the building should be checked by an expert who knows the norms in building conditions like location, design, materials used, etc. Hospital equipment must always be kept functional by an authorized person to avoid a halt to hospital operations. The loss or unavailability of health workers compromises care for the injured. Lastly, basic lifelines and services such as electrical power, water and sanitation should always be maintained by authorized people because a hospital's functionality relies on them. In other words, people are key in reducing such risks. For after all, people build hospitals, people keep them safe, people protect the facilities, and in the end, people save lives.

The difference in expense between building a safe and an unsafe hospital can be negligible but it can be a matter of life and death when disasters strike. Therefore, we can say that the most expensive hospital is the one that fails. What then is a disaster-safe hospital? A safe hospital will not collapse in disasters, killing patients and staff. It continues to function and provide its services as a critical community facility when it is most needed. It is organized with contingency plans in place and essential health workforce trained to keep the network operational.

The importance of hospitals and all kinds of health facilities extends beyond the direct life-saving role they play. They are home to critical health services such as public health laboratories, blood banks, rehabilitation facilities or pharmacies. They are the setting where health workers work tirelessly to ensure the highest level of service and availability. They safeguard public health in the aftermath of disasters. Health facilities have a symbolic social and political value and contribute to a community's sense of security and well-being. Because of this, the World Health Organization, along with the secretariat of the International Strategy for Disaster Reduction with the support of the World Bank is dedicating the 2008-2009 World Disaster Reduction Campaign to Hospitals Safe from Disasters.

According to Dr. Dean Shuey, Regional Adviser in Health Sector Development, WHO Western Pacific Region, the WHO in cooperation with the secretariat of the UN ISDR with the help of the World Bank aims to help protect the lives of patients and health workers by ensuring the structural resilience of health facilities. Making sure health facilities and health services are able to function in the aftermath of emergencies and disasters when they are most needed and improving the risk reduction capacity of health workers and institutions including emergency management.

Protecting health facilities from disasters is possible through the WHO's Emergency and Humanitarian Principles – Action, Preparedness and Collaboration.

ACTION - In order to protect our hospitals in times of emergencies, first of all, we must include risk reduction in the design and construction of all new health facilities and reduce vulnerability in existing health facilities through selecting and retrofitting the most critical facilities. Health workers are also central to identifying potential health risks from natural hazards and promoting personal and community risk reduction measures. WHO also encourages preventive medicine and attracts health research and innovation but in times of emergencies, WHO deploys workforce in devastated areas during emergencies and supports rapid health assessment of affected areas.

PREPAREDNESS – Dr. Ezekiel Nukuro (Regional Adviser in Human Resource Development – WHO Western Pacific Region) – "But acting during times of disasters may not be enough. We need to prepare. For instance, we avoid functional collapse through proper planning, improved localization and staff training. We encourage community based initiatives for emergency-preparedness. And we provide technical material and training modules on health and emergency management.

COLLABORATION – the WHO has played a pivotal role in collaborating with national and international partner agencies to maximize appropriate use of limited resources and collective efforts in emergency management.

When disasters happen, all the attention are normally focused on its victim. But how can assistance be fully provided if medical facilities also become victims? When hospitals and medical services fail due to catastrophes, countless will suffer and die, not only during calamities, but long into the future as well, because it will take time for calamity-stricken hospitals to recover and fully function again. But such tragedies can be prevented if we build hospitals with physically safer structures and foundations that can withstand typhoons, earthquakes, floods, and fires.

Emergency rooms of hospitals and medical centers get chaotic from receiving victims with different degrees of bruising and pain. In times of tragedies, most of us get overwhelmed attending to victims and survivors that we tend to forget the other possible victims of disasters.

The Philippines is reportedly the 4th most-hazard prone country in the world. Typhoons visit a dozen or more times yearly. Earthquakes wreck the country from time to time. Floods leave countless people homeless periodically. Fires destroy lives, buildings and properties all year round especially during summer time. Disasters in any form usually leave scores of victims for emergency workers to assist and be take care of.

According to Dra. Carmencita Banatin, Director of DOH-HEMS, the hospital is the most important facility in a community because this is where all victims of disaster are brought in. Purpose of health facilities is to decrease morbidity and mortality in relation to disaster and also psycho-social. When we talk of risk-reduction, it talks about Hazard, Vulnerability and Capacities. Hospitals should have policies in place and based on these policies, there should be plans which we call the Health Emergency Preparedness Response and Rehabilitation Plan where skills and training should be learned. There should be increased awareness through drills, networking, etc. and awareness should also be heightened that the purpose of a safe hospital is that it should function and be safe because it will be the last facility that should stand during a disaster. "We should build hospitals that can bear up with the atrocities of natural catastrophes, endure man-made disasters and survive the test of time". (National Center for Health Promotion - DOH, 2009)

According to the International Red Cross and Red Crescent Societies, the Philippines was the fourth most accident prone country in the world. The two institutions arrived at this conclusion after finding out that some 5,809,986 Filipinos were killed or injured as a result of disasters or man-made calamities over a ten-year period (1992-2001). In another report, the World Risk Report 2011 of the German Alliance Development Works ranks the Philippines as the third most disaster-prone country.

Top 10 Natural Disasters in Philippines
for the period 1900 to 2011
sorted by numbers of killed:

Disaster	Date	No Killed
Earthquake (seismic activity)	16-Aug-1976	6,000
Storm	5-Nov-1991	5,956
Earthquake (seismic activity)	16-Jul-1990	2,412
Storm	29-Nov-2004	1,619
Storm	13-Oct-1970	1,551
Storm	1-Sep-1984	1,399
Storm	30-Nov-2006	1,399
Volcano	31-Jan-1911	1,335
Mass movement wet	17-Feb-2006	1,126
Storm	3-Nov-1984	1,079

Figure 12 Top 10 Natural Disasters in the Philippines (1900-2011) by no. of fatalities

Top 10 Natural Disasters in Philippines
for the period 1900 to 2011
sorted by numbers of total affected people:

Disaster	Date	No Total Affected
Storm	12-Nov-1990	6,159,569
Storm	24-Sep-2009	4,901,763
Storm	21-Jun-2008	4,785,460
Storm	29-Sep-2009	4,478,491
Storm	21-Oct-1998	3,902,424
Storm	27-Sep-2006	3,842,406
Storm	20-Nov-1973	3,400,024
Storm	21-Oct-1988	3,250,208
Flood	Jul-1972	2,770,647
Storm	17-May-1976	2,700,000

Figure 13 Top 10 Natural Disasters in the Philippines sorted by no. of affected people

Top 10 Natural Disasters in Philippines
for the period 1900 to 2011
sorted by economic damage costs:

Disaster	Date	Damage (000 US$)
Flood	4-Sep-1995	700,300
Storm	29-Sep-2009	585,379
Storm	12-Nov-1990	388,500
Earthquake (seismic activity)	16-Jul-1990	369,600
Storm	21-Jun-2008	284,694
Storm	18-Oct-2010	275,745
Storm	3-Nov-1995	244,000
Storm	21-Oct-1988	240,500
Storm	24-Sep-2009	237,489
Flood	Jul-1972	220,000

Figure 14 Top 10 Natural Disasters in the Philippines sorted by economic damage costs

Source: "EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be - Université catholique de Louvain,Brussels,Belgium". See Appendix on “Summarized Table of Natural Disasters in Philippines from 1900 to 2011”

4.2 Discussion Of Paho Hospital Safety Index

4.2.1 Hospital Safety Index

The Hospital Safety Index is an easy-to-apply evaluation tool that helps hospital directors or administrators determine the likelihood that their hospital or health facility can remain operational in emergency situations. It was developed by the Pan American Health Organization (PAHO/WHO), Regional Office for the Americas of the World Health Organization, with the support of the Disaster Mitigation Advisory Group. It is the result of a lengthy process of dialogue, testing and revision with PAHO/WHO Member States. The Hospital Safety Index provides a snapshot in time of a hospital’s level of safety. The Index can and should be reapplied a number of times, over an extended period, in order to continuously monitor safety levels. In that way, safety is not seen as an absolute state of „yes-or-no' or 'all-or-nothing’, but rather as something that can be improved gradually. The Hospital Safety Index is not designed to replace detailed vulnerability studies. However, because these can be very costly and time consuming, the Hospital Safety Index is a cost-effective first step.

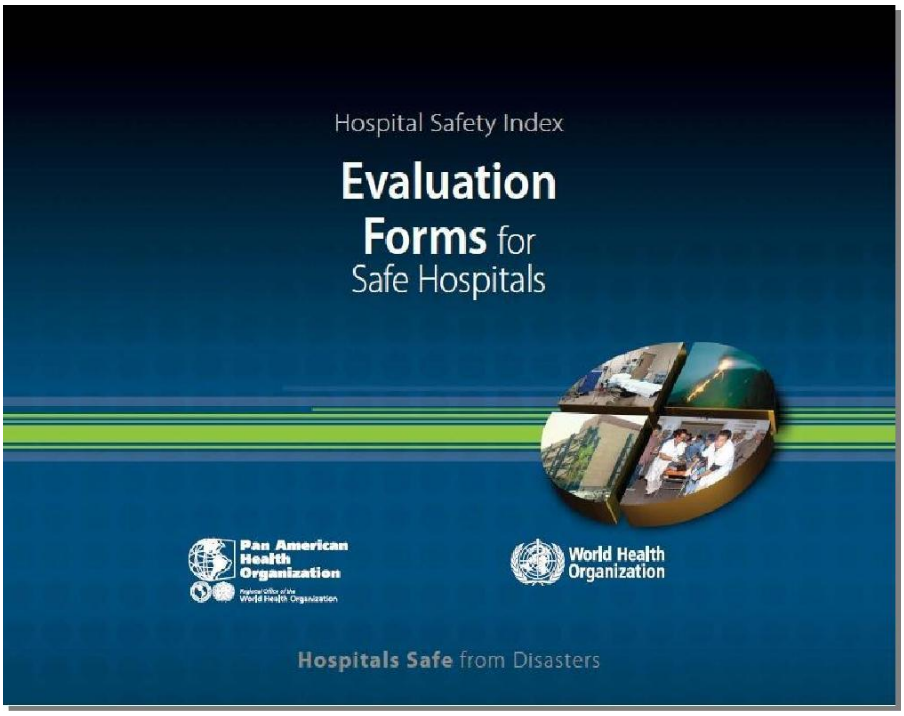


Figure 15 Hospital Safety Index Evaluation Form

The Hospital Safety Index is made up of three components: a safe hospitals checklist, a guide for evaluators, and a safety index calculator.

Determining a hospital's safety index begins with applying the safe hospitals checklist. This standardized checklist examines the level of safety of 145 items or areas that have an impact on a health facility's level of safety. The safety level of each area is rated as low, medium or high. The areas assessed are grouped into four categories: the hospital's geographical location in relation to natural hazards; its structural and non-structural safety; and items that affect its functional capacity - issues such as whether a hospital has a disaster committee, an emergency plan, or if maintenance is performed regularly.

The Hospital Safety Index alone will not transform a vulnerable health facility into one that is disaster-resilient, with well-trained staff. Nor will applying the Hospital Safety Index replace costly vulnerability studies, which can run into tens of thousands of dollars. However, hospital administrators will get a solid overview of where the facility stands in terms of safety, helping them decide where to invest to maximize return. Sometimes very small or low-cost improvements (relative to the overall cost of the facility) will go a long way towards improving safety.

It is important that hospital administrators and health managers view the safety score in positive light – which is why this instrument is called the "Safety" Index rather than the "Vulnerability" Index. The final score should not be viewed as a failing grade, but rather as a starting point for gauging how a health facility is likely to respond to major emergencies and disasters. This first but critical step is the cornerstone to ensuring that hospitals are safe from disasters. (Brittner, 2009)

Although the Hospital Safety Index is just getting off the ground, it has proved to be a powerful instrument for rallying country support around the issue of safe hospitals. Rating the safety of a health facility (as opposed to focusing on vulnerability) requires striking an appropriate balance between providing a secure environment for the patients, making health care accessible and factoring in economic considerations. This is a complex process and the Hospital Safety Index is only one of a variety of tools that managers can use to gather the information they need for sound decision making. (Cruz, 2009)

4.2.2 Hospital Safety Index Checklist

The Safety Index comprises of two forms, Form1: "General Information of the Health Facility" and Form 2: "Safe Hospitals Checklist". Form 1 includes general information about the health facility being evaluated and its treatment capacity while Form 2 is the checklist used for preliminary diagnosis of the hospital's safety in the event of disasters. It contains 145 variables, each of which has three safety levels: low, medium, and high. It is divided into four sections or modules namely, Geographic location of the health facility; Structural safety; Non-structural safety and Functional capacity.

The first module allows for a rapid description of hazards or dangers and geotechnical properties of soils at the site of the health facility. For the second module, evaluating structural safety of the facility involves assessment of the type of structure, materials, and previous exposure to natural and other hazards. The objective is to determine if the structure meets standards for providing services to the population even in cases of major disaster, or whether it could be impacted in a way that would compromise structural integrity and its functional capacity. Safety in terms of prior events involves two elements. The first is whether the facility has been exposed to natural hazards in the past, and its relative vulnerability to natural hazards. Second, the evaluators must determine how the facility was impacted or damaged in the past and how the damage was addressed. The evaluators attempt to identify potential risks in terms of the type of design, structure, construction materials, and critical components of the structure. Structural systems and the quality and quantity of construction materials provide the stability and resistance of a building against natural forces. Making adjustments in a structure for a given phenomenon is essential, since a structural solution can be valid for hurricanes but not for earthquakes. For the third module, the failure of non-structural elements does not usually put the stability of a building at risk, but it can endanger people and the contents of a building. Evaluators determine whether these elements could separate, fall, or tip which could have an impact on important structural elements. This analysis includes the safety of critical networks (for example, the water system, power, communications); heat, ventilation, and air conditioning (HVAC) systems in critical areas; and medical diagnostic and treatment equipment. Architectural elements such as facings, doors, windows, and cantilevers are evaluated to determine their vulnerability to water and the impact of flying objects. Safety of access to the facility and internal and external traffic are taken into account in this section, along with lighting systems, fire protection systems, false ceilings, and other components. Lastly, for the functional capacity, the module looks at the general organization of hospital management, implementation of disaster plans and programs, resources for disaster preparedness and response, level of training and disaster preparedness of the staff, and the safety of the priority services that allow the hospital to function. (Pan American Health Organization - World Health Organization, 2008)

SAFE HOSPITALS CHECKLIST

1. Elements relating to the GEOGRAPHIC LOCATION of the health facility (mark with an X where applicable).

1.1 Hazards Refer to hazard maps. Request the Hospital Disaster Committee to provide the map(s) showing safety hazards at the site of the building.	Hazard Level				OBSERVATIONS
	No hazard	Hazard level			
		LOW	AVERAGE	HIGH	
1.1.1 Geological phenomena					
Earthquakes Rate the hazard level of the hospital in terms of geotechnical soil analyses.	☐	☐	☐	☐	
Volcanic eruptions Refer to hazard maps of the region to rate the hospital's exposure to hazard in terms of its proximity to volcanoes, volcanic activity, routes of lava flow, pyroclastic flow, and ash fall.	☐	☐	☐	☐	
Landslides Refer to hazard maps to rate the level of hazard for the hospital in terms of landslides caused by unstable soils (among other causes).	☐	☐	☐	☐	
Tsunamis Refer to hazard maps to rate the level of hazard for the hospital in terms of previous tsunami events caused by submarine seismic or volcanic activity.	☐	☐	☐	☐	
Others (specify) .... Refer to hazard maps to identify other geological phenomena not listed above. Specify the hazard and rate the corresponding hazard level for the hospital.	☐	☐	☐	☐	
1.1.2 Hydro-meteorological phenomena					
Hurricanes Refer to hazard maps to rate the hazard level of the hospital in terms of hurricanes. It is helpful to take into account the history of such events when rating the hazard level of the facility.	☐	☐	☐	☐	
Torrential rains Rate the hazard level for the hospital in relation to flooding due to intensive rainfall, based on the history of such events.	☐	☐	☐	☐	
Storm surge or river flooding Rate the hospital's level of exposure to storm surge or river flooding hazards based on previous events that did or did not cause flooding in or around the hospital.	☐	☐	☐	☐	
Landslides Refer to geological maps to rate the hospital's level of exposure to landslide hazards caused by saturated soil.	☐	☐	☐	☐	
Others (specify) .... Refer to hazard maps to identify other hydro-meteorological hazards not listed above. Specify the hazard and rate the corresponding hazard level for the hospital.	☐	☐	☐	☐	

Figure 16 Safe Hospitals Checklist

4.2.3 Hospital Safety Index Calculator

The scores or values obtained for each component on the Checklist are recorded into an Excel spreadsheet that uses formulas to automatically calculate a numerical score for each of the 145 assessed components. The results place the facility into one of three safety categories: high, medium, or low. It is important to note that the values given to each component are weighted according to an agreed upon formula, which has been endorsed in Latin America and the Caribbean, but may not be applicable worldwide.

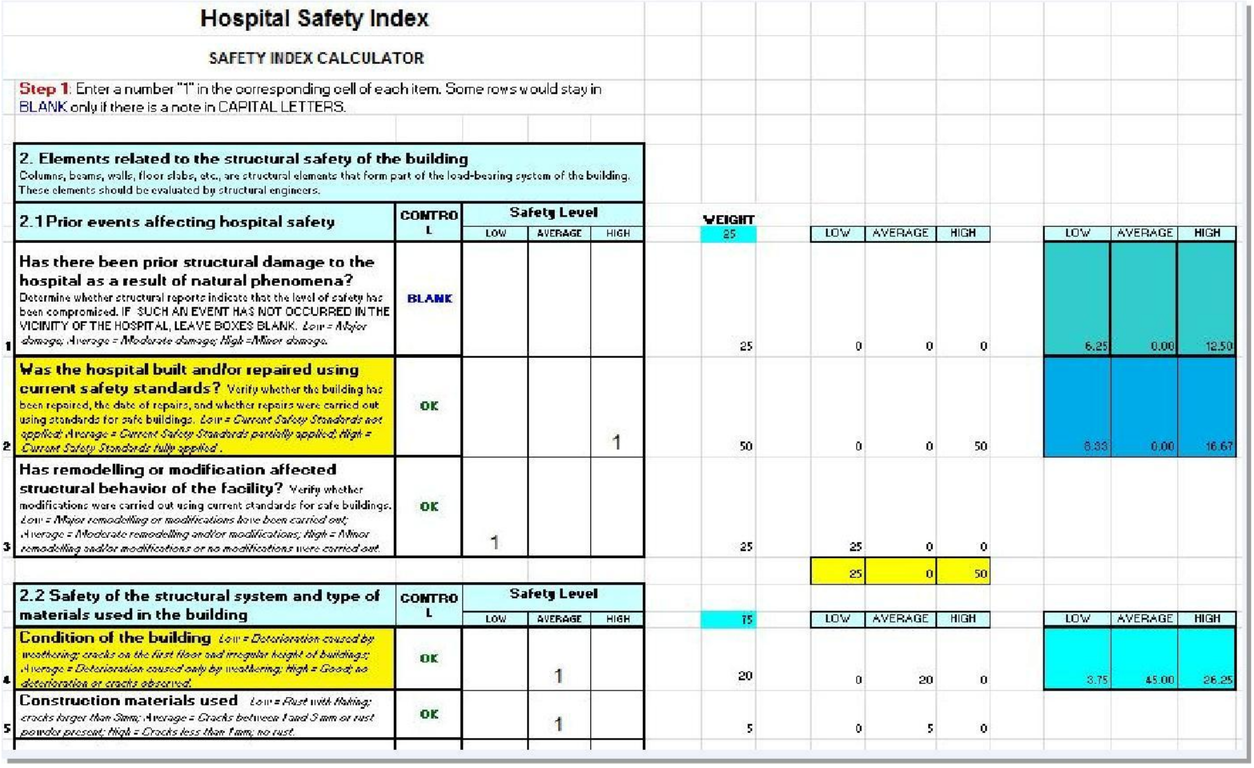


Figure 17 Hospital Safety Index Calculator

4.3 Discussion Of Doh-Hems Philippine Indicators

The Hospital Assessment Tool from DOH-HEMS and CHD-NCR is comprised of five sections, (1) General Information about the hospital, (2) Structural Indicators, (3) Non-Structural Indicators, (4) Non-Structural Indicators Highly Infectious Disease and (5) Functional Indicators. The checklist has four columns, YES, NO, N/A and Remarks. (DOH-HEMS, CHD-NCR, Dr. Noel R. Juban, 2009)

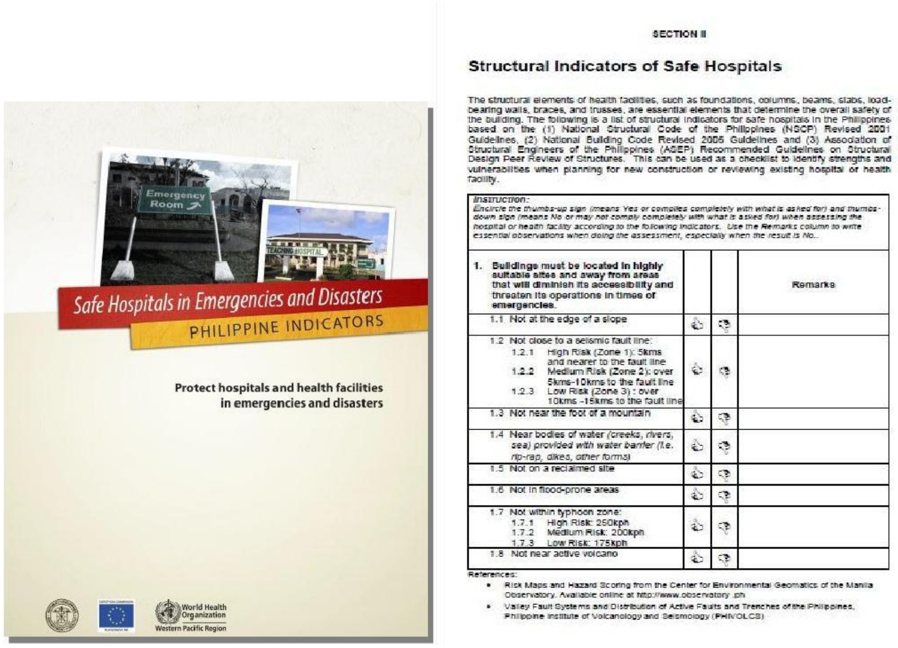
The set of indicators in the manual is a YES (complies completely) or NO (does not comply completely) questionnaire (with a thumbs-up and thumbs-down sign to be encircled). It also has a remarks column to write essential observations when doing the assessment, especially when the result is NO. The DOH-HEMS manual for safe hospitals has three main sections – Structural indicators, non-structural indicators and functional indicators. Two additional sections in the manual are additional non-structural indicators for hospitals with highly infectious diseases and additional functional indicators for hospitals with highly infectious diseases.

The structural elements of health facilities, such as foundations, columns, beams, slabs, load-bearing walls, braces, and trusses are essential elements that determine the overall safety of the building. The following is a list of structural indicators for safe hospitals in the Philippines based on the (1) National Structural Code of the Philippines (NSCP) Revised 2001 Guidelines,

(2) National Building Code Revised 2006 Guidelines and (3) Association of Structural Engineers of the Philippines (ASEP) Recommended Guidelines on Structural Design Peer Review of Structures. The Department of Health – Health Emergency Management Staff developed a checklist that can be used to identify strengths and vulnerabilities when planning for new construction or reviewing an existing facility. (Department of Health - Health Emergency Management Staff (DOH-HEMS), 2009)

Main sections in the Structural Indicators are the 1) location of the building (whether it is in a suitable site or not); 2)conformity to the requirements of the National Structural Code of the Philippines (NSCP, 2001) especially for wind and earthquake design; 3) shape and form of the hospital building; 4) continuing check and review of hospital structural system during construction and the entire period of occupancy; 5) investigation of cracks on the building; 6) as-built plans of all hospital building for reference purposes; and 7) building permit and occupancy permits. For the location of the building, specific indicators are that the hospital is not on a landslide-prone area, not close to a seismic fault line, not near the foot of a mountain, not near bodies of water, not on a reclaimed site or in areas at risk of liquefaction, not in flood-prone areas, not within typhoon zone, not near an active volcano and not in storm-surge-prone area. Section 2 (conformity to NSCP 2001) indicators include foundations, columns, beams, floors and slabs, trusses, walls and partitions, shear walls, roof systems and gutters and downspouts. Indicators taken into consideration for the shape and form of a hospital are that it has simple and symmetrical shape in both the lateral and longitudinal axes, the number of building floors, the building form, whether they are not top-heavy, there are no cantilevers, balanced massing and loading. For section 4, the indicators are peer review using Association of Structural Engineers of the Philippines (ASEP) guidelines, evaluation using Department of Public Works and Highways (DPWH) guidelines and structural certification by a qualified structural engineer. Also, cracks on the hospital system must be immediately investigated and addressed especially if they appear after an earthquake. Cracks on the following structural members are evaluated: foundation, column, floor slabs, trusses, walls and partitions and shear walls. For section 6, as built plans of all hospital buildings must be available for reference and must contain the architectural plans, structural plans including structural computations, electrical plans including electrical computations, sanitary plans, mechanical plans and electronics and communications plans. Lastly, permits such as building permits, occupancy permits, fire safety permit, elevator permit, generator permit and other permits as needed must also be readily available to satisfy the indicators.

Non-structural elements are all other elements that, without forming part of the resistance systems, enable the facility to operate. These include architectural elements, equipment and contents, and services of lifelines. Nearly 80% of the total cost of building a hospital is spent on non-structural components (World Health Organization, 2008). Non-structural indicators include safety of ceilings; safety of door entrances; safety of windows and shutters; safety of walls, divisions and partitions; safety of exterior elements (cornices, ornaments, façade, plastering, etc; safety of floor coverings, safety of lifeline facilities; communication system; domestic water supply system; medical and industrial gases system; fire suppression system; emergency exit system; HVAC systems in critical areas; medical and laboratory equipment and supplies used for diagnosis and treatment; and safety of personnel and patients. Functional Indicators include site and accessibility; internal circulation and interoperability; hospital emergency preparedness, response and recovery plan; hospital emergency management systems, procedures and protocols; availability of back-up system for critical services; human resources; and monitoring and evaluation.



SECTION II

Structural Indicators of Safe Hospitals

The structural elements of health facilities, such as foundations, columns, beams, slabs, load-bearing walls, braces, and trusses, are essential elements that determine the overall safety of the building. The following is a list of structural indicators for safe hospitals in the Philippines based on the (1) National Structural Code of the Philippines (NSCP) Revised 2001 Guidelines, (2) National Building Code Revised 2005 Guidelines and (3) Association of Structural Engineers of the Philippines (ASEP) Recommended Guidelines on Structural Design Peer Review of Structures. This can be used as a checklist to identify strengths and vulnerabilities when planning for new construction or reviewing existing hospital or health facility.

Instruction:
Encircle the thumbs-up sign (means Yes or complies completely with what is asked for) and thumbs-down sign (means No or may not comply completely with what is asked for) when assessing the hospital or health facility according to the following indicators. Use the Remarks column to write essential observations when doing the assessment, especially when the result is No.

1. Buildings must be located in highly suitable sites and away from areas that will diminish its accessibility and threaten its operations in times of emergencies.			Remarks
1.1 Not at the edge of a slope			
1.2 Not close to a seismic fault line: 1.2.1 High Risk (Zone 1): 5kms and nearer to the fault line 1.2.2 Medium Risk (Zone 2): over 5kms-10kms to the fault line 1.2.3 Low Risk (Zone 3) : over 10kms -15kms to the fault line			
1.3 Not near the foot of a mountain			
1.4 Near bodies of water *(creeks, rivers, sea) provided with water barrier (i.e. rip-rap, dikes, other forms)*			
1.5 Not on a reclaimed site			
1.6 Not in flood-prone areas			
1.7 Not within typhoon zone: 1.7.1 High Risk: 250kph 1.7.2 Medium Risk: 200kph 1.7.3 Low Risk: 175kph			
1.8 Not near active volcano			

References:

- Risk Maps and Hazard Scoring from the Center for Environmental Geomatics of the Manila Observatory. Available online at http://www.observatory.ph
- Valley Fault Systems and Distribution of Active Faults and Trenches of the Philippines, Philippine Institute of Volcanology and Seismology (PHIVOLCS)

Figure 18 Safe Hospitals in Emergencies and Disasters - Philippine Indicators

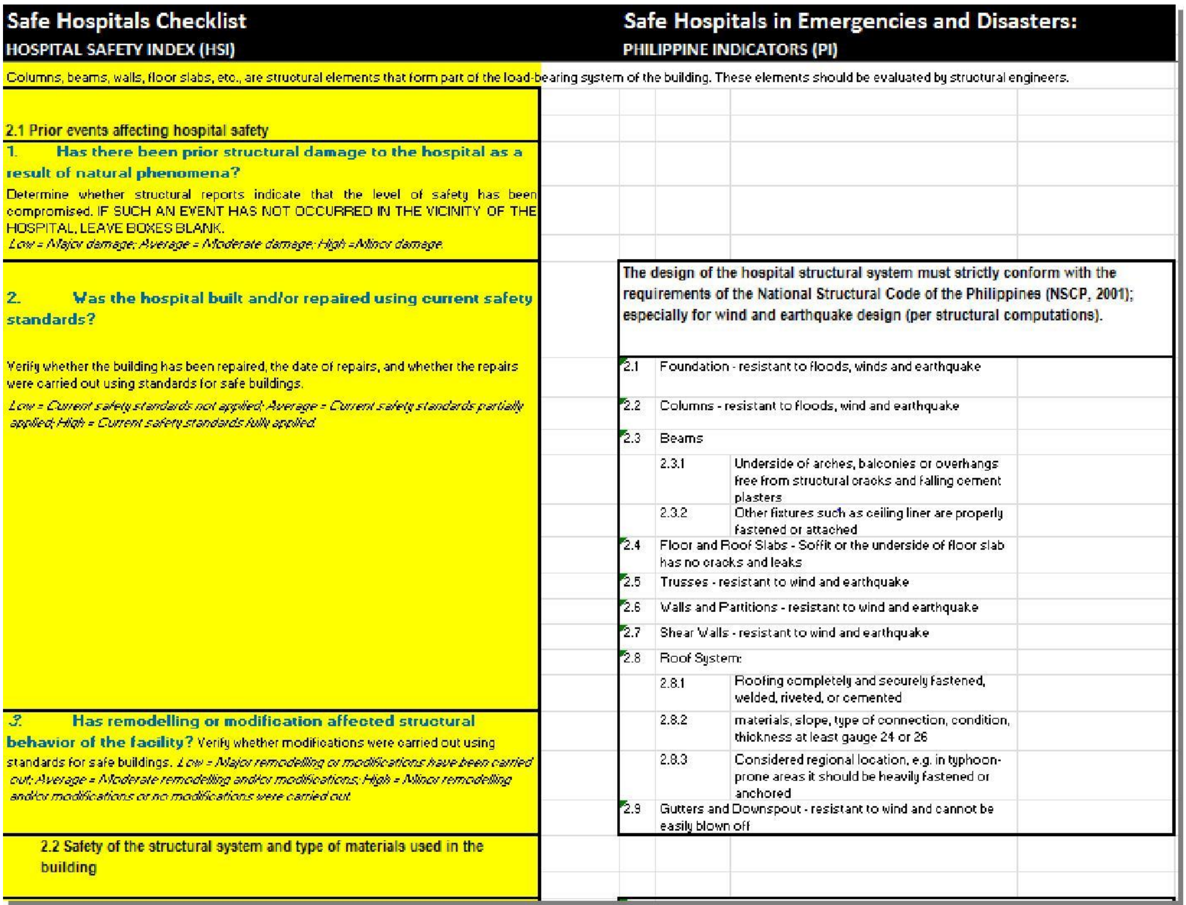
Aside from these main indicators, additional non-structural indicators for hospitals with highly infectious disease consist of wards; operating room and recovery room; laboratory room; emergency room; security and safety.

For the additional functional indicators for hospitals with highly infectious disease, it consists of site and accessibility; internal circulation and interoperability; equipment and supplies; hospital emergency management policies, guidelines, procedures and protocols; hospital systems; operational plan and contingency plans for internal or external disasters; plans for the operation, preventive maintenance, and restoration of critical services; human resources; and availability of medicines, supplies, instruments, and other equipment dedicated to control of highly infectious diseases (SARS, Avian Influenza); and Monitoring and Evaluation.

The codes, policies and guidelines on which the indicators are based are the National Building Code of the Philippines (PD 1096), The National Structural Code of the Philippines (5th ed, 2001), Philippine Electrical Code of 2000, Fire Code of the Philippines (PD 1185), Republic Act 8495 – Philippine Mechanical Code of 1998, Republic Act 344 – Accessibility Law, Republic Act 9275 – Philippine Clean Water Act of 2004, Republic Act 9003 – Ecological Solid Waste Management Act of 2001 and Administrative Order No. 2008 - 0021.

Also, a post-assessment questionnaire is accomplished, indicating the date and time the assessment was started and completed, evaluating team members, required documents availability and a general assessment of the visit including problems encountered and possible solutions.

After the initial assessment of the 25 hospitals was done, the group found out that it was an eye opener for the hospitals. The questions and issues of ease of use, relevance, effectiveness, scoring system and the effectiveness and accuracy of the indicators were raised. They were also able to recognize the significance of the tool as a guide to hospital renovations and constructions, planning and fund allocation. These findings led to the formulation of the next steps to be done which are to finalize the indicators for all hospital levels, the assessment of all hospitals, conducting of the Hospital Emergency Awareness and Response Training (HEART) which includes awareness for "Safe Hospitals" as well, the integration of the tool with licensing requirements for coursed through the Department of Health and lastly, to develop a better "Safe Hospitals" policy. (Department of Health Western Pacific Region, 2010)


Safe Hospitals Checklist | **Safe Hospitals in Emergencies and Disasters:**
HOSPITAL SAFETY INDEX (HSI) | **PHILIPPINE INDICATORS (PI)**

Columns, beams, walls, floor slabs, etc., are structural elements that form part of the load-bearing system of the building. These elements should be evaluated by structural engineers.

HOSPITAL SAFETY INDEX (HSI)	PHILIPPINE INDICATORS (PI)		
2.1 Prior events affecting hospital safety			
1. **Has there been prior structural damage to the hospital as a result of natural phenomena?** Determine whether structural reports indicate that the level of safety has been compromised. IF SUCH AN EVENT HAS NOT OCCURRED IN THE VICINITY OF THE HOSPITAL, LEAVE BOXES BLANK. *Low = Major damage; Average = Moderate damage; High = Minor damage.*			
2. **Was the hospital built and/or repaired using current safety standards?** Verify whether the building has been repaired, the date of repairs, and whether the repairs were carried out using standards for safe buildings. *Low = Current safety standards not applied; Average = Current safety standards partially applied; High = Current safety standards fully applied.*	**The design of the hospital structural system must strictly conform with the requirements of the National Structural Code of the Philippines (NSCP, 2001); especially for wind and earthquake design (per structural computations).**		
	2.1	Foundation - resistant to floods, winds and earthquake	
	2.2	Columns - resistant to floods, wind and earthquake	
	2.3	Beams	
		2.3.1	Underside of arches, balconies or overhangs free from structural cracks and falling cement plasters
		2.3.2	Other fixtures such as ceiling liner are properly fastened or attached
	2.4	Floor and Roof Slabs - Soffit or the underside of floor slab has no cracks and leaks	
	2.5	Trusses - resistant to wind and earthquake	
	2.6	Walls and Partitions - resistant to wind and earthquake	
	2.7	Shear Walls - resistant to wind and earthquake	
	2.8	Roof System:	
		2.8.1	Roofing completely and securely fastened, welded, riveted, or cemented
3. **Has remodelling or modification affected structural behavior of the facility?** Verify whether modifications were carried out using standards for safe buildings. *Low = Major remodelling or modifications have been carried out; Average = Moderate remodelling and/or modifications; High = Minor remodelling and/or modifications or no modifications were carried out.*		2.8.2	materials, slope, type of connection, condition, thickness at least gauge 24 or 26
		2.8.3	Considered regional location, e.g. in typhoon-prone areas it should be heavily fastened or anchored
	2.9	Gutters and Downspout - resistant to wind and cannot be easily blown off	
2.2 Safety of the structural system and type of materials used in the building			

Figure 19 Comparative Analysis of Hospital Safety Index and Philippine Indicators

5 DISCUSSION OF HSFDCBAT

The role of HSFDCBAT on hospitals is first assessment, then recommendations for the modules of Suitable Sites, Structural, Non-Structural and Functional aspects of the hospitals in the event of disasters. This tool has seventy seven (77) checkpoints and is divided into these modules. The checkpoints are identified for each module in this section but the details of these checkpoints can be referred to in the appendix. (See APPENDIX A: HSFDCBAT CONTENT DETAILS TABLE)

5.1 Content

5.1.1 Suitable Sites

This section was included as an independent module to isolate it from the Structural module for the reason that other checkpoints such as epidemic, contamination, pest infestation, hazardous material spills, radioactivity and social phenomena have no direct relation to the structural safety of the health facility.

For the Suitable Sites module, eighteen (18) checkpoints were used:

5.1.1.1 EARTHQUAKE

5.1.1.2 TYPHOON

5.1.1.3 VOLCANO

5.1.1.4 TSUNAMI

5.1.1.5 LANDSLIDE

5.1.1.6 TORRENTIAL RAINS

5.1.1.7 STORM SURGE

5.1.1.8 LIQUEFACTION

5.1.1.9 UNSTABLE SLOPES

5.1.1.10 EPIDEMIC

5.1.1.11 CONTAMINATION

5.1.1.12 FIRE

5.1.1.13 PEST INFESTATION

5.1.1.14 TERRORISM

5.1.1.15 EXPLOSION

5.1.1.16 HAZARDOUS MATERIAL SPILLS

5.1.1.17 SOCIAL PHENOMENA

5.1.1.18 RADIOACTIVITY

5.1.2 Structural Safety

For hospitals to be safe from the effects of natural disasters, the following are recommended structural design indicators: (National Center for Health Promotion - DOH, 2009)

- Design of building structural and non-structural elements conform with NSCP 2001 for wind and earthquake design
- Seismic importance factor of 1.25 and wind importance factor of 1.15 should be used for structural design

- Immediate occupancy category as may be required by the client
- No major cracks on structural members. Minor or hairline cracks are localized and repairable
- Buildings are designed up to Maximum Moment Magnitude 7 for those near active earthquake fault lines.
- Located at least ten (10) meters away from both sides of a fault line
- Readily available as-built construction drawings for reference purposes
- Complete with necessary building and occupancy permits
- Curtain glass walls conform with NSCP requirements for wind design
- Glass doors and windows resist basic wind speed of 200-250 kph with regional application of secondary covers.
- Structural design of buildings have undergone review using ASEP guidelines and issued with structural certification.
- For existing buildings, rapid evaluation has been performed to determine structural vulnerability and cross-checked with hazard maps. Buildings highly vulnerable subjected to detailed structural evaluation
- Construction materials have been thoroughly checked by a Quality Control Engineer during construction
- All existing buildings should be certified by a qualified civil/structural engineer. All buildings that do not conform to the present code should be analyzed and strengthened or retrofitted

Based on these, the Structural Safety module used these fourteen (14) checkpoints:

5.1.2.1 STRUCTURAL HISTORY

5.1.2.2 STRUCTURAL SYSTEM

5.1.2.3 STRUCTURAL STANDARDS

5.1.2.4 CONDITION OF BUILDING

5.1.2.5 CONSTRUCTION MATERIALS

5.1.2.6 FORM IRREGULARITIES

5.1.2.7 HOSPITAL SIZE (PHYSICAL)

5.1.2.8 FOUNDATIONS

5.1.2.9 ADJACENT STRUCTURES

5.1.2.10 STRUCTURAL REDUNDANCY

5.1.2.11 STRUCTURAL RESILIENCE

5.1.2.12 CONTINUING CHECK

5.1.2.13 AS-BUILT PLANS

5.1.2.14 PERMITS

5.1.3 Non-Structural Safety

In Non-Structural Safety, architectural elements and non-load bearing components of the structure are evaluated. Their conditions before, during and after a disaster are being assessed. There are thirty six (36) checkpoints in this module and they are the following:

PRE, DURING and POST-DISASTER

5.1.3.1 ELECTRICAL SYSTEMS

5.1.3.2 TELECOMMUNICATIONS SYSTEMS

5.1.3.3 WATER SUPPLY SYSTEM

5.1.3.4 FUEL STORAGE

5.1.3.5 MEDICAL GASES

5.1.3.6 HVAC SYSTEMS

5.1.3.7 FURNISHINGS AND EQUIPMENT

5.1.3.8 MEDICAL AND LABORATORY EQUIPMENT

ARCHITECTURAL ELEMENTS

5.1.3.9 ROOF SYSTEM

5.1.3.10 BUILDING ENVELOPE

5.1.3.11 INTERIOR WALLS

5.1.3.12 FIRE PROTECTION SYSTEM

5.1.3.13 MOVEMENT INSIDE BUILDING

5.1.3.14 MOVEMENT OUTSIDE THE BUILDING

5.1.3.15 LIGHTING SYSTEM

5.1.3.16 REDUNDANT OPEN SPACES

5.1.3.17 REFUGE ROOMS

5.1.3.18 HAZARDOUS WASTES

5.1.3.19 INFECTION CONTROL

5.1.3.20 PEST CONTROL

5.1.4 Functional Capacity

The Functional Capacity module focuses on the disaster-readiness of a health facility based on the organization and plans in place in case such emergencies occur. This module has nine (9) checkpoints:

5.1.4.1 ORGANIZATION OF HOSPITAL DISASTER COMMITTEE

5.1.4.2 ORGANIZATION OF EMERGENCY OPERATION CENTER

5.1.4.3 OPERATIONAL PLANS FOR DISASTERS

5.1.4.4 EPIDEMIOLOGICAL SURVEILLANCE COMMITTEE

5.1.4.5 TRANSPORT & LOGISTICS

5.1.4.6 CONTINGENCY PLAN FOR MEDICAL TREATMENTS IN DISASTERS

5.1.4.7 PLANS FOR OPERATION, PREVENTIVE MAINTENANCE AND RESTORATION OF CRITICAL SERVICES

5.1.4.8 AVAILABILITY OF MEDICINES, SUPPLIES, INSTRUMENTS OR EQUIPMENTS FOR USE IN DISASTERS

5.1.4.9 HIGHLY INFECTIOUS DISEASES

5.1.5 Survey

HSFDCBAT has a Survey module to get the users‟ assessment in using the tool and has these checkpoints as survey areas:

5.1.5.1 USABILITY/EASE OF USE

5.1.5.2 RELIABILITY

5.1.5.3 EFFICIENCY

5.1.5.4 REUSABILITY/SCALABILITY

5.1.5.5 COMPLETENESS

5.1.5.6 FUNCTIONALITY

5.1.5.7 ERRORS/BUGS/CRASHES

5.1.5.8 SIGNIFICANCE/RELEVANCE

5.1.5.9 SECURITY/DATA INTEGRITY

5.1.5.10 OVERALL RATING

5.2 HSFDCBAT TOOL

5.2.1 OVERVIEW

Hospitals Safe From Disasters Computer-Based Assessment Tool (HSFDCBAT) is a comprehensive computer-based assessment tool aimed to provide a means to assess the disaster-readiness of health facilities using Microsoft VB.NET (Visual Basic .NET) (see Figure 20) as the developing software for the graphical user interface (GUI) or the front-end and Microsoft Access 2007 for the database or back-end (see Figure 21).

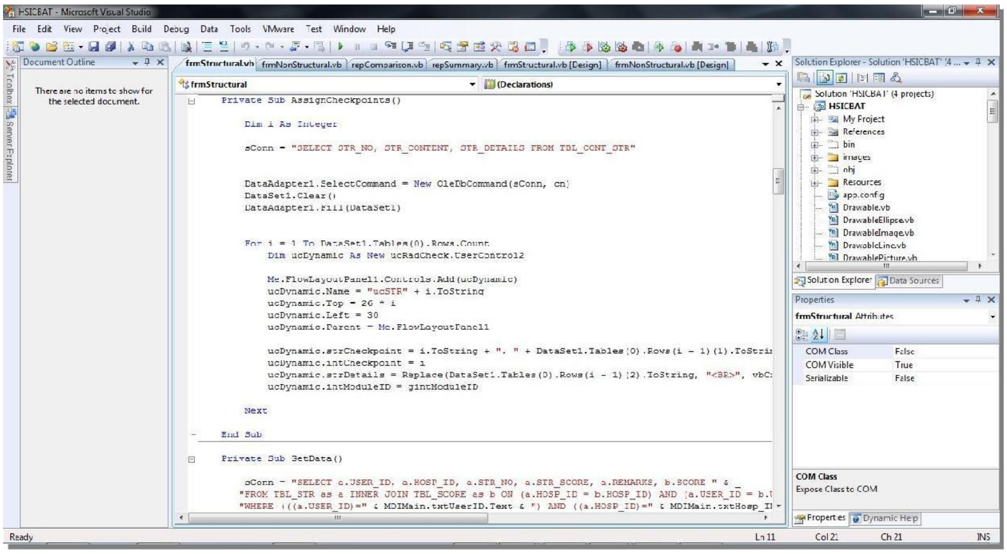


Figure 20 Code-behind of HSFDCBAT in Microsoft Visual Studio.NET

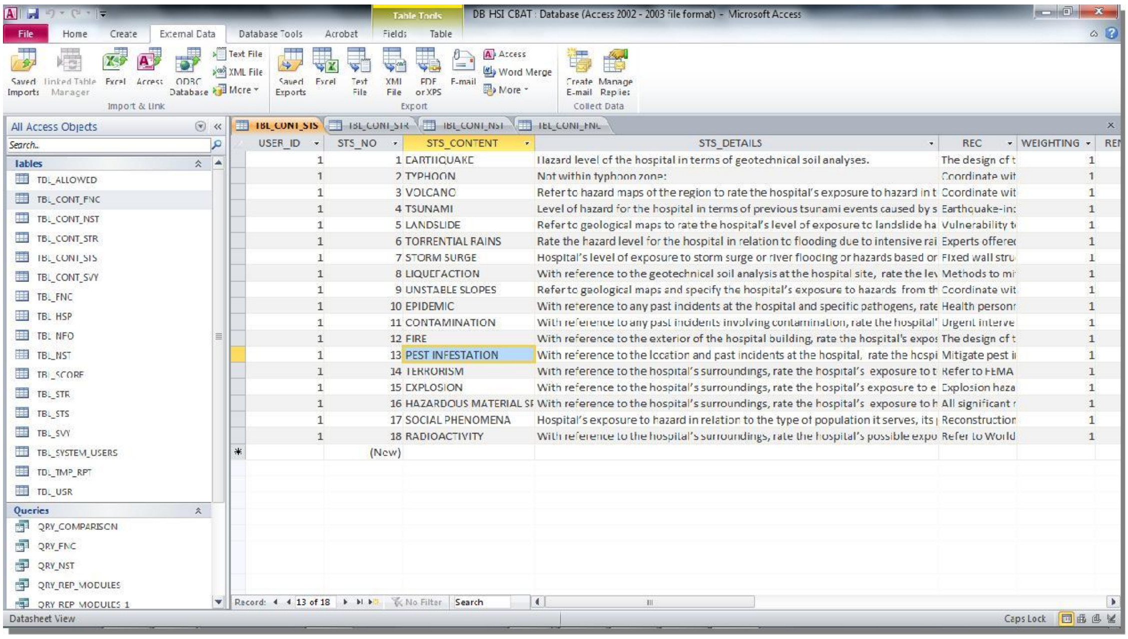


Figure 21 Database of HSFDCBAT using Microsoft Access

It is composed of six (6) modules – General Information, Suitable Sites, Structural Safety, Non-Structural Safety, Functional Capacity and Survey. The General Information module serves as the module where relevant information on the health facility like the name of the facility, address, contact details, etc. are entered and saved while the Survey module serves as a survey at the end of the assessment which evaluates the user experience. The other four (4) remaining modules are the main modules used for the assessment of the health facility's disaster-readiness.

The system also has maintenance functionalities as well as reporting capabilities. For the maintenance, users are created by the system administrator for each hospital and are given access rights and encrypted passwords for security and authorization. The content, checkpoint weights and images for the assessment modules can also be modified within this functionality. Reports for each hospital's assessment, comparison with other facilities and recommendations for the hospital on their next action plan can be generated after each evaluation.

Some of HSFDCBAT" s salient features are the following:

- For this version, weighting system used is same across the board (i.e. weight = 1.0 for all checkpoints)

- Formula for "SAFE SCORE" is:

$$\text{SAFE SCORE} = \frac{\left(\frac{\sum SCORE * WEIGHT}{\sum ITEM * WEIGHT}\right)}{5} * 100 = \_\_\_\ \%$$

- The lower the percentage risk, the better for the hospital facility, meaning it has a lower probability of failure or risk for the corresponding checkpoint or module.

- The HSFDCBAT system has links to guides and references for the users to help them in answering the tool. This can be seen in the "Details" and "Recommendations" button for each checkpoint.

- Descriptive "Observation" or "Remarks" column is provided to input additional information for the checkpoint being assessed

- Documents and reports generated from the HSFDCBAT will be visible to concerned DOH parties. Authorization is part of the system wherein users can only view their hospital data while the administrator/DOH Representative will be able to access all the data and have the capability to compare notes and generate reports.

- The “Recommendations” button appears for “High Risk” or “Highest Risk” checkpoints to guide the user in their next action plans for the implementation of disaster-readiness in the hospital

- Non-structural elements are grouped into pre-, during and post-disasters with pre as the usual compliance and regular checks based on the Building codes as well as the hospital’s procedures based on their respective bench books. During is how these elements will behave during disasters, most important of which is the anchorage and stability. Lastly, the post-disaster is whether these elements can still function and at what capacity or level after the disaster and after the damage has been done

- Images are used for visual representation of checkpoints (i.e use of infographics)

- Advantages of HSFDCBAT (VB.NET over Microsoft Excel) are customizable reports, scalability, data is generated based on the database; transfer and analysis of data between authorized personnel is faster and more convenient.

- This is similar to “expert systems” although a simpler and more user-friendly interface.

- Since this is just a prototype of a computer-based assessment tool, a complete team is not needed yet as in full-fledged software. It was also kept in mind that developing full-fledged software is difficult and that even if a complete software development team is formed, the time needed to develop such software would not be enough, given the time to finish this thesis. The researcher acted as the programmer as well.

- PAHO/DOH assessment tools are too long and have too many items (145 for PAHO, 222+ for DOH-HEMS, 77 for HSFDCBAT)

- The HSFDCBAT system will make the assessment of disaster-readiness here in the Philippines quantifiable as opposed to the thumbs-up, thumbs down rating system wherein the question being answered is compliance or not, without having a degree of risk for each checkpoint

- The checkpoints are grouped and the final scores or ratings for these groups or modules are independent of each other versus general rating for other assessment systems. Through this method, the weakness of the hospital is emphasized and corresponding action plans are suggested to the users versus just a general recommendation for other assessment tools

- With these methodologies, there would be more focus on which checkpoints should be worked at and the possible problem areas will be pin-pointed and then eventually addressed

- The system also has computations and corresponding weights for the “Suitable Sites” module as opposed to descriptive evaluation only. The module is also being tallied and given a score, depending on the site and climate conditions here in the Philippines

- Instant reports can be generated after completing the assessment tool.

- Comparative analysis of hospitals based on “Safe Scores” can be generated.

- Recommendation reports can be immediately generated for the hospital‟ s next action plan.

- Assessment will be on a per category/grouping basis

- Different Philippine codes are used as references such as National Structural Code of the Philippines (NSCP), Building Code, Fire Code, DOH Requirements, etc. to assess the compliance of the hospitals

- Proposed schedule of assessment with HSFDCBAT is if new construction, it can be used during the design stage. If existing, health facilities will have cyclic checking preferably yearly which will coincide with other license renewals.

5.2.2 User's Guide

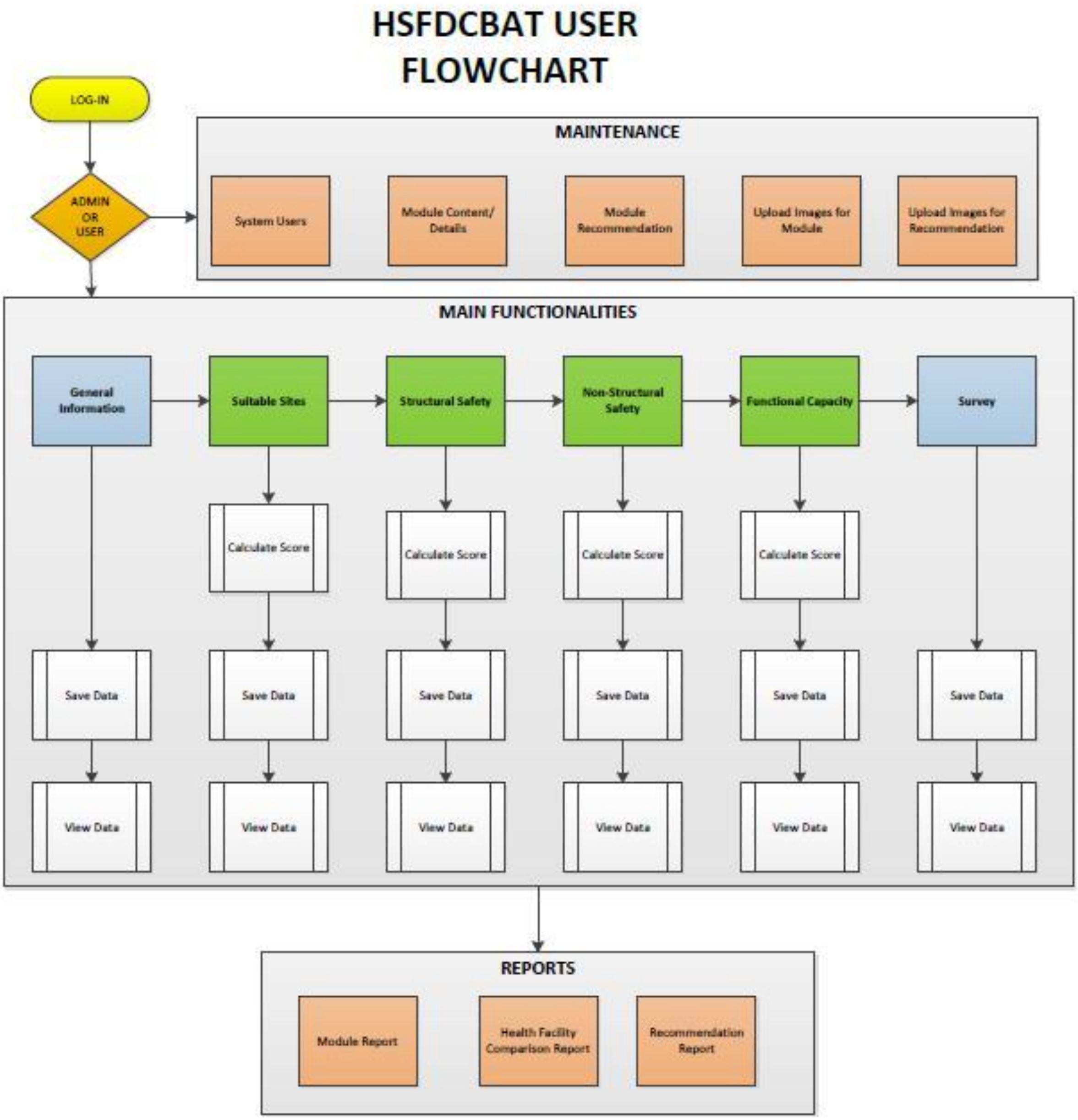


Figure 22 HSFDCBAT User's Flowchart

In using the HSFDCBAT, the user logs in first, depending on whether he is an ADMIN or just a normal USER. There are certain functionalities that the user is authorized to do depending on the user access assigned to him.

If the user is a normal USER created and given user access by the administrator to have access only on his corresponding hospital, he can log-in with his credentials on the Log-in Module (see Figure 24). The user will then be brought to the Main Menu screen (see Figure 23) where he is supposed to accomplish all the modules in a particular order.

The first module to complete is the General Information module (see Figure 35). In this module, information like name of facility, address, contact details, and other pertinent hospital information is filled up by the user. After completing the module he can now save the data and then proceed to the next module which is the Suitable Sites module (see Figure 36). In this module, the user is tasked to select whether a certain checkpoint is at lowest risk, low risk, medium risk, high risk, highest risk or not applicable based on his assessment with respect to their hospital. The user can click on the "Show Details" button to see the details of a certain checkpoint. He will then be shown a dialog (see Figure 40) with a brief explanation of the checkpoint as well as an accompanying image or infographic for a clearer idea on what the checkpoint is about. He can then close this dialog and then proceed with the other checkpoints.

After going through all the checkpoints and identifying their risk ratings, the user can now click on the "Calculate Score" button to show the risk rating or the "safe score" for the current module. Once the score is already computed, the user can now save the data for the accomplished module, in this case, the Suitable Sites Module. The lower the percentage risk, the better for the hospital, meaning it is able to comply with the Hospitals Safe from Disasters requirements.

The user can then do the same steps for the following disaster-readiness modules, namely Structural Safety, Non-Structural Safety and Functional Capacity (Figure 37-39). It should be noted, though, that the succeeding modules will not be enabled if the previous module has not been completed yet (i.e. Calculate Score and Save)

If all the disaster-readiness modules are already accomplished, the user can now proceed to the Survey module (see Figure 42) where he can assess the HSFDCBAT tool he just used by rating the system for each criteria with a score from 1 to 5, with 1 being the highest (Very Much) and 5 being the lowest (Not at All) similar to UP‟ s grading system. After finishing all the criteria, he can now save his inputs for the survey. This completes the assessment of the health facility for the normal USER of the HSFDCBAT. If the user wants to view the data for his respective hospital, he can just click on any of the module tabs and the corresponding module dialog will be shown with all the saved data and scores but with disabled controls so that it cannot be edited anymore. (Only the ADMIN has this capability for this version of the tool). In the View state, checkpoints with a "High Risk" or "Highest Risk" rating will have a "Recommendations" button enabled so that the user can click on it and see what action plan is needed to fix the checkpoint in question. A "Recommendations" dialog will be shown similar to the "Details" dialog showing the recommendation explanation as well as accompanying images if applicable. (see Figure 41)

On the other hand, if the user is logged in as an ADMIN. He can view and edit and delete any of the hospital's data and generate reports from them (see Figure 25). Reports that can be generated from the HSFDCBAT tool are the HSFDCBAT Score report for all modules (see Figure 43), Comparison Report among health facilities (see Figure 45), and Recommendation Reports (see Figure 46), for any health facility. In the recommendation reports, checkpoints which have "High Risk" and "Highest Risk" ratings are highlighted in red and have corresponding recommendations or action plans for the user's reference.

Other maintenance functions that can be done by the ADMIN are to create System Users with their corresponding username and encrypted passwords (see Figure 26); change the contents and weight of each checkpoint or survey criteria depending on which module is being edited (both "Details" and "Recommendations" content can be edited) (see Figure 27) and to upload informative images for these content as well. (see Figure 33-34)

5.2.3 Graphical User Interface (Gui):

Figure 23 Main Menu

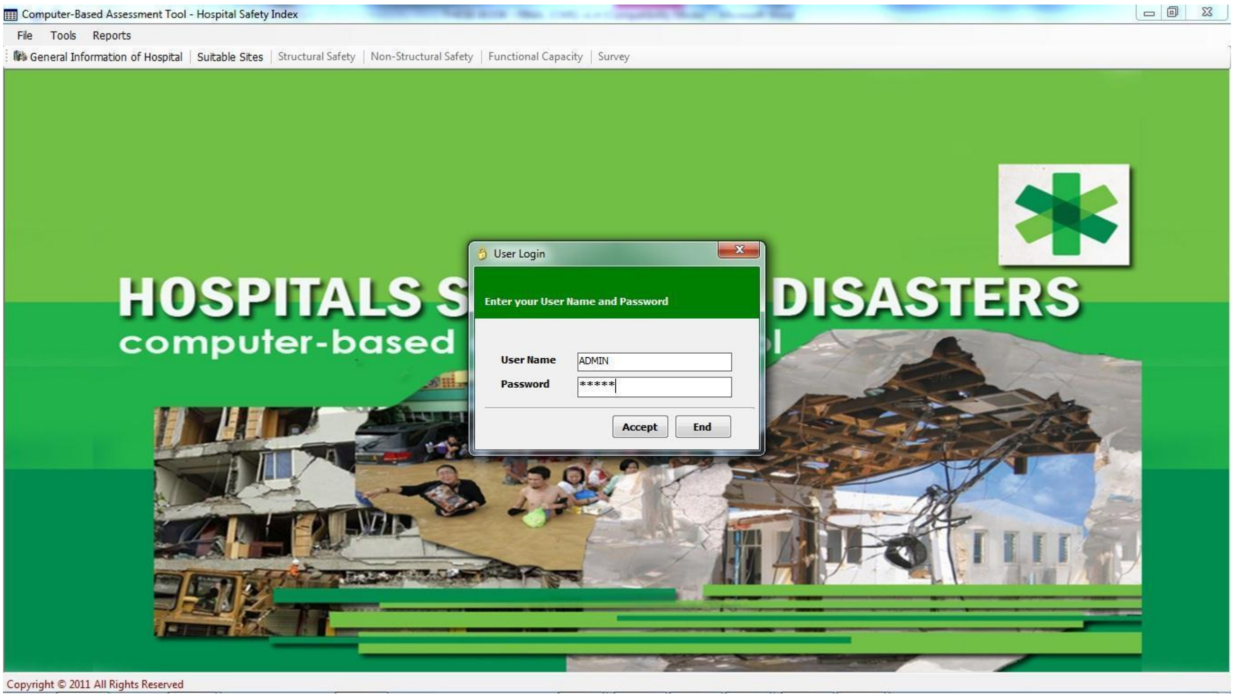


Figure 24 User Log-In Module

MAINTENANCE MODULES

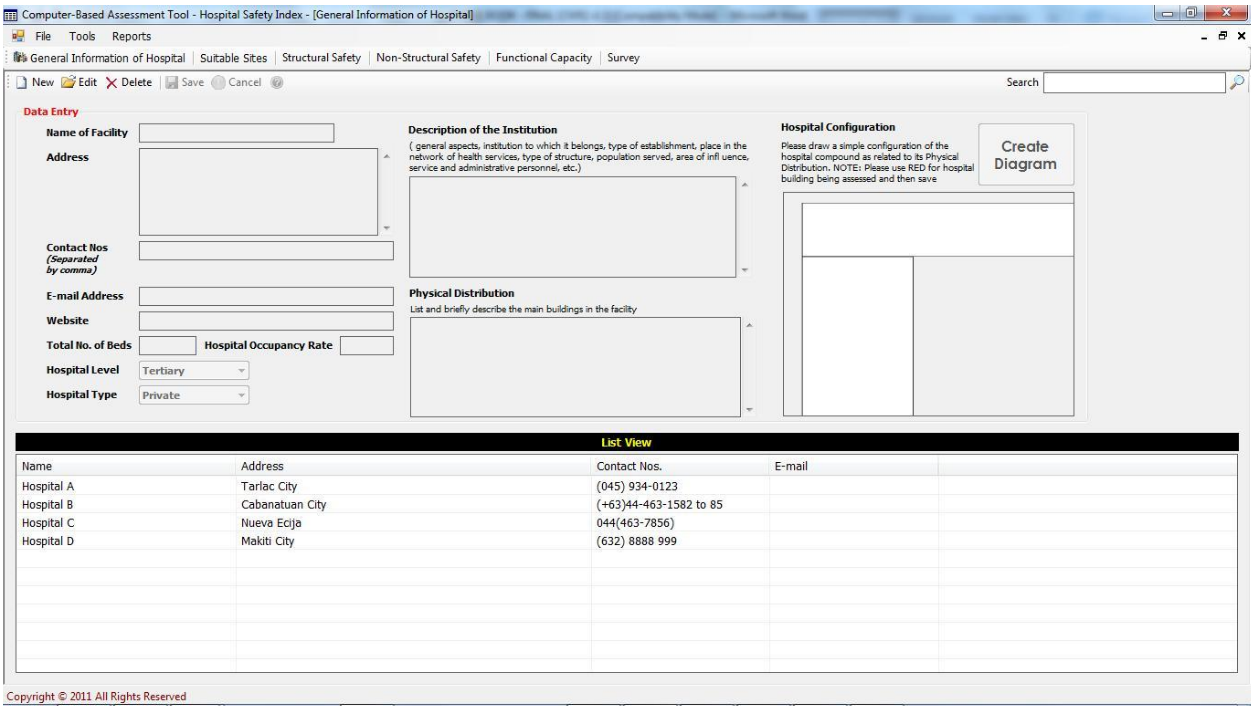


Figure 25 General Information Maintenance Module

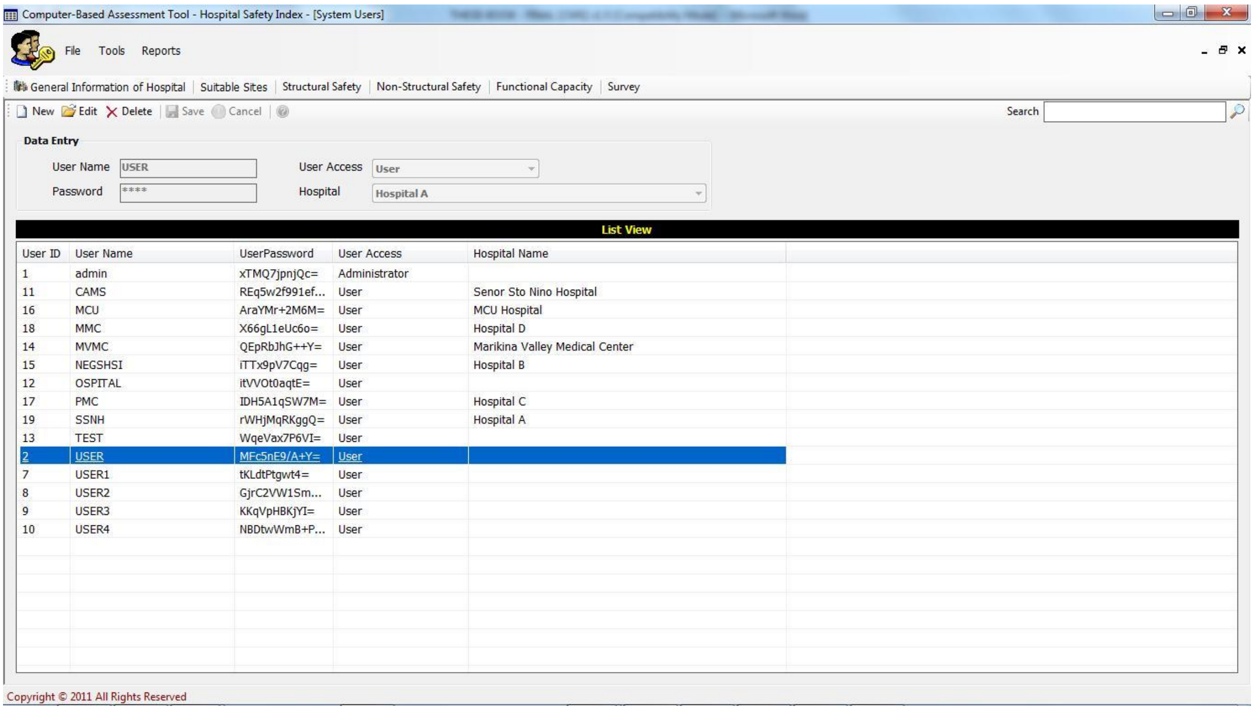


Figure 26 System Users Maintenance Module

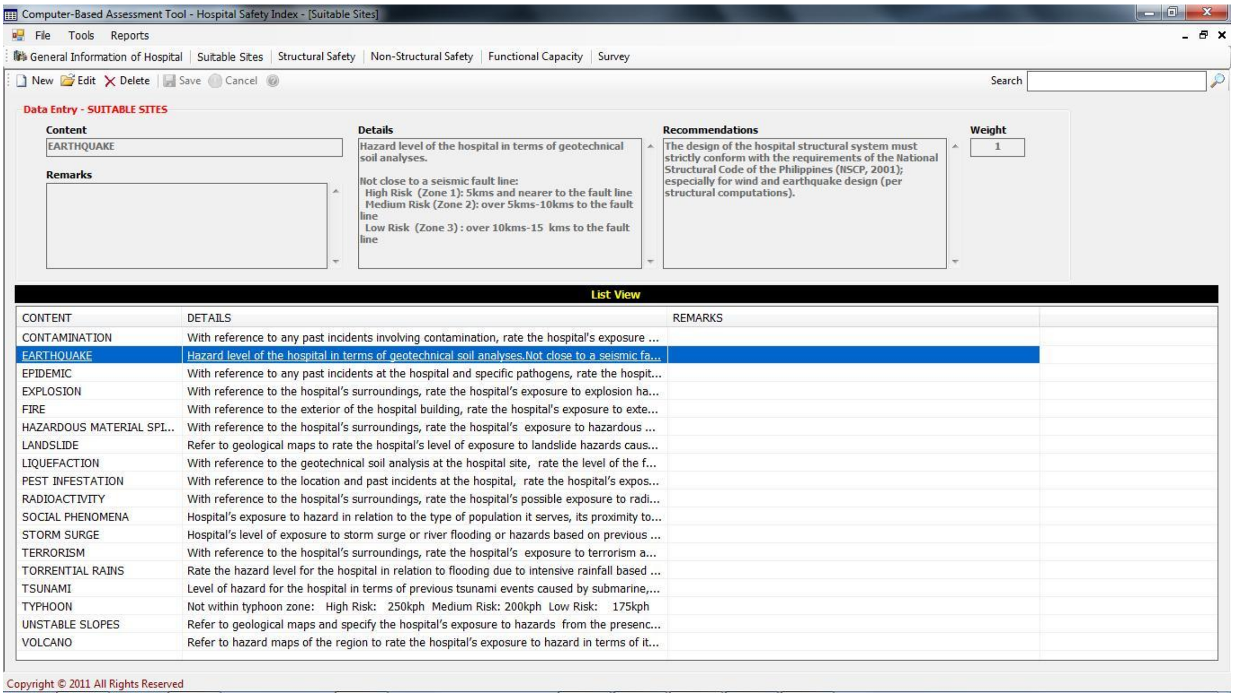


Figure 27 Suitable Sites Maintenance Module

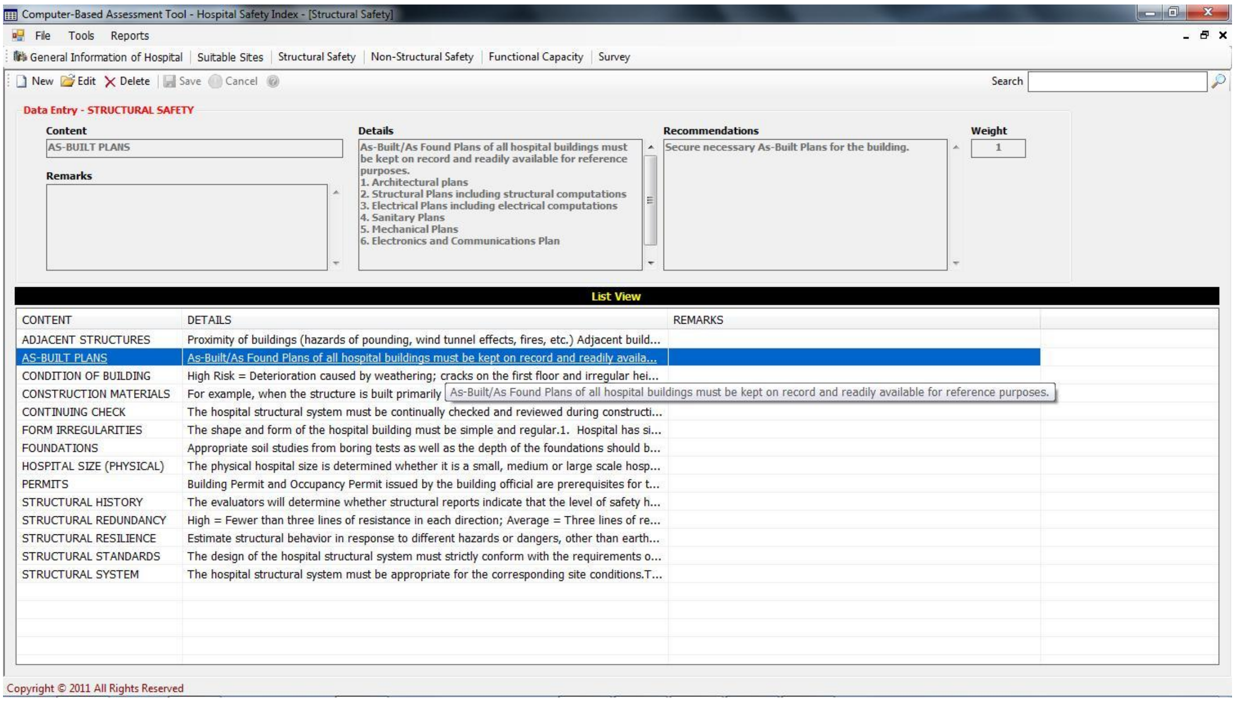


Figure 28 Structural Safety Maintenance Module

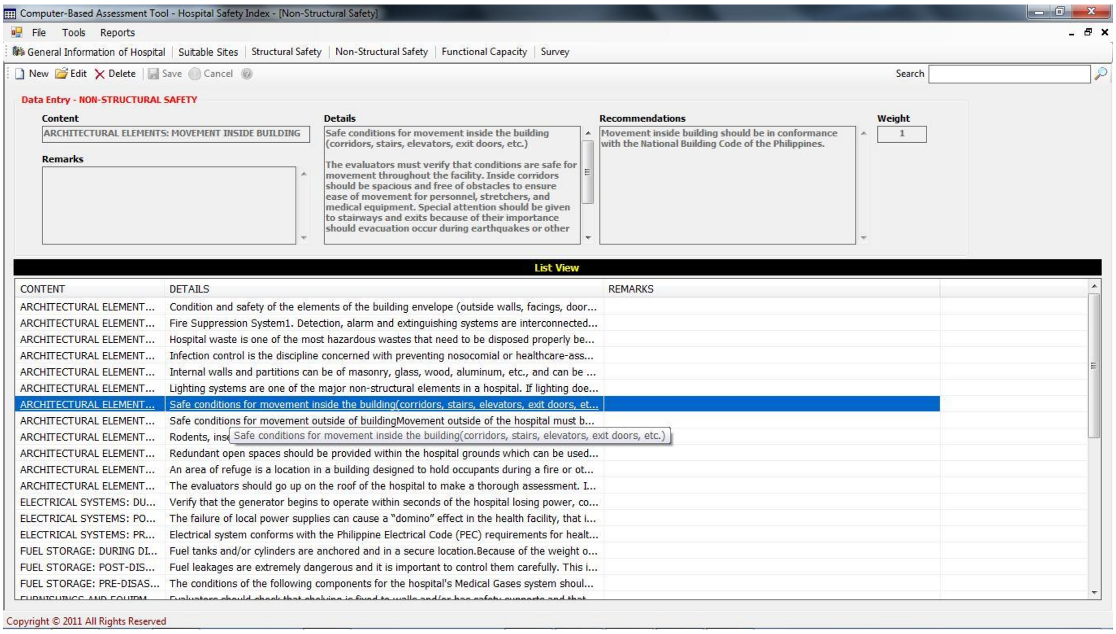


Figure 29 Non-Structural Safety Maintenance Module

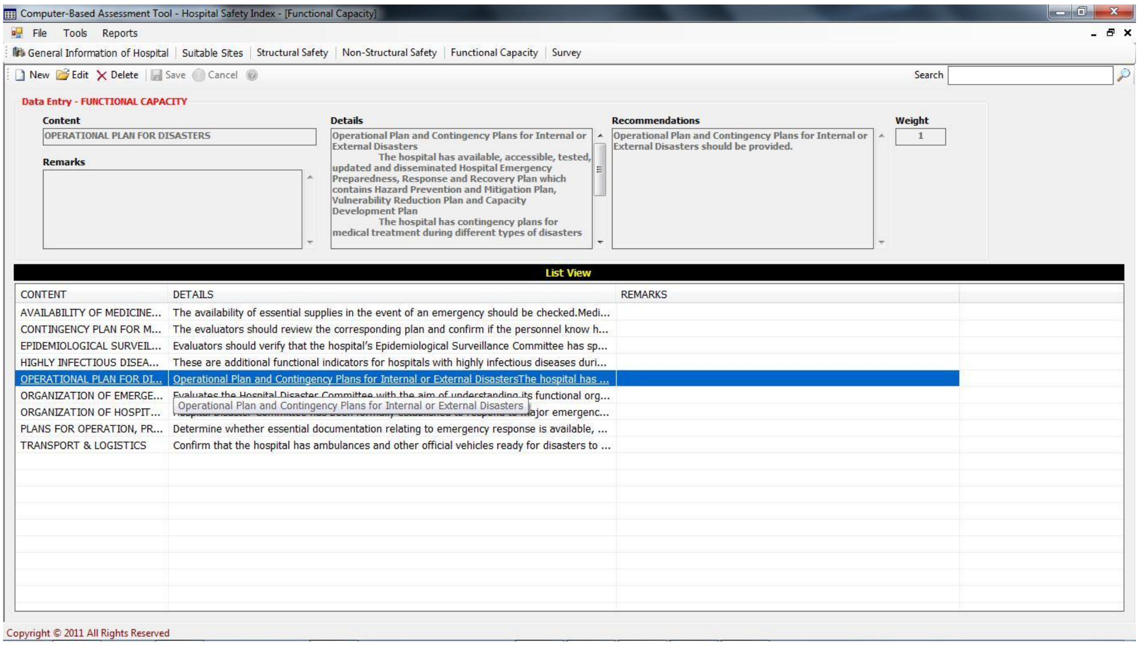


Figure 30 Functional Capacity Maintenance Module

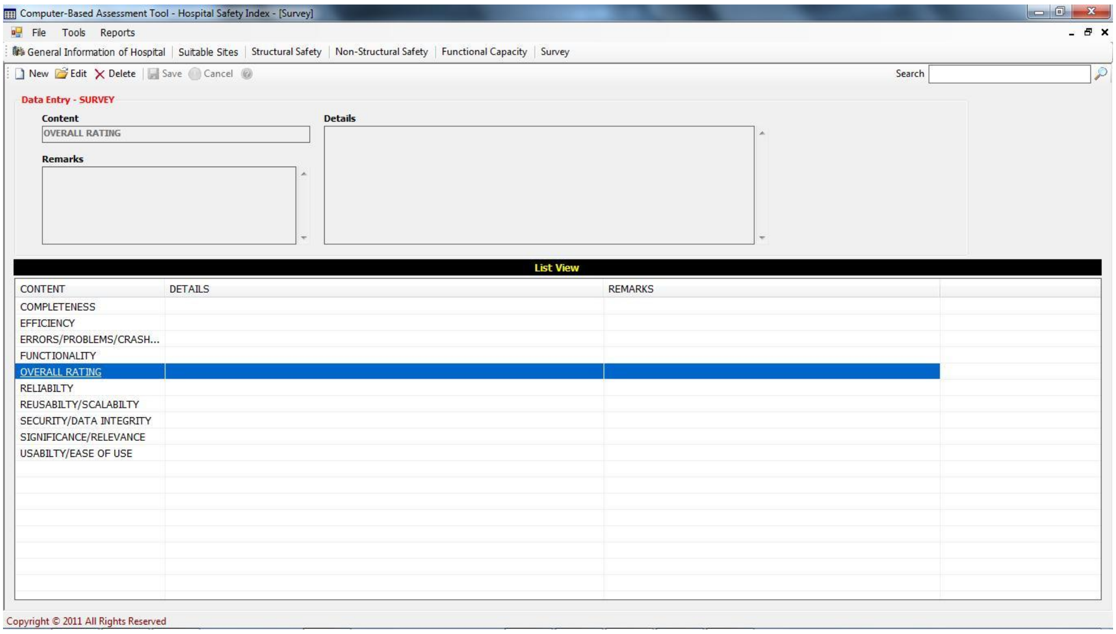


Figure 31 Survey Maintenance Module

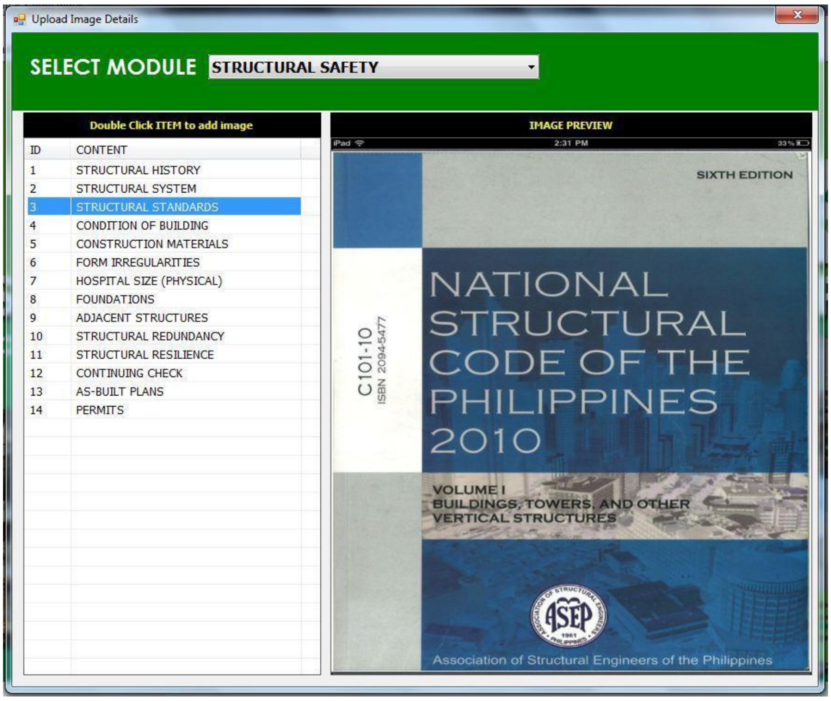


Figure 32 Upload Image - Details Maintenance Module (STRUCTURAL)

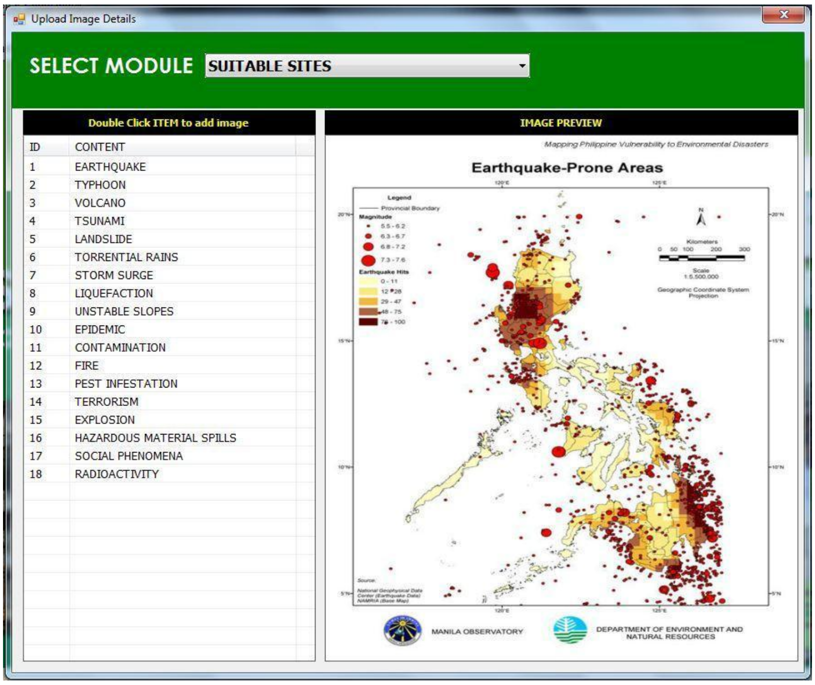


Figure 33 Upload Image - Details Maintenance Module (SUITABLE SITES)

Figure 34 Upload Image - Recommendations Maintenance Module

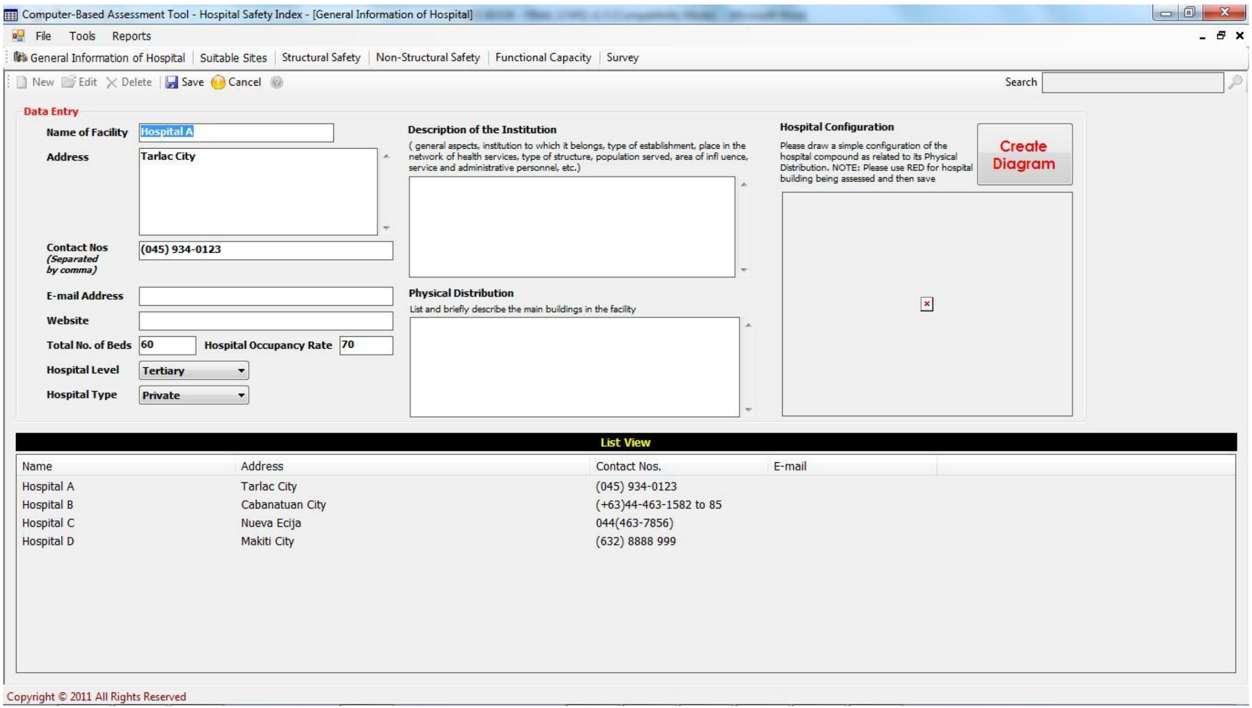


Figure 35 General Information Module

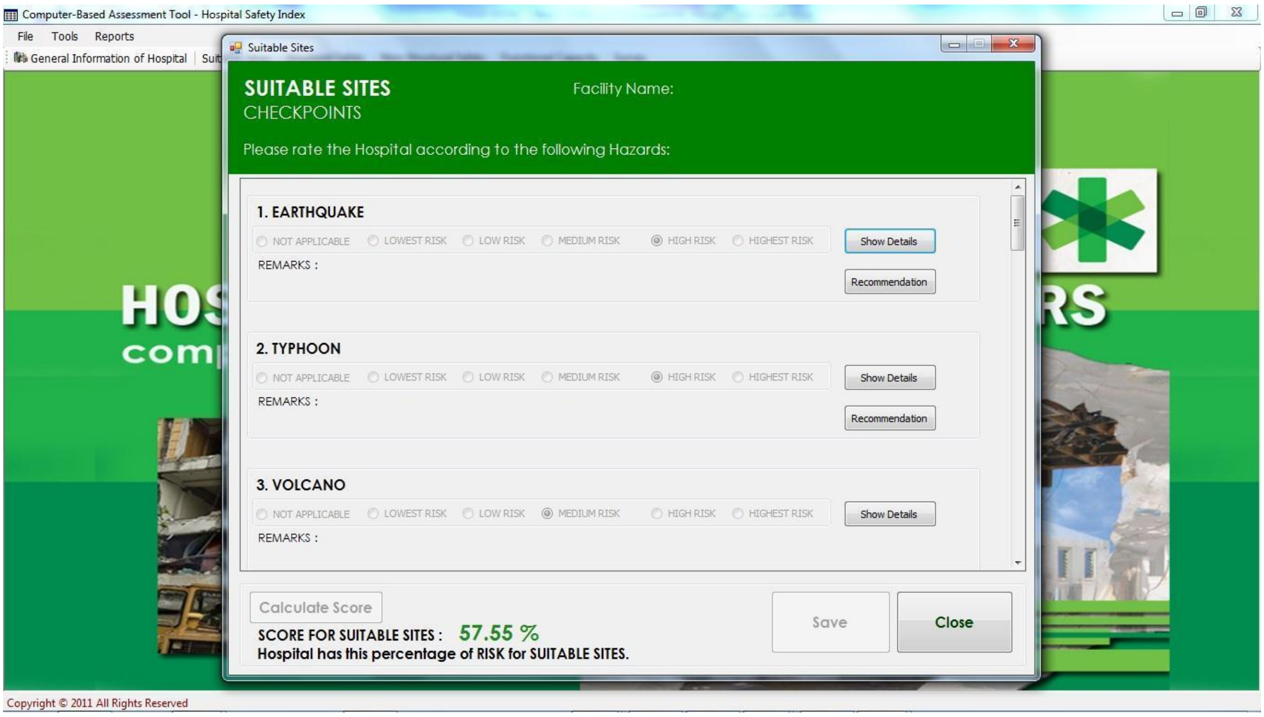


Figure 36 Suitable Sites Module

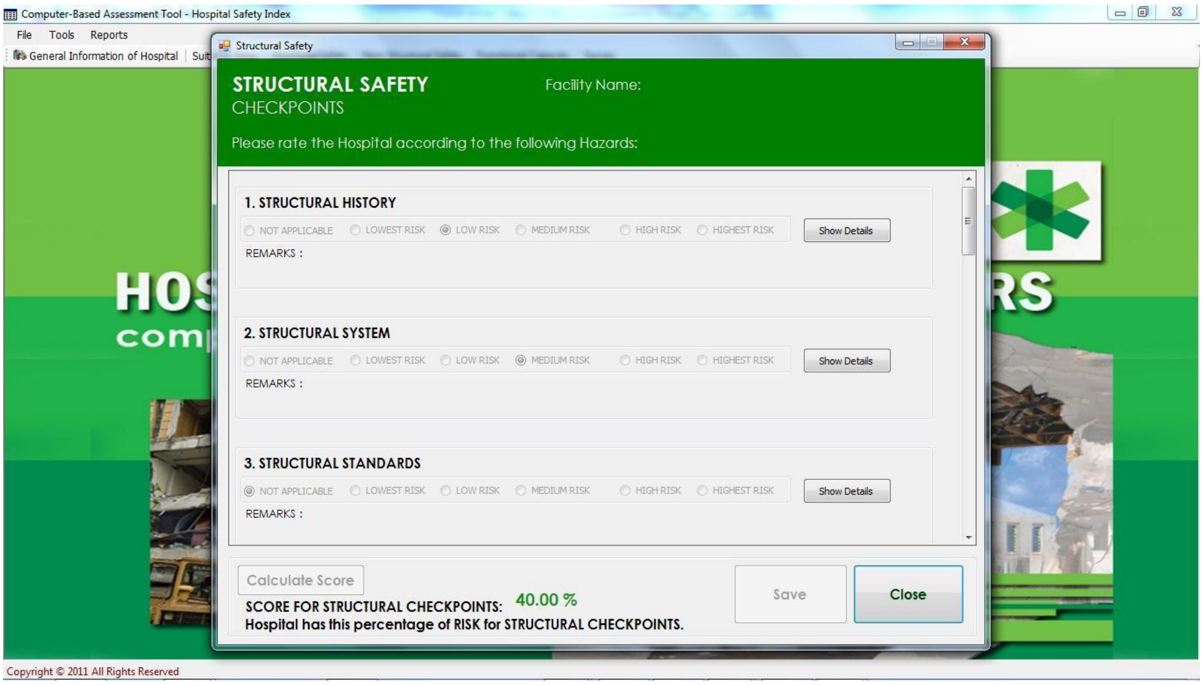


Figure 37 Structural Safety Module

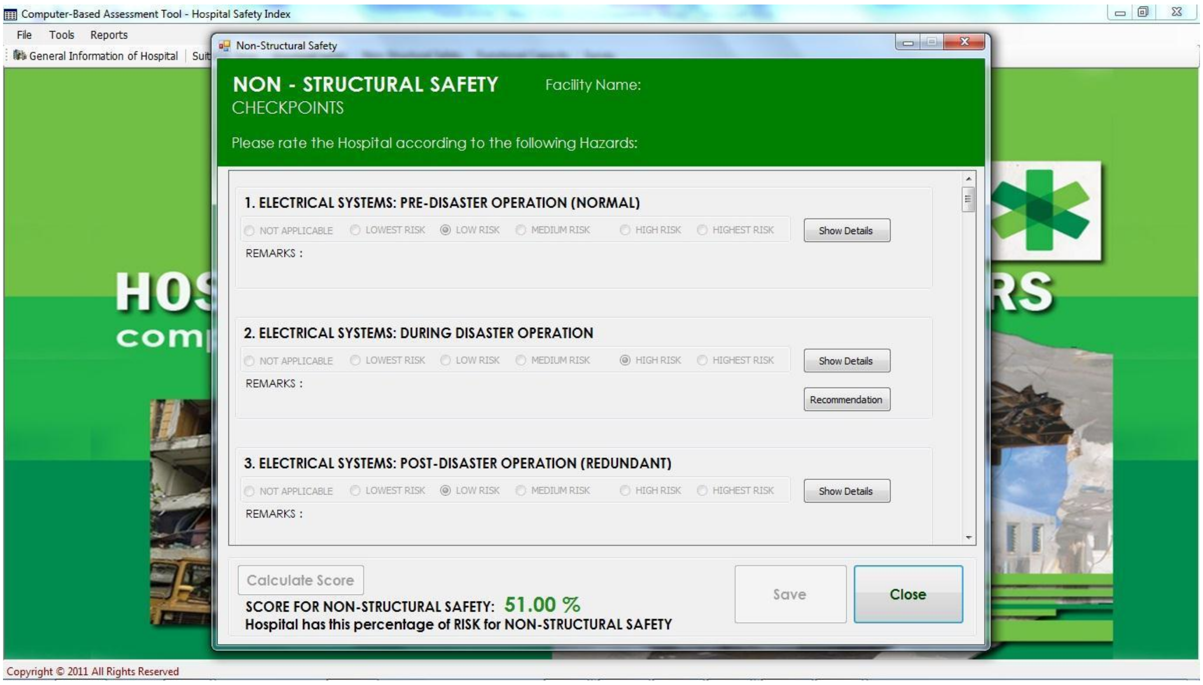


Figure 38 Non-Structural Safety Module

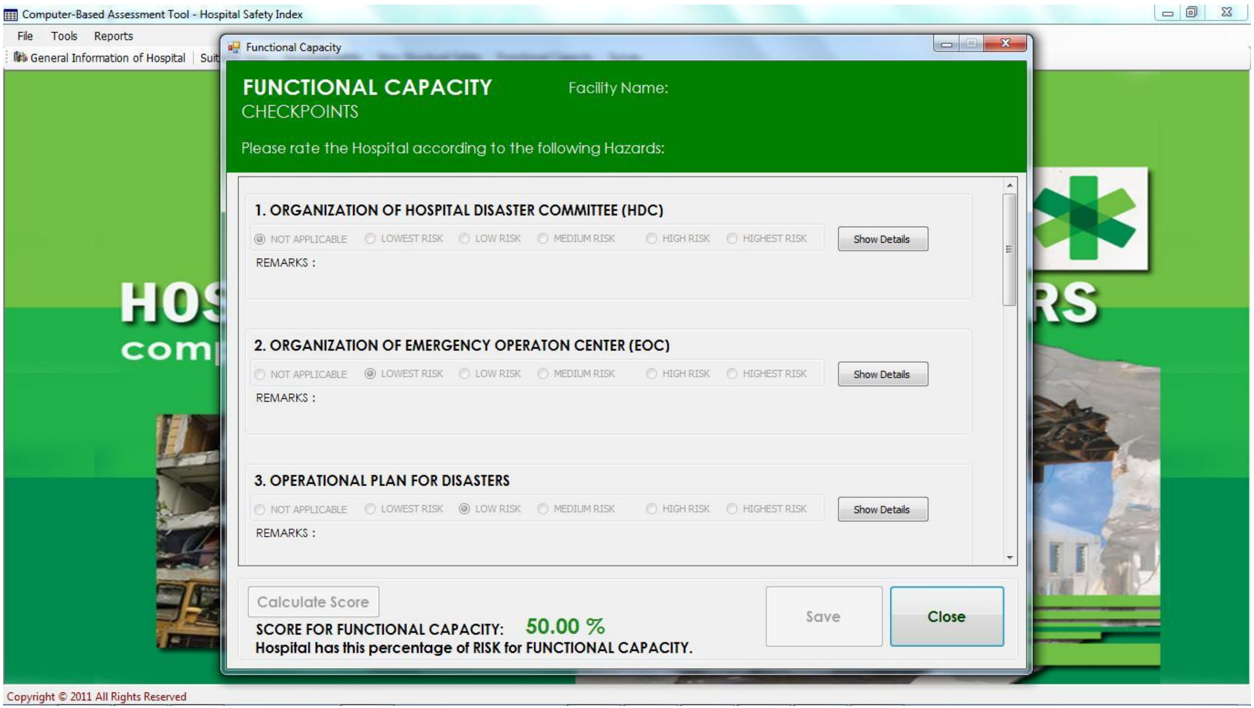


Figure 39 Functional Capacity Module

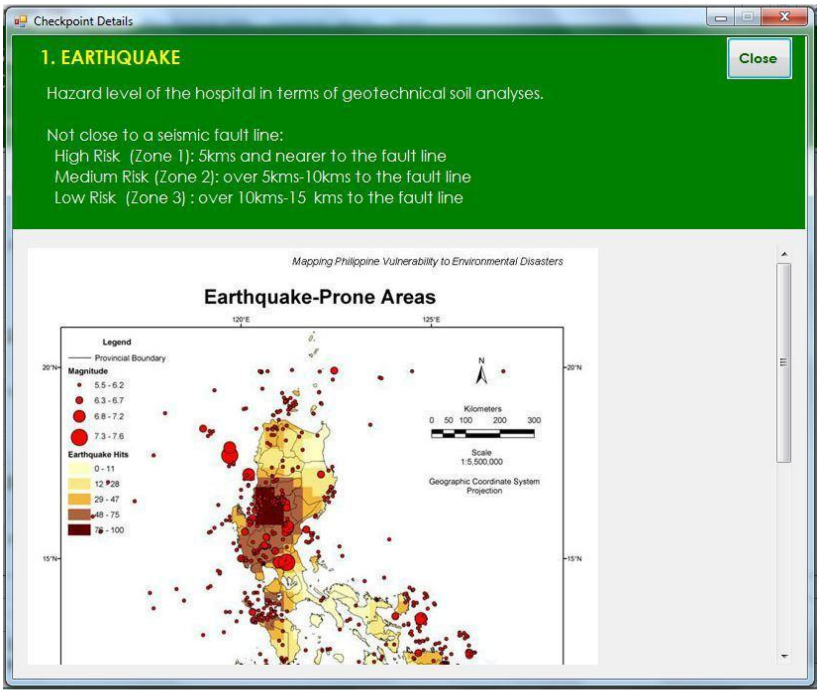


Figure 40 Details Dialog

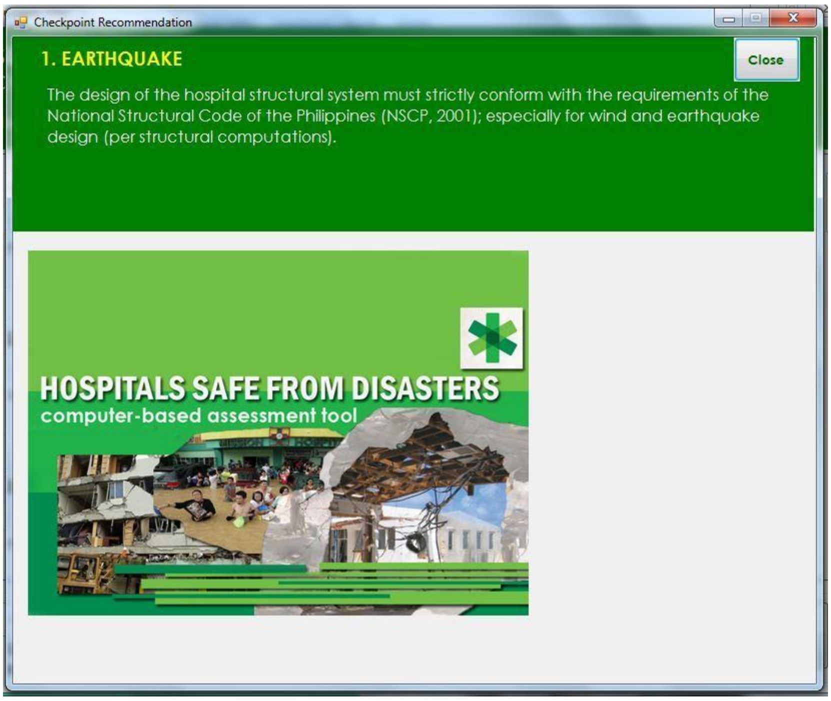


Figure 41 Recommendations Dialog

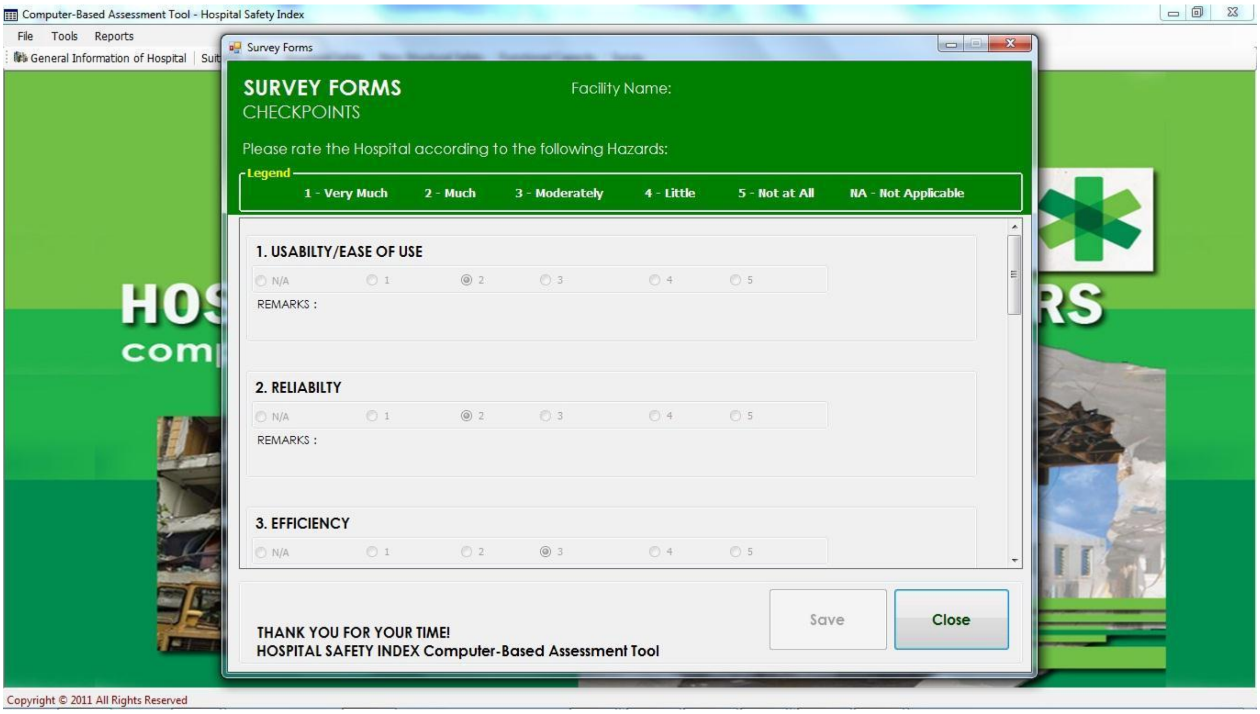


Figure 42 Survey Module

REPORT MODULES

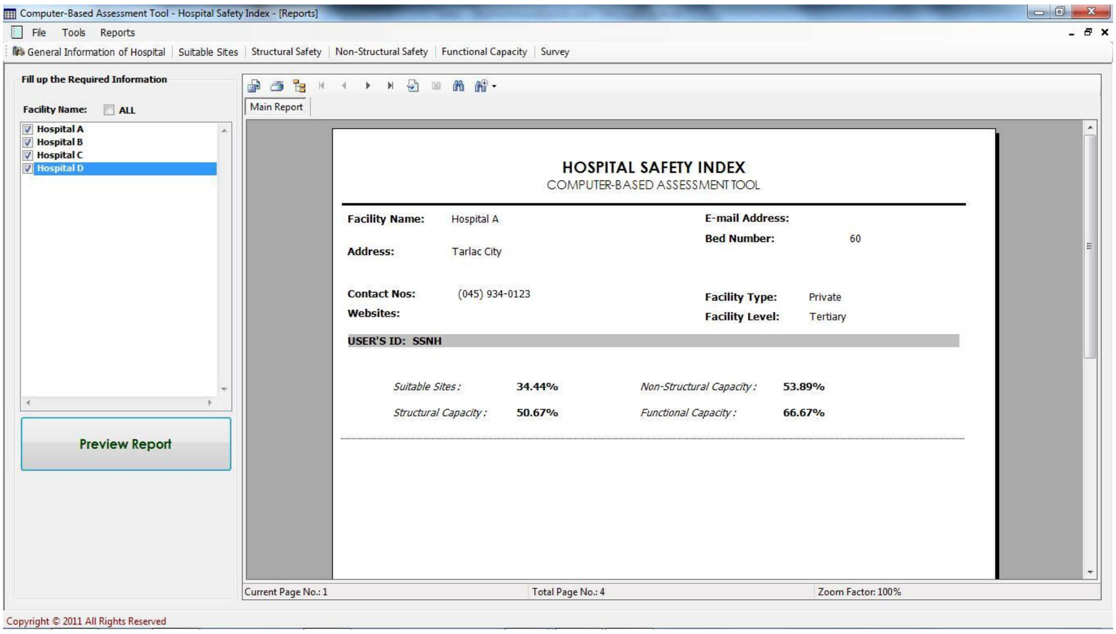


Figure 43 Report - Modules (Hospital "Disaster-Safe Scores")

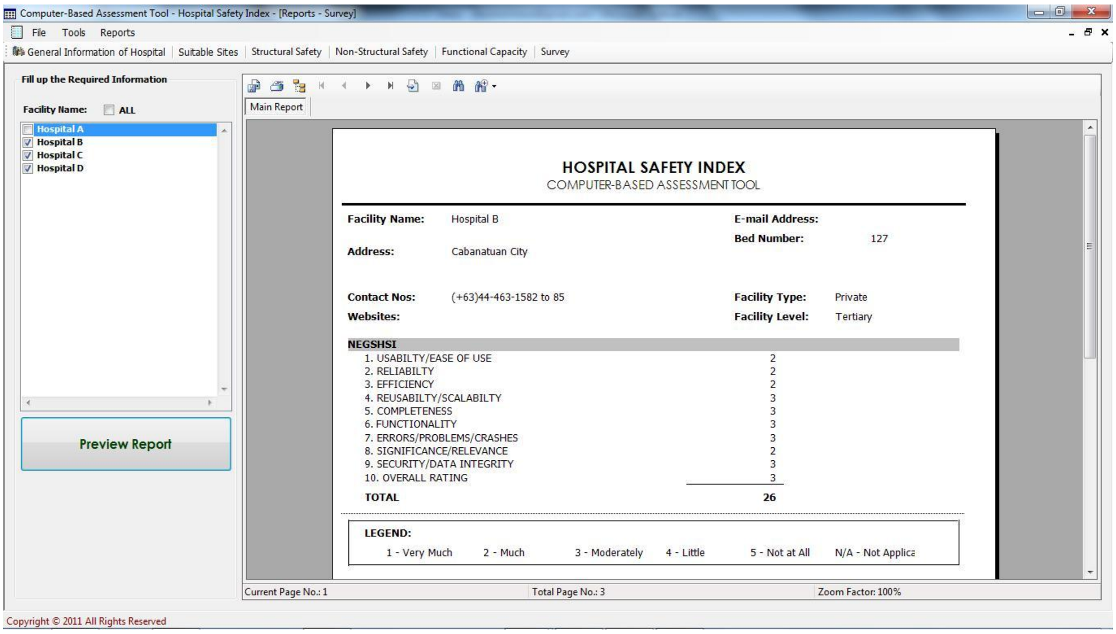


Figure 44 Report - Survey

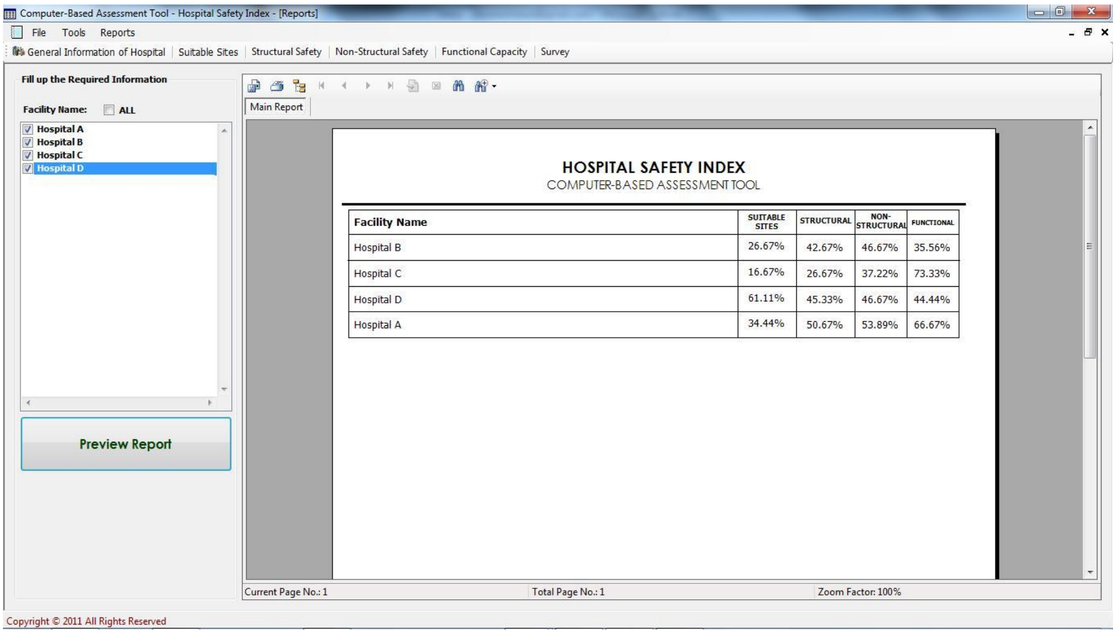


Figure 45 Report - Facility Comparison

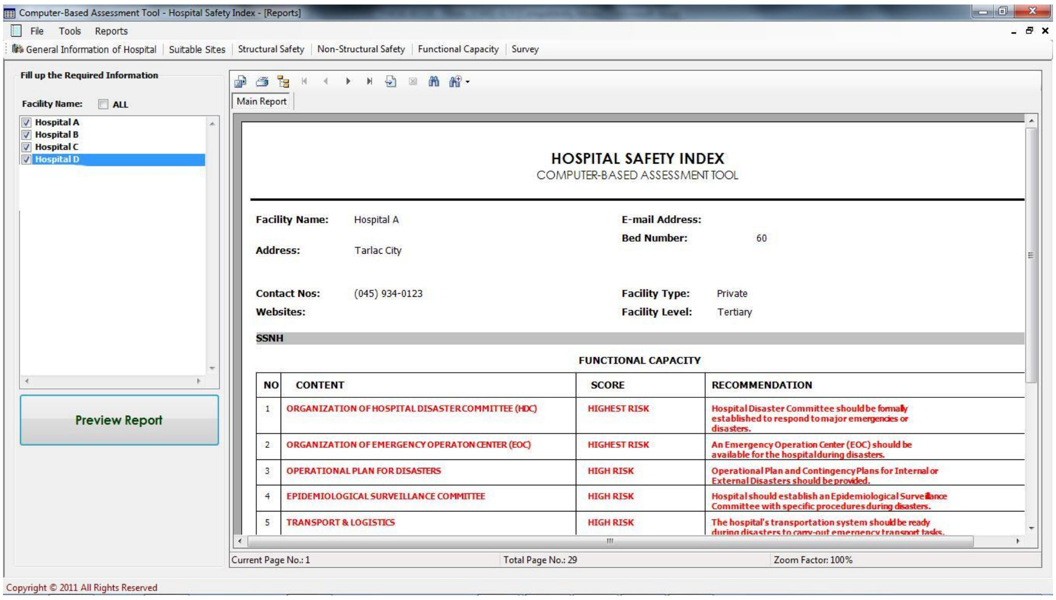


Figure 46 Report - Recommendation Report

5.2.4 Database Structure:

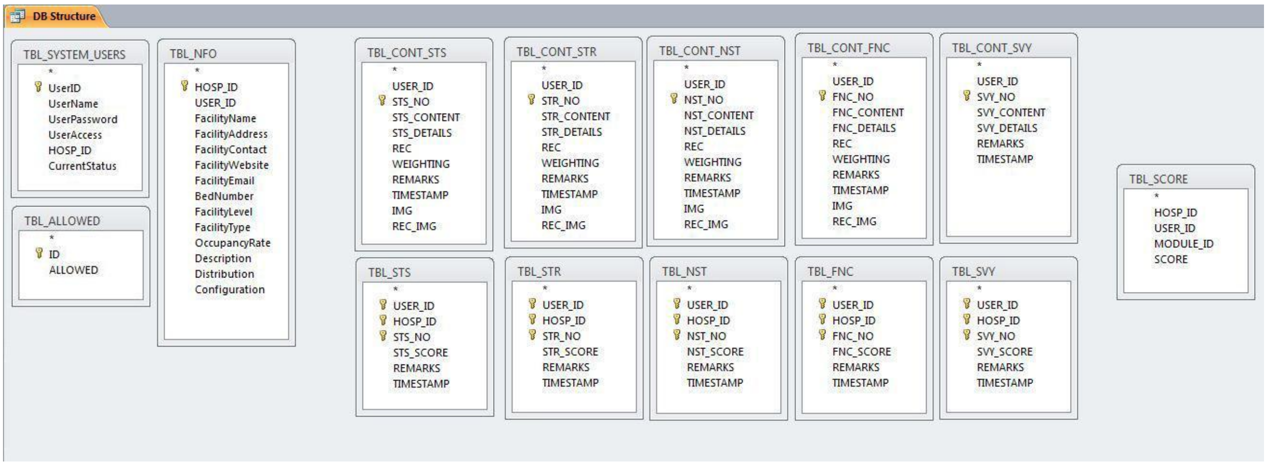


Figure 47 HSFDCBAT Database Structure

TABLES:

- System Users Table (TBL_SYSTEM_USERS) – this table contains the user information, user name and encrypted password, user access whether ADMIN or normal USER, the hospital the user is affiliated with and the user's current status, whether ACTIVE or INACTIVE

TBL_SYSTEM_USERS

UserID	UserName	UserPassword	UserAccess	HOSP_ID	CurrentStatu	Click to Add
1	admin	xTMQ7jpnjQc=	Administrator	3	InActive	
2	USER	MFc5nE9/A+Y=	User	3	InActive	
7	USER1	tKLdtPtgwt4=	User	4	InActive	
8	USER2	GjrC2VW1SmM=	User	3	InActive	
9	USER3	KKqVpHBKjYI=	User	3	Active	
10	USER4	NBDtwWmB+Pw=	User	3	InActive	
11	CAMS	REq5w2f991efvNjP8tldug==	User	8	InActive	
12	OSPITAL	itVVOt0aqtE=	User	9	InActive	
13	TEST	WqeVax7P6VI=	User	3	InActive	
14	MVMC	QEpRbJhG++Y=	User	10	Active	
15	NEGSHSI	iTTx9pV7Cqg=	User	11	Active	
16	MCU	AraYMr+2M6M=	User	12	Inactive	
17	PMC	IDH5A1qSW7M=	User	13	Active	
18	MMC	X66gL1eUc6o=	User	14	InActive	
19	SSNH	rWHjMqRKggQ=	User	15	InActive	

Figure 48 System Users Table

- Allowed Users Table (TBL_ALLOWED) - this table stores the authorized type of user access for the system

- Table for General Information of Hospital (TBL_NFO) – this table stores the general information on the hospital composed of the facility name, address, contact details, email address, website, number of beds, facility level, facility type, occupancy rate, description and hospital configuration

TBL_NFO

HOSP_ID	USER_ID	FacilityName	FacilityAddress	FacilityContact
11	1	Hospital B	Cabanatuan City	(+63)44-463-1582 to 8!
13	1	Hospital C	Nueva Ecija	044(463-7856)
14	1	Hospital D	Makiti City	(632) 8888 999
15	1	Hospital A	Tarlac City	(045) 934-0123
(New)				

Figure 49 General Information Table

- Content Table for Suitable Sites (TBL_CONT_STS) – stores the checkpoint contents for Suitable Sites, including the details, recommendations and the weight of the checkpoint

TBL_CONT_STS

USER_ID	STS_NO	STS_CONTENT	STS_DETAILS	REC	WEIGHTING
1	1	EARTHQUAKE	Hazard level of the hospital in terms of geotechnical soil analyses.	The design of t	1
1	2	TYPHOON	Not within typhoon zone:	Coordinate wit	1
1	3	VOLCANO	Refer to hazard maps of the region to rate the hospital's exposure to hazard in t	Coordinate wit	1
1	4	TSUNAMI	Level of hazard for the hospital in terms of previous tsunami events caused by s	Earthquake-inc	1
1	5	LANDSLIDE	Refer to geological maps to rate the hospital's level of exposure to landslide ha	Vulnerability t	1
1	6	TORRENTIAL RAINS	Rate the hazard level for the hospital in relation to flooding due to intensive rai	Experts offere	1
1	7	STORM SURGE	Hospital's level of exposure to storm surge or river flooding or hazards based or	Fixed wall stru	1
1	8	LIQUEFACTION	With reference to the geotechnical soil analysis at the hospital site, rate the le	Methods to mi	1
1	9	UNSTABLE SLOPES	Refer to geological maps and specify the hospital's exposure to hazards from th	Coordinate wit	1
1	10	EPIDEMIC	With reference to any past incidents at the hospital and specific pathogens, rate	Health personr	1
1	11	CONTAMINATION	With reference to any past incidents involving contamination, rate the hospital'	Urgent interve	1
1	12	FIRE	With reference to the exterior of the hospital building, rate the hospital's expo	The design of t	1
1	13	PEST INFESTATION	With reference to the location and past incidents at the hospital, rate the hospi	Mitigate pest i	1
1	14	TERRORISM	With reference to the hospital's surroundings, rate the hospital's exposure to t	Refer to FEMA	1
1	15	EXPLOSION	With reference to the hospital's surroundings, rate the hospital's exposure to e	Explosion haza	1
1	16	HAZARDOUS MATERIAL SI	With reference to the hospital's surroundings, rate the hospital's exposure to h	All significant r	1
1	17	SOCIAL PHENOMENA	Hospital's exposure to hazard in relation to the type of population it serves, its	Reconstruction	1
1	18	RADIOACTIVITY	With reference to the hospital's surroundings, rate the hospital's possible expo	Refer to World	1
	(New)				

Figure 50 Content Table for Suitable Sites

- Content Table for Structural Safety (TBL_CONT_STR) - stores the checkpoint contents for Structural Safety, including the details, recommendations and the weight of the checkpoint

TBL_CONT_STR

USER_ID	STR_NO	STR_CONTENT	STR_DETAILS	REC	WEIGHTING
1	1	STRUCTURAL HISTORY	The evaluators will determine whethe	Historical accou	1
1	2	STRUCTURAL SYSTEM	The hospital structural system must be	Adequate struc	1
1	3	STRUCTURAL STANDARDS	The design of the hospital structural sy	Refer to Natior	1
1	4	CONDITION OF BUILDING	High Risk = Deterioration caused by we	Regularly checl	1
1	5	CONSTRUCTION MATERIALS	For example, when the structure is bui	Construction M	1
1	6	FORM IRREGULARITIES	The shape and form of the hospital bui	If hospital shap	1
1	7	HOSPITAL SIZE (PHYSICAL)	The physical hospital size is determine	Structural prop	1
1	8	FOUNDATIONS	Appropriate soil studies from boring te	Geotechnical s	1
1	9	ADJACENT STRUCTURES	Proximity of buildings (hazards of pour	Refer to Natior	1
1	10	STRUCTURAL REDUNDANCY	High = Fewer than three lines of resista	Refer to Natior	1
1	11	STRUCTURAL RESILIENCE	Estimate structural behavior in respon:	Refer to Natior	1
1	12	CONTINUING CHECK	The hospital structural system must be	Hospital admir	1
1	13	AS-BUILT PLANS	As-Built/As Found Plans of all hospital	Secure necess	1
1	14	PERMITS	Building Permit and Occupancy Permit	Permits as requ	1
	(New)				

Figure 51 Content Table for Structural Safety

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- Content Table for Non-Structural Safety (TBL_CONT_NST) - stores the checkpoint contents for Non-Structural Safety, including the details, recommendations and the weight of the checkpoint

TBL_CONT_NST

USER_ID	NST_NO	NST_CONTENT	NST_DETAILS	REC	WEIGHTING
1	1	ELECTRICAL SYSTEMS: PRE-DISASTER OPERATION (NORMAL)	Electrical system conforms with t	Refer to the Ph	1
1	2	ELECTRICAL SYSTEMS: DURING DISASTER OPERATION	Verify that the generator begins	Refer to Philip	1
1	3	ELECTRICAL SYSTEMS: POST-DISASTER OPERATION (REDUNDANT)	The failure of local power suppli	Redundant pov	1
1	4	TELECOMMUNICATION SYSTEMS: PRE-DISASTER OPERATION (NOR	The conditions of the following c	Proper check o	1
1	5	TELECOMMUNICATION SYSTEMS: DURING DISASTER OPERATION	The evaluators should confirm th	Anchorage for	1
1	6	TELECOMMUNICATION SYSTEMS: POST-DISASTER OPERATION (REI	The evaluator will check the cond	Alternative cor	1
1	7	WATER SUPPLY SYSTEM: PRE-DISASTER OPERATION (NORMAL)	The conditions of the following c	Conditions of v	1
1	8	WATER SUPPLY SYSTEM: DURING DISASTER OPERATION	Water tank has permanent reser	Water supply s	1
1	9	WATER SUPPLY SYSTEM: POST-DISASTER OPERATION (REDUNDAN	Alternative water supply to majc	Alternative wa	1
1	10	FUEL STORAGE: PRE-DISASTER OPERATION (NORMAL)	The conditions of the following c	The conditions	1
1	11	FUEL STORAGE: DURING DISASTER OPERATION	Fuel tanks and/or cylinders are a	Anchorage for	1
1	12	FUEL STORAGE: POST-DISASTER OPERATION (REDUNDANT)	Fuel leakages are extremely dan	Fuel tanks/stor	1
1	13	MEDICAL GASES: PRE-DISASTER OPERATION (NORMAL)	The condition of the following cc	Condition of th	1
1	14	MEDICAL GASES: DURING DISASTER OPERATION	Gas tanks and cylinders are locat	Anchorage for	1
1	15	MEDICAL GASES: POST-DISASTER OPERATION (REDUNDANT)	Availability of alternative source	Alternative sou	1
1	16	HVAC SYSTEMS: PRE-DISASTER OPERATION (NORMAL)	Conditions for the following com	The hospital's	1
1	17	HVAC SYSTEMS: DURING DISASTER OPERATION	Anchorage for HVAC equipment	Provide afficie	1
1	18	HVAC SYSTEMS: POST-DISASTER OPERATION (REDUNDANT)	Because they are critical elemen	Redundant sys	1
1	19	FURNISHINGS AND EQUIPMENT: PRE-DISASTER OPERATION (NORI	Condition of office furnishings ar	Condition of of	1
1	20	FURNISHINGS AND EQUIPMENT: DURING DISASTER OPERATION	Evaluators should check that she	Anchorage of f	1
1	21	FURNISHINGS AND EQUIPMENT: POST-DISASTER OPERATION (REC	Furnishings and equipment shou	Provide furnish	1
1	22	MEDICAL AND LABORATORY EQUIPMENT: PRE-DISASTER OPERATI	Condition and safety of the equi	Regularly checl	1
1	23	MEDICAL AND LABORATORY EQUIPMENT: DURING DISASTER OPER	Evaluators should verify that she	Proper anchora	1
1	24	MEDICAL AND LABORATORY EQUIPMENT: POST-DISASTER OPERAT	Medical and laboratory equipme	Medical and lal	1

Figure 52 Content Table for Non-Structural Safety

- Content Table for Functional Capacity (TBL_CONT_FNC) - stores the checkpoint contents for Functional Capacity, including the details, recommendations and the weight of the checkpoint

TBL_CONT_FNC

USER_ID	FNC_NO	FNC_CONTENT	FNC_DETAIL	REC	WEIGHTING
1	1	ORGANIZATION OF HOSPITAL DISASTER COMMITTEE (HDC)	Hospital Disast	Hospital Disast	1
1	2	ORGANIZATION OF EMERGENCY OPERATON CENTER (EOC)	Evaluates the H	An Emergency	1
1	3	OPERATIONAL PLAN FOR DISASTERS	Operational Pla	Operational Pla	1
1	4	EPIDEMIOLOGICAL SURVEILLANCE COMMITTEE	Evaluators shoi	Hospital should	1
1	5	TRANSPORT & LOGISTICS	Confirm that th	The hospital's t	1
1	6	CONTINGENCY PLAN FOR MEDICAL TREATMENTS IN DISASTERS	The evaluators	Contingency pl	1
1	7	PLANS FOR OPERATION, PREVENTIVE MAINTENANCE AND RESTORATION OF CRI	Determine wh	Plans for opera	1
1	8	AVAILABILITY OF MEDICINES, SUPPLIES, INSTRUMENTS OR EQUIPMENTS FOR USE	The availability	The availability	1
1	9	HIGHLY INFECTIOUS DISEASES	These are addi	Highly infectio	1
*	(New)				

Figure 53 Content Table for Functional Capacity

- Content Table for Survey (TBL_CONT_SVY) – this table contains the items for evaluation in the survey for HSFDCBAT user satisfaction rating

TBL_CONT_SVY

USER_ID	SVY_NO	SVY_CONTENT	SVY_DETAILS	REMARKS
1	1	USABILTY/EASE OF USE		
1	2	RELIABILTY		
1	3	EFFICIENCY		
1	4	REUSABILTY/SCALABILTY		
1	5	COMPLETENESS		
1	6	FUNCTIONALITY		
1	7	ERRORS/PROBLEMS/CRASHES		
1	8	SIGNIFICANCE/RELEVANCE		
1	9	SECURITY/DATA INTEGRITY		
1	10	OVERALL RATING		
*	(New)			

Figure 54 Content Table for Survey

- Safe Score Table for Suitable Sites (TBL_STS) – storage table for the scores selected by the user for the Suitable Sites module

TBL_STS

USER_ID	HOSP_ID	STS_NO	STS_SCORE	REMARKS	TIMESTAMP
1	3	1	5		
1	3	2	5		
1	3	3	4		
1	3	4	4		
1	3	5	4		
1	3	6	3		
1	3	7	4		
1	3	8	4		
1	3	9	3		
1	3	10	4		
1	3	11	3		

Figure 55 Safe Score Table for Suitable Sites

- Safe Score Table for Structural Safety (TBL_STR) – storage table for the scores selected by the user for the Structural Safety module

TBL_STR

USER_ID	HOSP_ID	STR_NO	STR_SCORE	REMARKS	TIMESTAMP
1	3	1	3		
1	3	2	4		
1	3	3	1		
1	3	4	2		
1	3	5	4		
1	3	6	3		
1	3	7	3		
1	3	8	5		
1	3	9	4		
1	3	10	3		
1	3	11	1		
1	3	12	2		

Figure 56 Safe Score table for Structural Safety

- Safe Score Table for Non-Structural Safety (TBL_NST) – storage table for the scores selected by the user for the Non-Structural Safety module

TBL_NST

USER_ID	HOSP_ID	NST_NO	NST_SCORE	REMARKS	TIMESTAMP
1	3	1	3		
1	3	2	5		
1	3	3	3		
1	3	4	3		
1	3	5	2		
1	3	6	1		
1	3	7	3		
1	3	8	4		
1	3	9	5		
1	3	10	6		
1	3	11	5		
1	3	12	4		

Figure 57 Safe Score Table for Non-Structural Safety

- Safe Score Table for Functional Capacity (TBL_FNC) – storage table for the scores selected by the user for the Functional Capacity module

TBL_FNC

USER_ID	HOSP_ID	FNC_NO	FNC_SCORE	REMARKS	TIMESTAMP
1	3	1	1		
1	3	2	2		
1	3	3	3		
1	3	4	4		
1	3	5	5		
1	3	6	6		
1	3	7	5		
1	3	8	4		
1	3	9	3		
1	3	10	2		
2	3	1	3		
2	3	2	2		
2	3	3	3		

Figure 58 Safe Score Table for Functional Capacity

- Safe Score Table for Survey (TBL_SVY) – storage table for the scores selected by the user for the Structural Safety module

TBL_SVY

USER_ID	HOSP_ID	SVY_NO	SVY_SCORE	REMARKS	TIMESTAMP
1	3	1	3		
1	3	2	3		
1	3	3	4		
1	3	4	5		
1	3	5	6		
1	3	6	5		
1	3	7	4		
1	3	8	3		
1	3	9	2		
1	3	10	1		
2	3	1	3		
2	3	2	3		

Figure 59 Safe Score Table for Survey

- Safe Score Summary Table (TBL_SCORE) – contains the User ID, Hospital ID, Module ID and the corresponding score for that module.

TBL_SCORE

HOSP_ID	USER_ID	MODULE_ID	SCORE
3	1	STS	57.55
3	1	STR	40.00
3	1	NST	51.00
3	1	FNC	50.00
3	2	STS	59.00
3	2	STR	51.00
3	2	NST	48.00
3	2	FNC	46.00
3	8	STS	38.06
4	7	STS	47.00
4	7	STR	47.00
4	7	NST	53.00

Figure 60 Safe Score Summary Table

QUERIES

- Query for Suitable Sites Safe Score (QRY_STS) – a database query in getting the disaster-readiness rating (% risk) for the Suitable Sites module
- Query for Structural Safety Score (QRY_STR) - a database query in getting the disaster-readiness rating (% risk) for the Structural Safety module
- Query for Non-Structural Safety Safe Score (QRY_NST) - a database query in getting the disaster-readiness rating (% risk) for the Non-Structural Safety module
- Query for Functional Capacity Safe Score (QRY_FNC) - a database query in getting the disaster-readiness rating (% risk) for the Functional Capacity module
- Query for Survey (QRY_SVY) - a database query in getting the user satisfaction rating based on the use of HSFDCBAT
- Query for Module Safe Score Reports (QRY_STS) – a database query to retrieve the data for the Module Reports from the database
- Query for Comparison Reports (QRY_COMPARISON) – a database query to retrieve the data for the Comparison Reports from the database

Query for Recommendation Reports (QRY_REP_MODULES) – a database query to retrieve the data for the Recommendation Reports from the database

6 DISCUSSION OF HEALTH FACILITIES

Due to the sensitivity of the data gathered and the agreed upon confidentiality and anonymity with the health facilities involved in this research work, only some minor information and minimal, non-specific data relevant to the study are divulged in this paper.

6.1 Hospital A

6.1.1 Bed Capacity. The bed capacity for Hospital A is forty (40) beds with 85% occupancy rate.

6.1.2 Area. Approximate Gross Floor Area for Hospital A is around 2,000 square meters

6.1.3 Shape & Size. Relatively small tertiary hospital with a basic L-shaped footprint including annex. It has four (4) storeys with roof deck.

6.1.4 Building History. Main building was constructed in 1992 and the annex building was completed on January 2006

6.1.5 Location. Hospital A is located at the Northern part of Tarlac (Central Luzon)

6.1.6 Contact Person/User Designation. HSFDCBAT was used and assessed by the Hospital Administrator together with its Head of Engineering and Maintenance.

6.1.7 DOH/WHO Workshop. Hospital personnel involved in the study have not attended any workshop on Safe Hospitals at the time of study.

Figure 61 Sample Floor Plan of Hospital A

Figure 62 Facade of Hospital A

Figure 63 Hospital A Annex Building

6.2 Hospital B

6.2.1 Bed Capacity. The hospital bed capacity for Hospital B is 127 beds with a 70% occupancy rate.

6.2.2 Area. Approximate Gross Floor Area for Hospital A is around 5,400 square meters

6.2.3 Shape & Size. Medium-sized, 2-storey hospital which is mostly rectangular and slightly L-shaped.

6.2.4 Building History. Original structure was built in 1978 and renovation of Hospital B started after 20 years in 1998 and then in 2009 up to present

6.2.5 Location. Hospital B is located at Nueva Ecija, Central Luzon.

6.2.6 Contact Person/User. Contact for this hospital is a Maintenance Officer/Pollution Control Officer.

6.2.7 DOH/WHO Workshop. Attended WHO/DOH Workshop on March 2011 at Angeles City, Pampanga

Figure 64 Facade of Hospital B (Building 1)

Figure 65 Facade of Hospital B (Building 2)

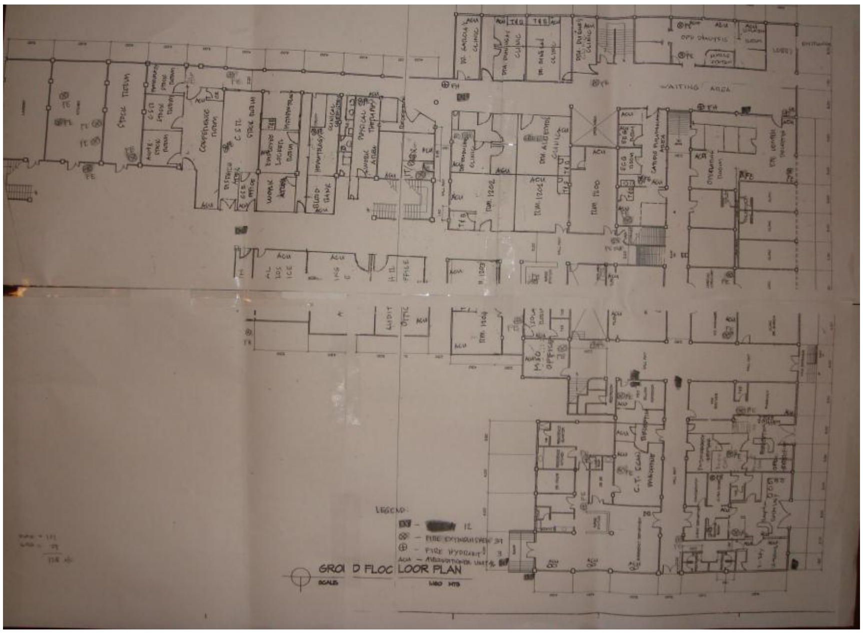

Figure 66 Sample Floor Plan of Hospital B

6.3 Hospital C

6.3.1 Bed Capacity. Hospital C has a 150-bed capacity with occupancy rate ranging from 60 to 70%.

6.3.2 Area. Approximate Gross Floor Area for Hospital C is around 4,800 square meters

6.3.3 Shape & Size. Hospital C has a basic rectangular configuration with front façade having a semi-circle shape and has four (4) storeys.

6.3.4 Building History. Original structure was erected in 1996 and expansion was done in 2006

6.3.5 Location. Hospital C is located at Nueva Ecija, Central Luzon.

6.3.6 Contact Person/User. Safety Officer/Security and Facilities Head

6.3.7 DOH/WHO Workshop. Hospital personnel involved in the study have not attended any workshop on Safe Hospitals at the time of study.

Figure 67 Hospital C

Figure 68 Facade of Hospital C

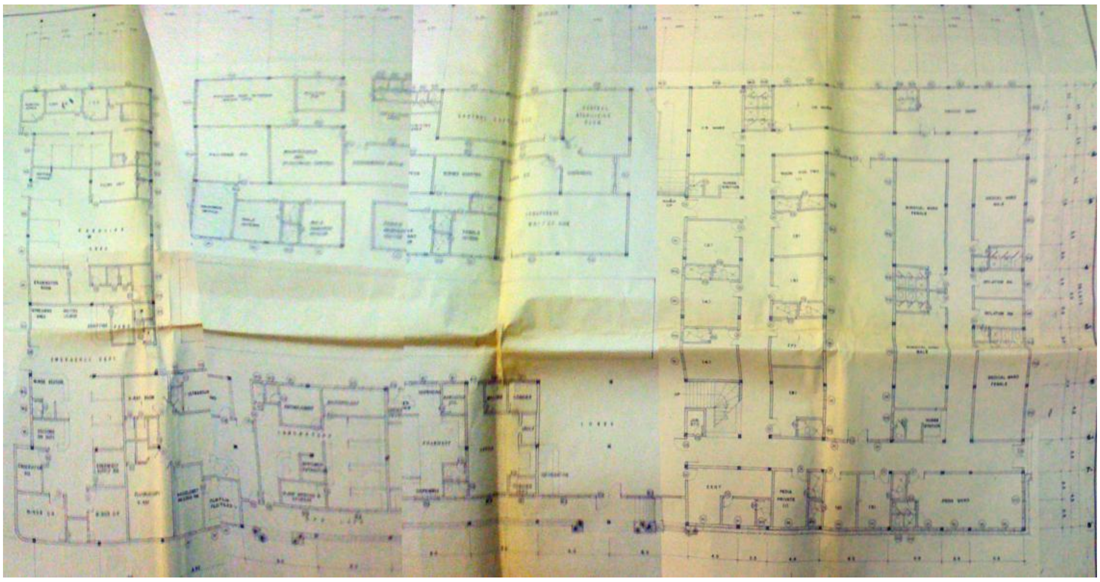

Figure 69 Sample Floor Plan of Hospital C (Main)

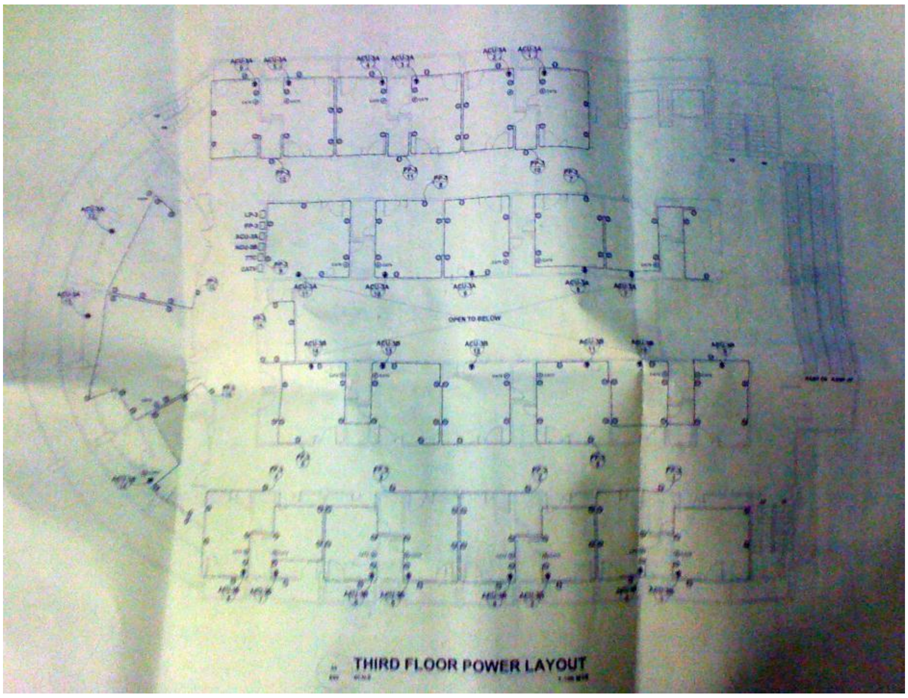

Figure 70 Sample Floor Plan of Hospital C (Front)

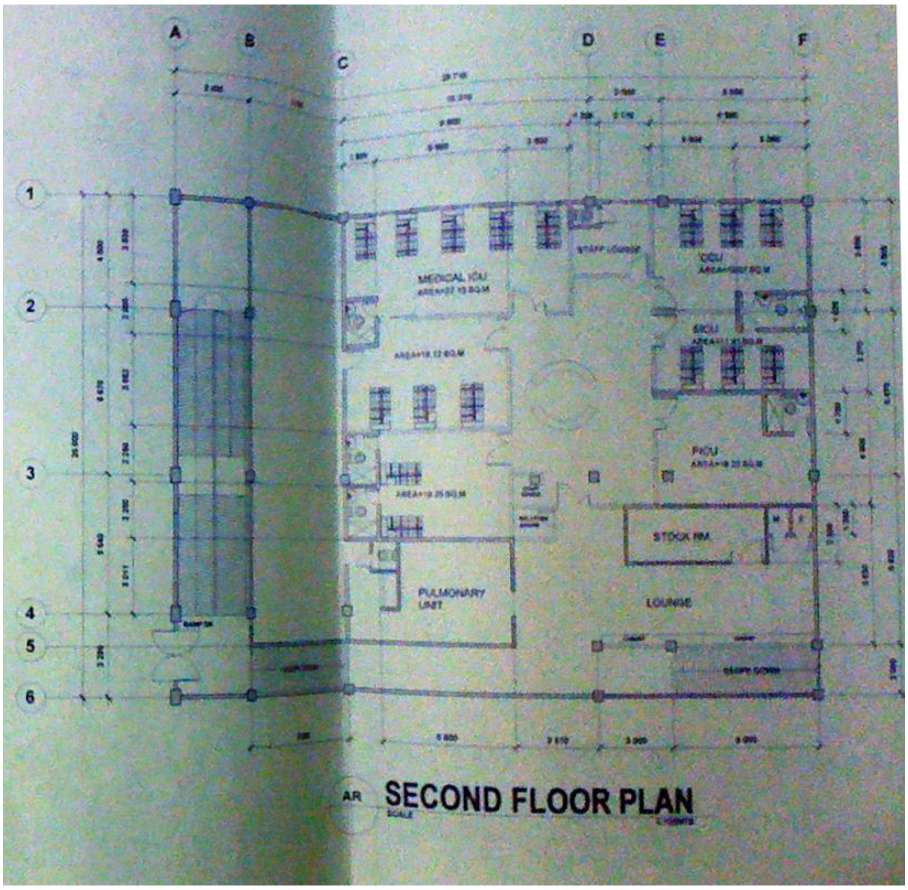

Figure 71. Sample Floor Plan of Hospital C (Rooms)

6.4 Hospital D

6.4.1 Bed Capacity. Hospital D has a 500-bed capacity with occupancy rate of 84 %.

6.4.2 Area. Approximate Gross Floor Area for Hospital D is around 3 hectares.

6.4.3 Shape & Size. Hospital D is a relatively large hospital with a basic rectangular shape for its main building and one in a cylindrical shape within the compound, having two towers, one with ten (10) floors and the other with eight (8) floors. The health facility also has five (5) basement levels for parking.

6.4.4 Building History. Original structure was erected in 1969, continuous improvements, retrofitting and expansions were done up until 2008 when latest expansion was occupied.

6.4.5 Location. Hospital D is located in Metro Manila

6.4.6 Contact Person/User. Safety Officer - Facility Management & Engineering Division

6.4.7 DOH/WHO Workshop. Hospital personnel involved in the study are continuously attending workshop on Safe Hospitals and other seminars on fire and emergencies at the time of study.

Figure 72 Hospital D (Side**)**

Figure 73 Hospital D (New Building)

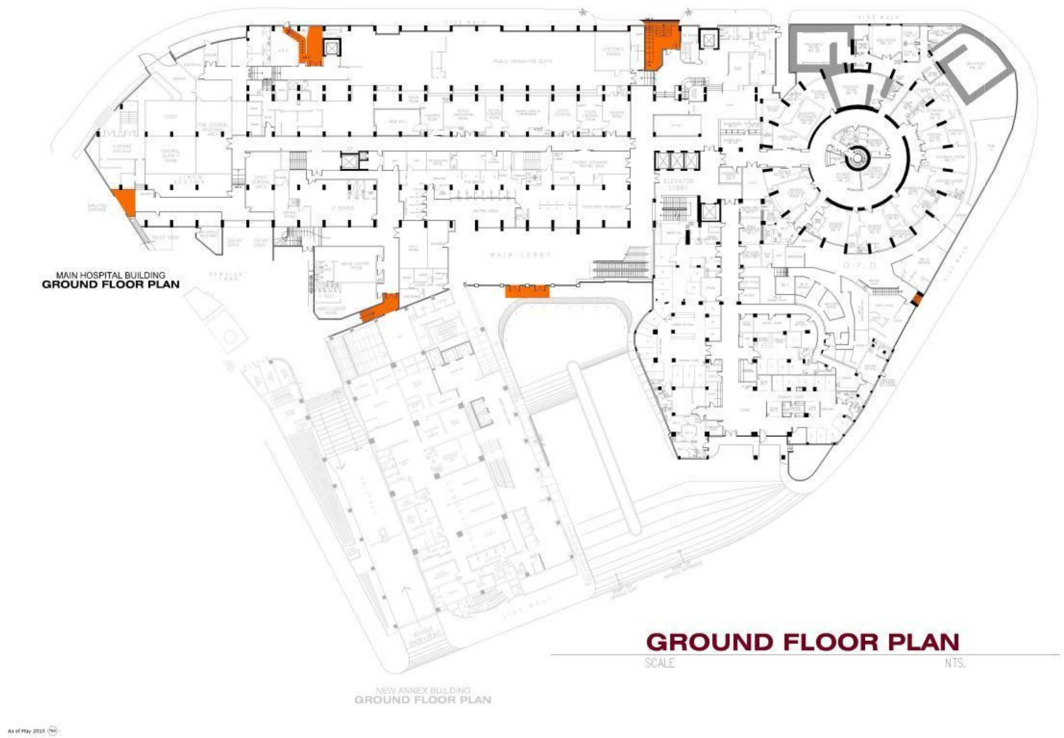

Figure 74 Sample Floor Plan Hospital D

7 FINDINGS & ANALYSIS

7.1 Hospital A

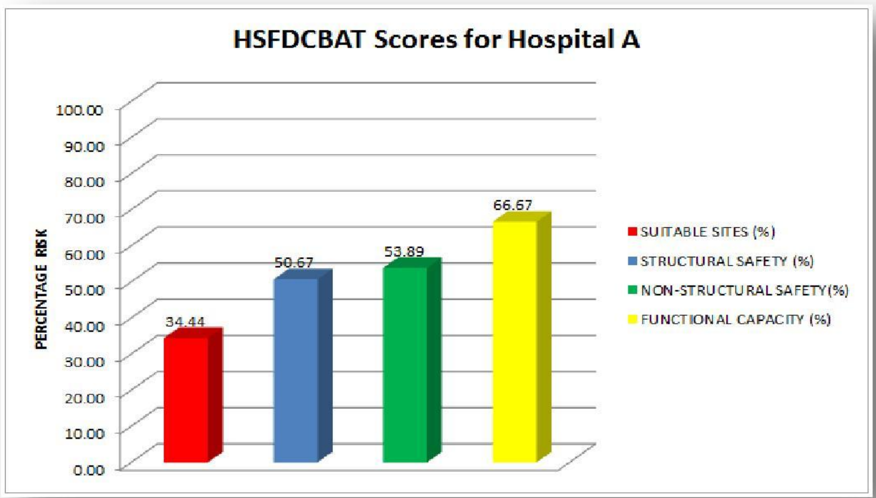

Figure 75 HSFDCBAT Scores for Hospital A

7.1.1 Suitable Sites

Hospital A had a **34.44%** risk for Suitable Sites and its high risk areas include Storm Surge, Fire and Social Phenomena. Being near a river, when the river swells up due to storms, typhoons and torrential rains, the hospital has a high risk of being flooded. Fire is also a concern for the hospital because of inefficient fire exits and non-functional dry stand pipes. For social phenomena, its location being near the plaza and the municipal hall, several cases of untoward incidents have happened within the vicinity of the hospital especially during town fiestas.

7.1.2 Structural

For the structural module**, Hospital A** had a **50.67 %** risk rating. This is mainly because of the high risk areas such as Structural History, Form Irregularities, Adjacent Structures, Continuing Check, As-Built Plans and Permits. The main building of this hospital was built in 1992 and its four-storey annex building was connected to it in 2005, giving it an L-shaped form. This made the hospital’s form more irregular and thus, leaving it more susceptible to lateral forces. On its left side is an adjacent church which clearly didn’t follow the easement regulations in the National Building Code, posing a major threat to the hospital should disasters like earthquake and fire happen.

After the hospital’s numerous renovations and revisions throughout the years, an up-to-date as-built plan is not available in the hospital’s records. Also, it has not been checked yet by ASEP or DPWH representatives through rapid evaluation or any other form of structural assessment.

7.1.3 Non-Structural

For the non-structural module, **Hospital A** has a **53.89 %** risk rating. Areas for concern include Telecommunication Systems, Water Supply System, Fuel Storage, Furnishings and Equipment, Medical and Laboratory Equipment, Fire Protection System, Movement outside the Building, Refuge Rooms, Redundant/Open Spaces and Infection Control.

The hospital is not convinced enough that these architectural elements within their hospital can withstand the damage and destruction brought about by disasters. Its water supply system already has leaks, the reserve storage capacity of the overhead water tanks are not enough in case water supply is cut, fuel storage reserve capacity is not enough for the generators and other equipment, fire protection system is not up-to-date and networked, the dry stand pipe is not functional, entrance to the building is too narrow and ends in a cul-de-sac, the hospital has no refuge rooms and redundant/open spaces big enough to accommodate patients in case there will be an influx of disaster-related victims and because of this, infection control cannot be contained by the hospital. These are just some of the major concerns of the hospital in terms of its non-architectural elements.

7.1.4 Functional

Hospital A has a relatively high **66.67%** risk rating for its functional capacity. High risk areas are the Organization of Hospital Disaster Committee (HDC), Organization of Emergency operations Center (EOC) and Contingency Plan for Medical Treatments in Disasters. This high risk is evident because of the absence of the documents, organizations and plans pertaining to the checkpoints mentioned above. The representative of the hospital said that these are still in process for compliance and are still parts of their future action plans.

7.1.5 Survey

The **Hospital A** representative rated the HSFDCBAT with an effective overall rating of **1.40** (with 1.00 being the highest and 5.00 being the lowest, similar to UP‟ s grading system). The only concern of the user is the occurrence of minor glitches/bugs when the module is being saved. Other than that, the user commended the innovation of the tool, its versatility as well as its ease of use.

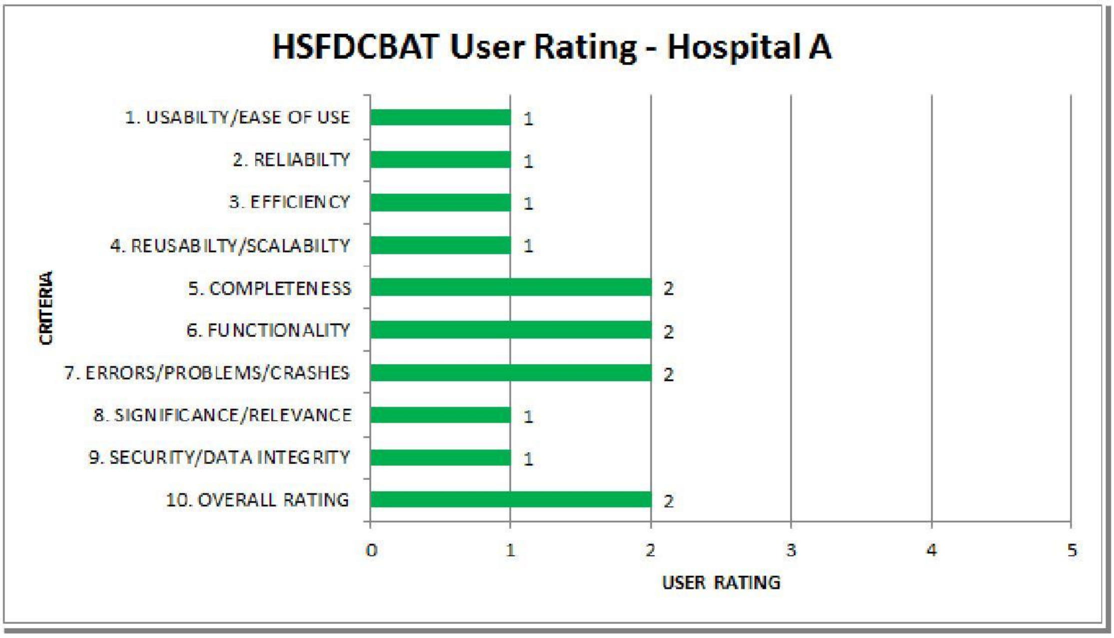

Figure 76 HSFDCBAT User Rating - Hospital A

7.2 Hospital B

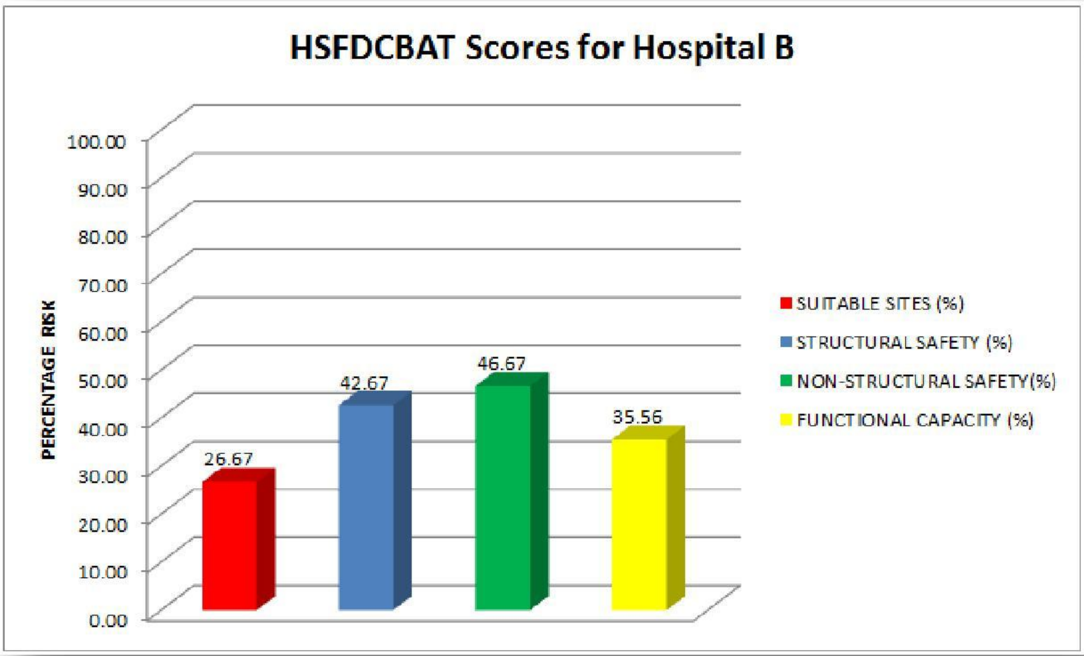

Figure 77 HSFDCBAT Scores for Hospital B

7.2.1 Suitable Sites

Hospital B had a **26.67%** risk for Suitable Sites and its areas for concern include Earthquake, Typhoon, Torrential Rains and Epidemic. The province already experienced a major earthquake in 1990 and this is the main concern for the hospital. Typhoons and torrential rains are also frequently cutting across the region so the threat of floods has always been a cause for alarm. Also, epidemics such as A(H1N1) and Swine Flu have been reported in the area and thus measures are being done to avert these threats.

7.2.2 Structural

For the structural module, **Hospital B** had a **42.67 %** risk rating. This is mainly because of the high risk areas such as Structural Standards, Hospital Size, Foundations, Adjacent Structures and Continuing Checks. Like Hospital A, it has not been checked yet by ASEP or DPWH representatives through rapid evaluation or any other form of structural assessment. The hospital is also surrounded by adjacent structures and buildings that prove to be major threats especially during earthquakes.

For the other areas for concern, the hospital representative was not sure if the foundations for the hospital where sufficient enough to support the building based on the revised structural codes and standards considering its expansion and renovations.

7.2.3 Non-Structural

For the non-structural module, **Hospital B** has a **46.67 %** risk rating. Areas for concern include Telecommunication Systems, Medical Gases, Furnishings and Equipment, Medical and Laboratory Equipment, Movement outside the Building, Refuge Rooms and Redundant/Open Spaces.

Hospital B doesn't have refuge rooms or redundant spaces which are important during disasters. The anchorage for furnishings and laboratory equipment during disasters are also some of the causes for concern as well as the reliability of the telecommunication conduits. Construction materials used based on fire-rated products as advised by the Bureau of Fire Protection (BFP).

7.2.4 Functional

Hospital B has a relatively low **35.56%** risk rating for its functional capacity. Having attended workshops on safe hospitals organized by WHO and DOH, the hospital is already aware of these functional requirements and is already practicing and implementing them. Action plans were developed and then introduced to the hospital management and staff. They already have operational plans for disasters for earthquakes and fire, but for typhoons, it is still in progress. The only concerns for this module are the presence of Epidemiological Surveillance Committee which is not yet fully functional, Transport & Logistics and Highly Infectious Diseases.

7.2.5 Survey

The **Hospital B** representative rated the HSFDCBAT with an effective overall rating of **1.60** (with 1.00 being the highest and 5.00 being the lowest, similar to UP‟ s grading system). Some of the concerns of the user are completeness, functionality and bugs. The significance and relevance as well as the usability of the system were also lauded by the user.

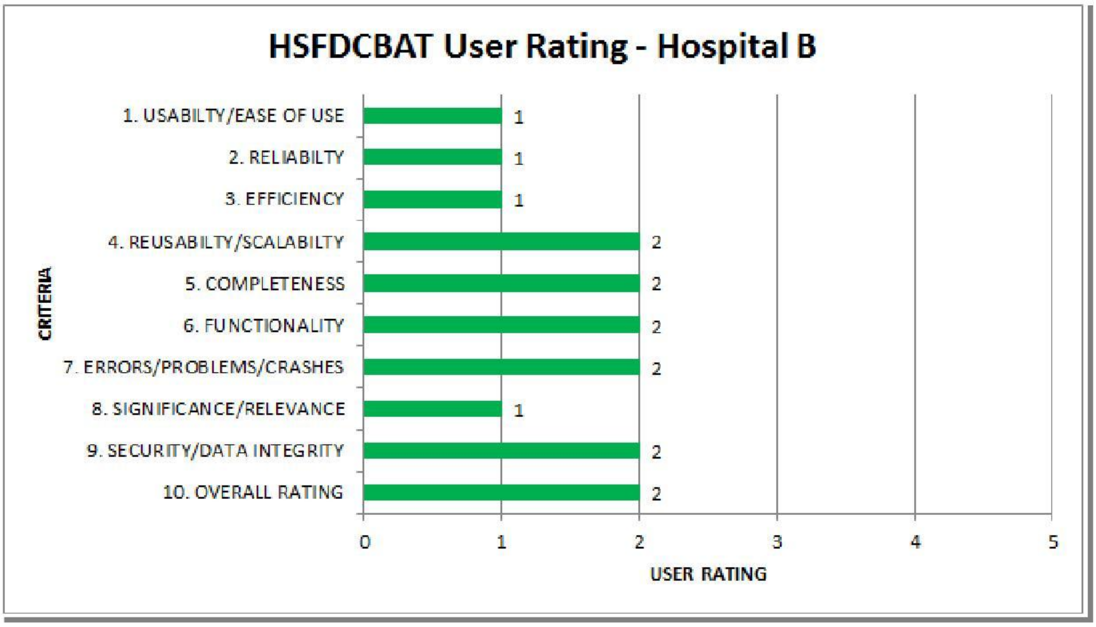

Figure 78 HSFDCBAT User Rating - Hospital B

7.3 Hospital C

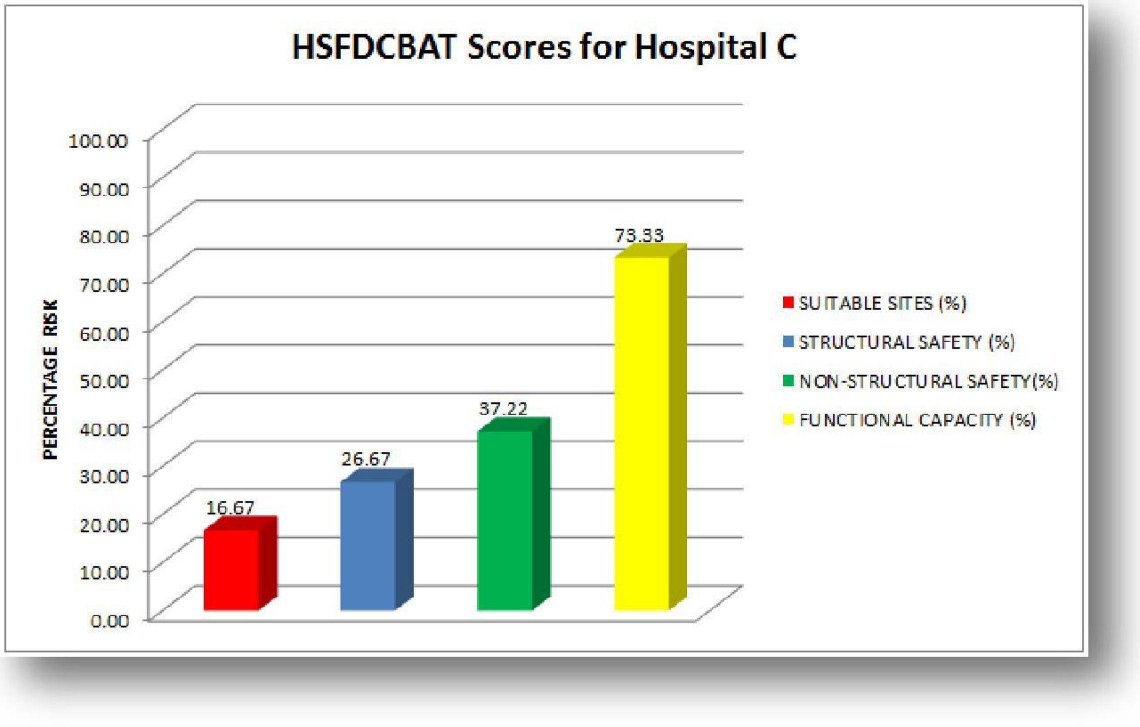

Figure 79 HSFDCBAT Scores for Hospital C

7.3.1 Suitable Sites

Hospital C had a **16.67%** risk for Suitable Sites and its areas for concern from the perception of the hospital representative are Epidemic and Social Phenomena. It can also be noted that Hospital C is within the same location as Hospital A, in the Nueva Ecija Area. So it can also be added that Earthquake, Typhoon and Torrential Rains which cause flash floods in the vicinity are also some points of concern. It can be remembered that on July 16, 1990, Luzon was hit by a 7.8 Magnitude earthquake and Nueva Ecija was one of the most severely affected. On social phenomena, the study showed that patient visitors are usually the cause of problems.

7.3.2 Structural

For the structural module, **Hospital C** had a **26.67 %** risk rating. Similar to the previous hospitals studied, Structural Standards and Continuing Check are the areas of risk for the same reasons. Other areas of concern are Hospital Size and Structural Resilience.

In the study, it was mentioned that cracks are not evident and that there are many revisions but no as-built plan

7.3.3 Non-Structural

For the non-structural module, **Hospital C** has a **37.22 %** risk rating. Areas for concern include Fuel Storage and Water Supply

System. Hospital C also doesn't have refuge rooms or redundant spaces which are noticeably absent in most of the sample hospitals. It can also be noted that the hospital representative claimed that the hospital is ready for fires because it was his expertise, being a former fire safety officer. On the other hand, he admitted that he was not adept with engineering info because he was newly-installed in position and it was not his expertise but he asked the help of other more knowledgeable reference persons in the hospitals.

According to the hospital representative, early on before his time, requirements on safety were not met by the administration. Then they provided secondary exit based on the Bureau of Fire Protection requirements. He also stressed the importance of fire escapes/fire exits.

Other notable points during the assessment regarding non-structural safety were that the open field surrounding the hospital may act as a redundant space during emergencies; main and standby generator with ATS are available; the hospital has a very limited communication network but with internet. The hospital has no cistern tank and the dry stand pipes are not functional but for compliance only. They have two (2) 5000-gallons reserve tank water capacity and 14 drums of fuel reserve. Medical gases have piping and are regularly delivered, consume 1000 tons per month. They are concerned with leaks, polycarbonate roofs and canopies. Parking and ambulance ingress and egress are also a concern. Pest control is being outsourced. Lastly, medical equipment are provided with locks.

7.3.4 Functional

Hospital C has a very high **73.33%** risk rating for its functional capacity. Similar to Hospital A, this high risk is evident because of the absence of the documents, organizations and plans pertaining to the checkpoints such as the Hospital Disaster Committee (HDC) and Emergency Operations Center (EOC) as well as disaster preparedness plans. These are still in process for compliance and are still parts of their future action plans.

7.3.5 Survey

The **Hospital C** representative rated the HSFDCBAT with an effective overall rating of **1.80** (with 1.00 being the highest and 5.00 being the lowest, similar to UP‟ s grading system). Some of the concerns of the user are completeness, functionality and bugs. The significance and relevance as well as the usability of the system were also lauded by the user. Its reliability and some bugs encountered during the assessment were some of the issues raised by the user.

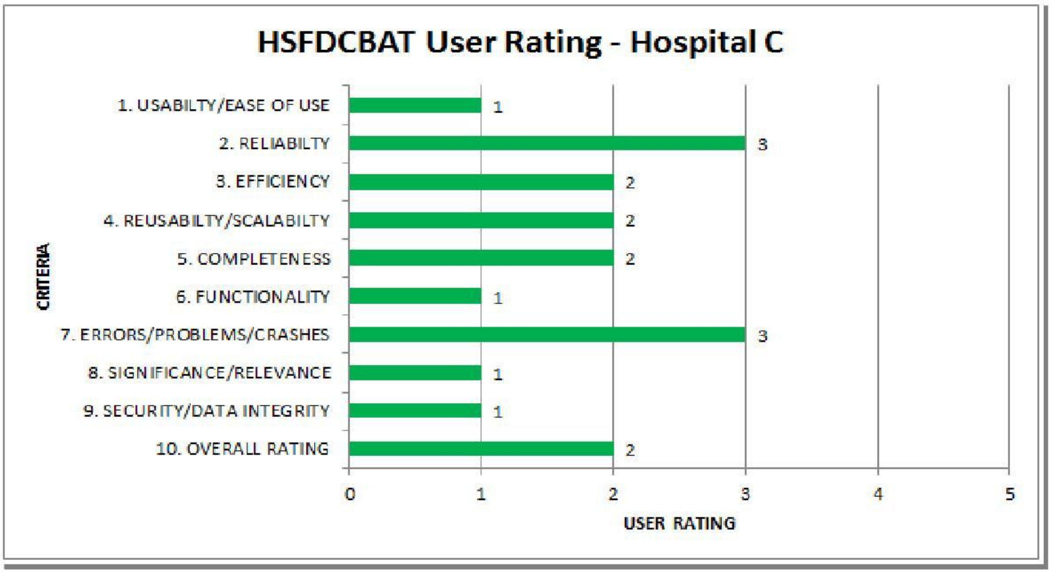

Figure 80 HSFDCBAT User Rating - Hospital C

7.4 Hospital D

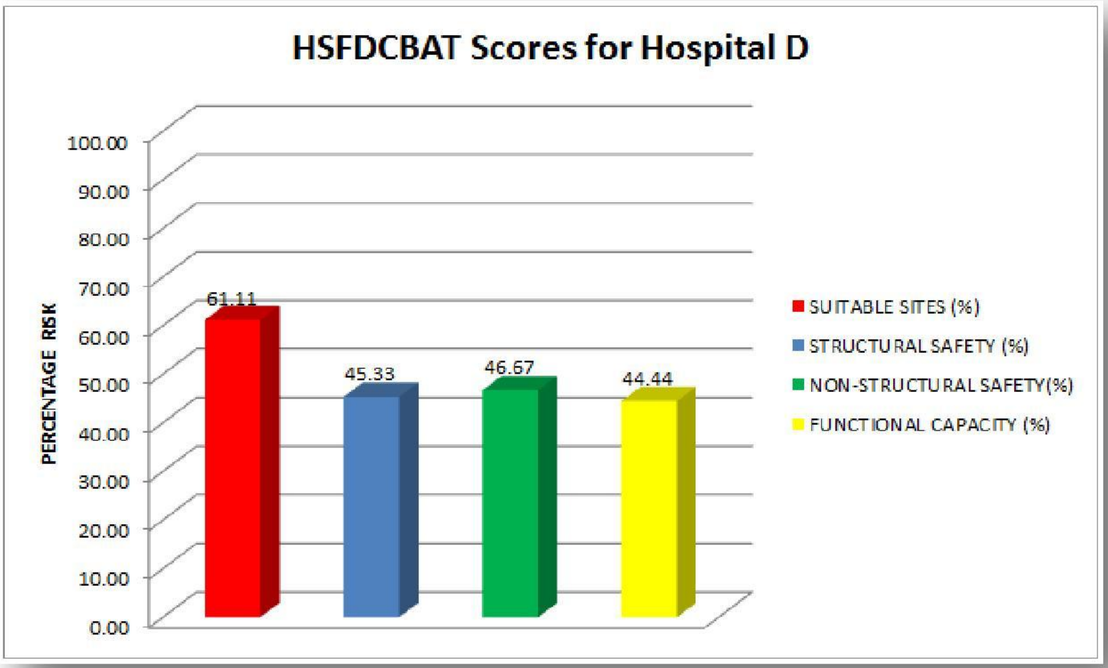

Figure 81 HSFDCBAT Scores for Hospital D

7.4.1 Suitable Sites

Hospital D had a **61.11 %** risk for Suitable Sites. Most of the checkpoints were considered high risk by the hospital representative because of the following explanations:

- Based on Metro Manila Earthquake Impact Reduction Study (MMEIRS), Earthquake: Hospital area is at High Risk, Pasig at Highest Risk
- Typhoons: whole of Philippines at risk with typhoon
- Tsunamis, 5-6 km from Manila Bay, at risk but not much impact
- No liquefaction potential for hospital foundation
- Epidemic, high risk – hospital because of influx of patients with diseases
- Fire – highest risk because of several occurrences of incipient fires in the hospital
- Hazardous wastes - medium risk because of chemicals in hospitals
- Hazardous material spills – high risk
- Terrorism – Explosion, bomb threats, security concerns because of VIP patients

7.4.2 Structural

For the structural module, **Hospital D** had a **45.33 %** risk rating. These were the points raised during the assessment to explain the score:

- Hospital is certified by structural engineers
- No history of structural defects
- Retrofitted old building to meet building code, fire code, structural code, new building was occupied 2008, complies with most of codes
- Minimal cracks
- Irregular shaped with two towers
- Tower 1, 10 floors, Tower 2, 8 floors with 5 basements for parking
- Continuing check – for scheduling
- As built plans –exist
- Permits – PME permit, only Fire Permit is available.

7.4.3 Non-Structural

For the non-structural module, **Hospital D** has a **46.67 %** risk rating. These were some of the points raised by the hospital representative:

- Electrical: 100% back-up system
- Telecom: risk with movement of conduit systems during disasters
- Water: standby water supply system (deep well)
- Fuel storage: 9 days supply, though hospital is near Pandacan area
- Medical gases: 1 week supply of reserve medical oxygen (supplied) and back-up tanks.
- Stable HVAC systems
- Furnitures are movable, Anchored equipment
- Fire protection system not yet fully networked, partial compatibility with other systems. The hospital has no ramp, but as per Bureau of Fire, compartmentalization was used to compensate. In less than 2 years, 4 incipient fires (beginning stage) in the hospital from records of Bureau of Fire.
- Photoluminiscent lights, 100 % backup power
- Refuge rooms – two towers, similar to Petronas Towers in Malaysia
- Redundant space – parking area, agreement with open lot owner
- Strict infection control and pest control

7.4.4 Functional

For the functional module, **Hospital D** has a **44.44 %** risk rating. These were some of the points raised by the hospital representative:

- The hospital is very much prepared when it comes to functional. It has a fire brigade & disaster preparedness committee
- Operational plans are contained in manual
- The hospital has third party ambulances (AeroMed) because according to them, it is difficult to maintain motor pool

- The hospital has contingency plans – tie up with Red Cross, SHAP, tie up with LGU‟ s
- availability of medicines – existence of warehouse
- planning phase in coordination with infection control center
- All staff were trained to respond to emergencies
- Hospital was already surveyed by DOH, headed by Dr. Pesigan of the Emergency and Humanitarian Action (EHA) unit of the WHO Regional Office for the Western Pacific (WPRO) \

7.4.5 Survey

The **Hospital D** representative rated the HSFDCBAT with an effective overall rating of **2.10** (with 1.00 being the highest and 5.00 being the lowest, similar to UP‟ s grading system). Some of the concerns of the user are completeness, functionality and relevance. General comments were to make the tool more detailed and more specific. Security of the tool and the readily available reports as well as the recommendations was commended by the user.

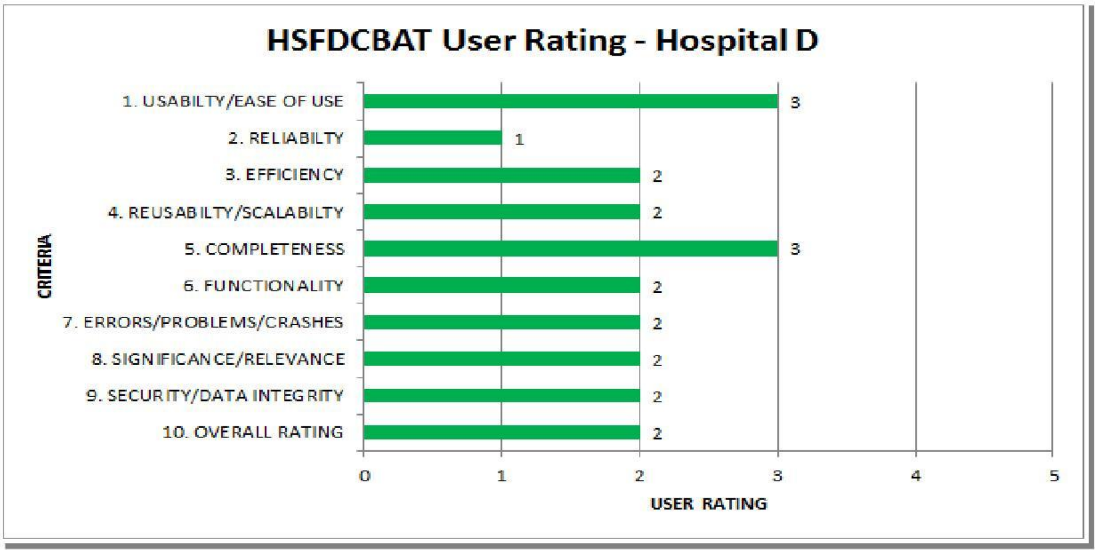

Figure 82 HSFDCBAT User Rating - Hospital D

7.5 Comparative Analysis

COMPARISON AREAS	Hospital A	Hospital B	Hospital C	Hospital D
SUITABLE SITES (%)	34.44	26.67	16.67	61.11
STRUCTURAL SAFETY (%)	50.67	42.67	26.67	45.33
NON-STRUCTURAL SAFETY(%)	53.89	46.67	37.22	46.67
FUNCTIONAL CAPACITY (%)	66.67	35.56	73.33	44.44
SURVEY RESULTS	1.40	1.60	1.80	2.10
BED CAPACITY	40	127	150	497
OCCUPANCY RATE (%)	85.00	70.00	60.00	84.00
AREA (SQ M)	2000	5400	4800	30000
SHAPE	L-SHAPE	REGULAR	REGULAR	COMBINATION
SIZE	SMALL	MEDIUM	MEDIUM	LARGE
NO.OF STOREYS	4	2	4	10
YEARS OF EXISTENCE	19	33	15	42
LOCATION	Tarlac	Nueva Ecija	Nueva Ecija	Metro Manila
DOH/WHO WORKSHOP (Y/N)	N	Y	N	Y
RENOVATION (Y/N)	Y	Y	Y	Y
EXPANSION (Y/N)	Y	Y	Y	Y

Figure 83 Tabulated Comparative Analysis of Hospitals

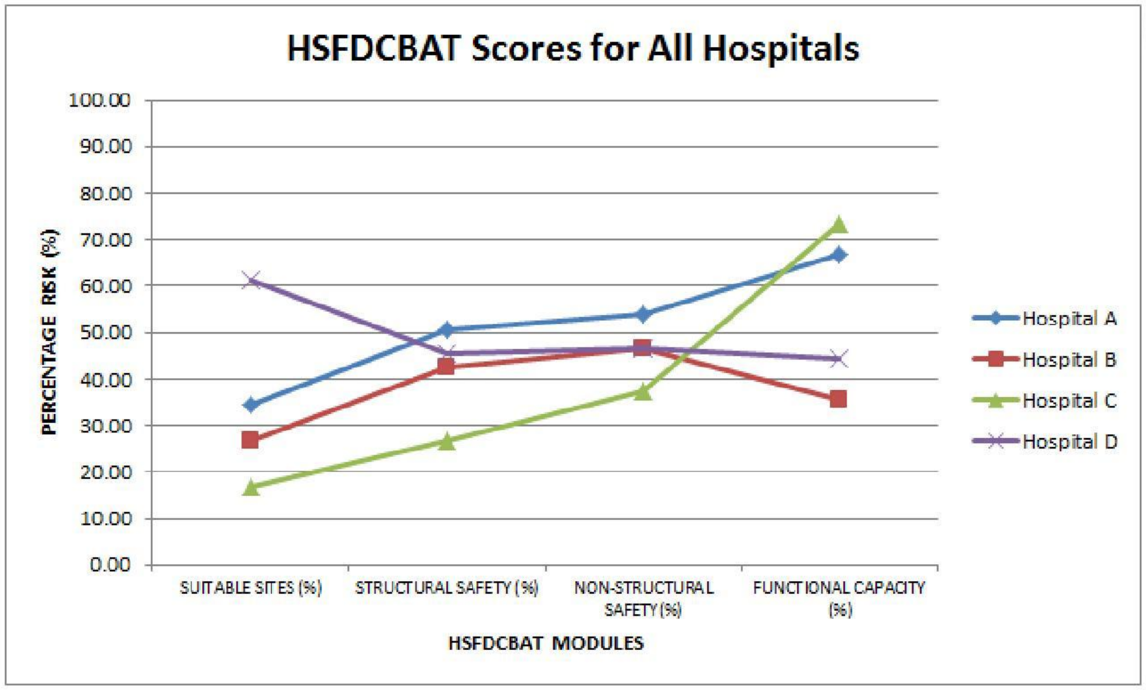

Figure 84 HSFDCBAT Scores for All Hospitals

The study highlighted the common high risk areas for all the hospitals based on their HSFDCBAT scores. For the Suitable Sites module, the common high risk areas are EARTHQUAKE, TYPHOON, TORRENTIAL RAINS, STORM SURGE, SOCIAL PHENOMENA and EPIDEMIC. The last checkpoint mentioned was evident among all hospitals, showing that they are all highly at risk when an epidemic occurs after a disaster.

For the Structural Safety module, high risk areas are different for each hospital with ADJACENT STRUCTURES and CONTINUING CHECK having the most vulnerability. Some of the other checkpoints in high risk that are distributed among the health facilities are STRUCTURAL HISTORY, STRUCTURAL STANDARDS, CONSTRUCTION MATERIALS, FORM IRREGULARITIES, AS-BUILT PLANS and PERMITS. This shows the substantial concern of the health facilities regarding their structures. Some key points raised here were retrofitting of their old buildings as well as the needed funds for its implementation.

For the Non-Structural module, the TELECOMMUNICATION SYSTEMS, anchorage of FURNISHINGS & EQUIPMENT, MOVEMENT OUTSIDE THE BUILDING, FIRE PROTECTION SYSTEM, REFUGE ROOMS, REDUNDANT / OPEN SPACES are the high risk checkpoints. The last two areas showed that the absence of accessible areas during disasters is a foremost concern for most of the hospitals.

High Risk Functional Capacity is evident for Hospitals A & C because of non-existent or in-process Hospital Disaster Committee and Emergency Operations Center. TRANSPORT AND LOGISTICS, absence of EPIDEMIOLOGICAL SURVEILLANCE COMMITTEE and concerns on HIGHLY INFECTIOUS DISEASES during and after a disaster complete the high risk areas for their Functional Capacity.

7.5.1 Safe Score vs. Bed Capacity

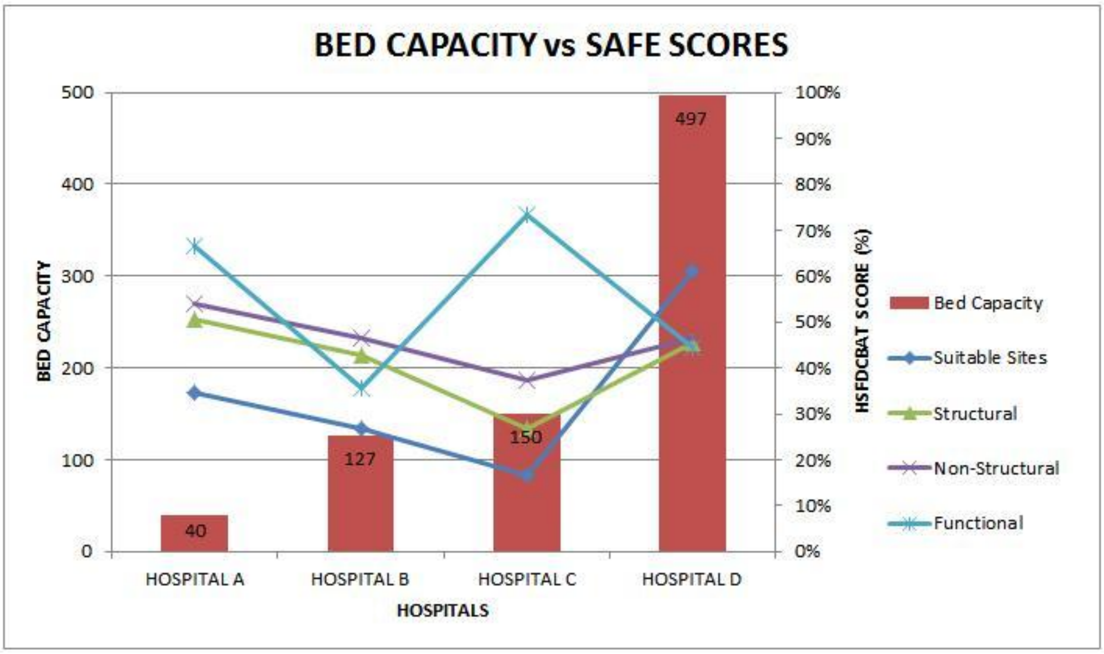

Figure 85 Safe Score vs Bed Capacity

The study showed that for Hospital A, Hospital B and Hospital C, their Structural, Non-Structural and Suitable Sites scores are inversely proportional with the health facility's bed capacity. As the hospital bed capacity increases, their HSFDCBAT scores decrease as well.

7.5.2 Safe Score vs Floor Area

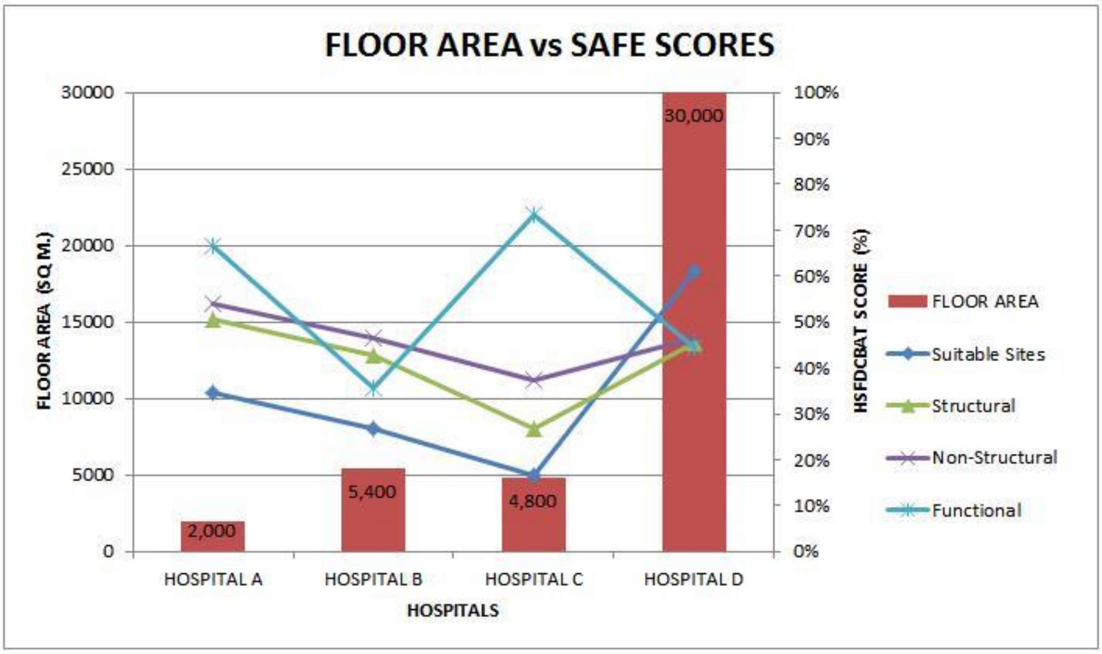

Figure 86 Safe Score vs Floor Area

No conclusion can be derived from this relationship because the trend of the floor area is also varying compared to the HSFDCBAT scores for all modules so pinpointing a direct relationship between these two factors would be non-conclusive, at least for this study.

7.5.3 Safe Score vs Occupancy Rate

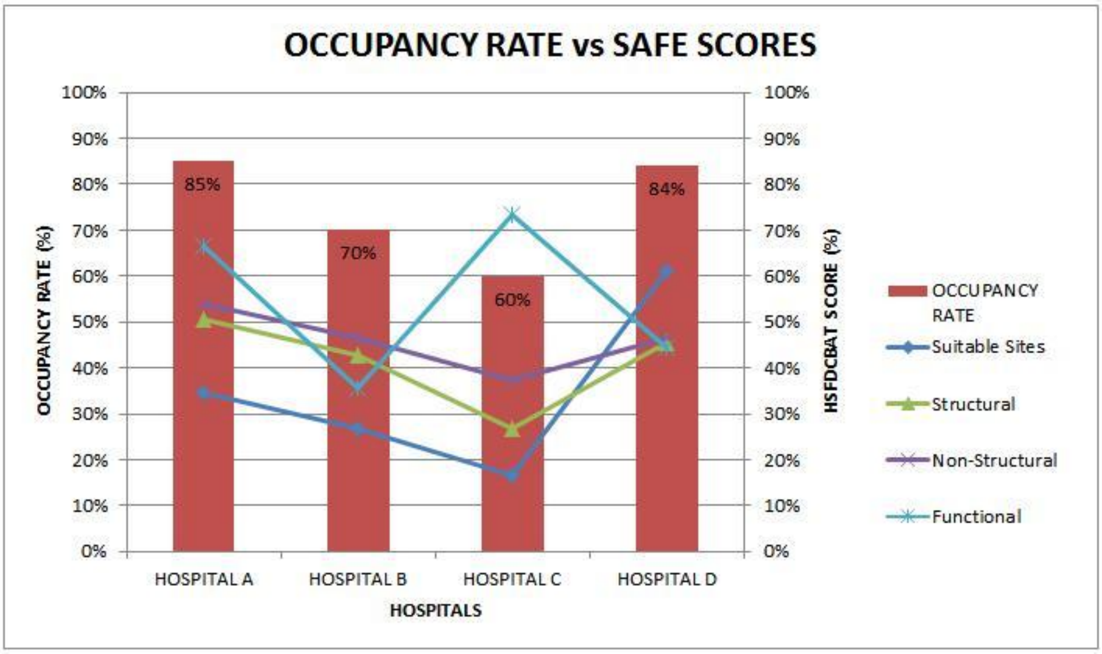

Figure 87 Safe Score vs Occupancy Rate

The study showed that for all the hospitals, the occupancy rates of the building follows the trend of their Structural and Non-Structural components. The trend line was also evident for Suitable Sites except for Hospital D. This may mean that patient occupancy depends on the health facility's structural and architectural (non-structural) soundness as well as if it's at a suitable location.

7.5.4 Safe Score vs. Max. No. of Storeys

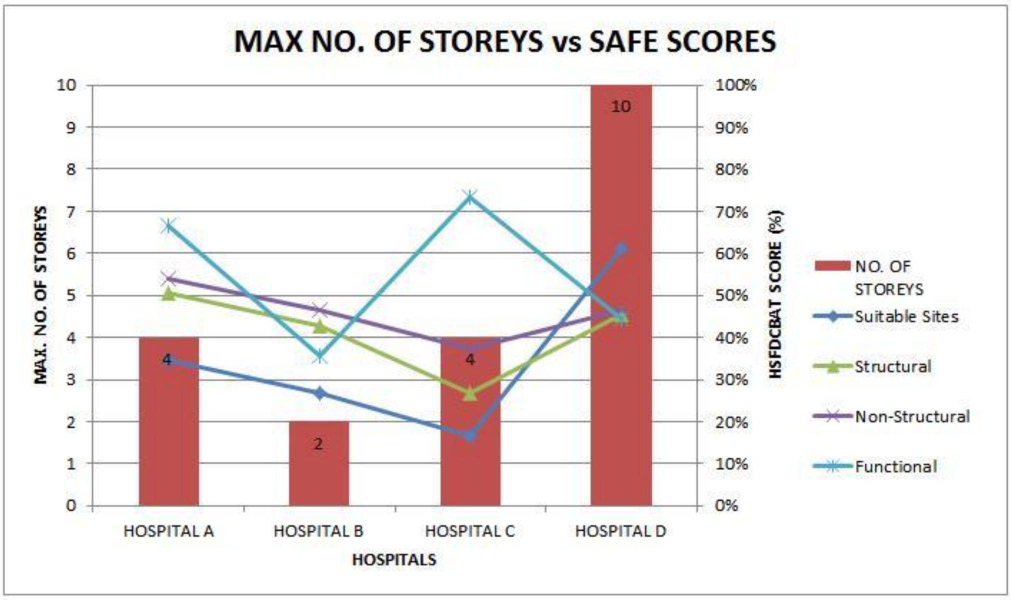

Figure 88 Safe Score vs Maximum No. of Storeys

Hospital A and Hospital C have consistent trend lines for Structural and Non-Structural Capacity with both having four (4) storeys. HSFDCBAT Scores for the health facilities are 50.67% and 53.89% for Hospital A and 26.67% and 37.22% for

Hospital C. They have the same maximum floors so this physical aspect (height) of the structure shows a relationship with the Structural and Non-Structural aspects of the health facilities.

7.5.5 Safe Score vs. Years of Existence

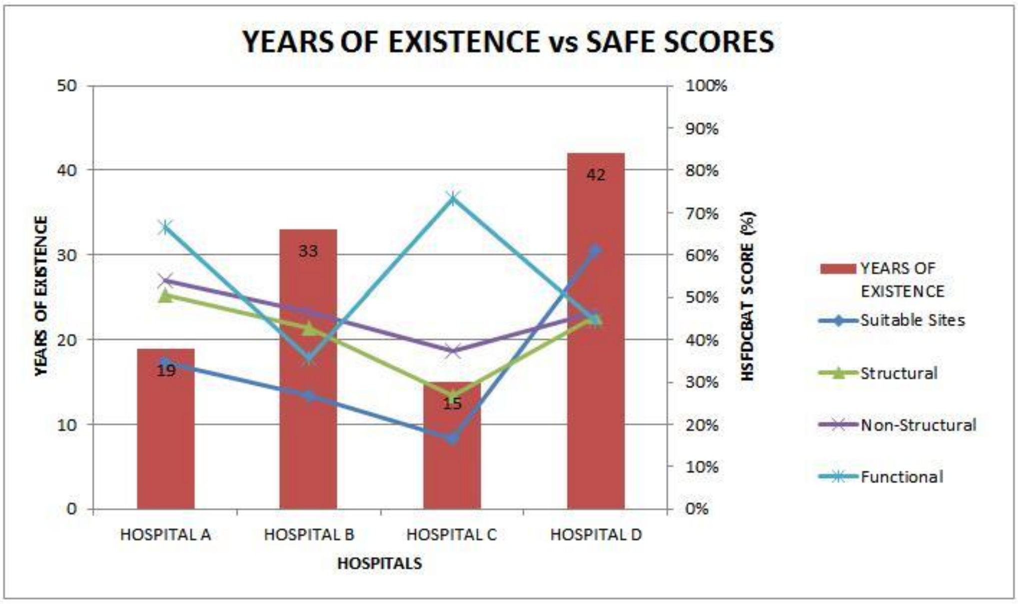

Figure 89 Safe Scores vs Years of Existence

Hospital A and Hospital C have consistent trend lines for Structural and Non-Structural Capacity having been constructed 19 years and 15 years ago respectively. HSFDCBAT Scores for the health facilities are 50.67% and 53.89% for Hospital A and 26.67% and 37.22% for Hospital C. They have about the same age so the deterioration as well the expansion and renovation that is closely related with the Structural and Non-Structural modules are evident in this graph.

7.5.6 Safe Score vs. Relative Size & Shape

The study showed that both Hospital B and Hospital C, having a medium sized foot print and regular shape have the lowest Structural Safety risk rating with scores of 42.67% and 26.67% respectively. The reason for this may be the basic structural principle that the regularity of size and form will produce less structural stresses when lateral forces and other forces for that matter act on them.

7.5.7 Safe Score vs. Location

The study showed that the health facilities from Nueva Ecija have the lowest risks rating on the Suitable Sites module. Hospital B has a 26.67% score while Hospital C has a 16.67% score on this module. Hospital A in Tarlac also has a relative low risk rating of 34.44% but not as low as the ones in Nueva Ecija. This could be due to the fact that these hospitals are located in the Central Luzon Area where natural risks are not that high. Hospital D has a relatively high risk of 61.11% mainly because of its proximity to the West Valley Fault. Location of the hospital can be an important aspect in its disaster-readiness because the conditions and environment on where it is situated defines what type of disasters the health facility will be susceptible to.

7.5.8 Safe Score vs. DOH Workshop

The study showed that Hospital B and Hospital D, who both attended the WHO/DOH-HEMS workshop on Hospitals Safe from Disasters have the lowest risks on the Functional Capacity Module with scores of 35.56% and 44.44% respectively. This is due to the fact that the requirements for the Functional Capacity of the hospital were thoroughly discussed in those workshops so the planning and implementation of checkpoints like the Disaster Management Committee and the Emergency Operations Center were effectively delegated.

7.5.9 Safe Score vs. Renovation/Expansion

No conclusion can be derived from this relationship because all the hospitals underwent renovation and expansion in recent years but they have varying HSFDCBAT scores for all modules so pinpointing a direct relationship between these two factors would be non-conclusive, at least for this study.

7.6 HSFDCBAT and the Localized Hospital Safety Index

7.6.1 Suitable Sites

From the interviews and outputs of the study, it was established that for Suitable Sites, hospital owners and developers should keep in mind that before building new hospitals, it should be ascertained that a structure is away from active faults and flood-prone areas. They have to make sure that the design is feasible, within the budget required and planned for the long-term. The risk vulnerability of each hospital should also be mapped to arrive at solutions for their specific risk.

For existing hospital buildings, a detailed evaluation should be conducted to determine whether it complies with the codes as well as the risk requirements. From this evaluation, an exclusion criterion for when to retrofit or relocate should be created because of hospitals serving as catchment areas during disasters. Relocation could deprive persons in those areas of medical services but if the risk is very high, relocation may be the only option.

7.6.2 Structural Safety

The study also brought about hospital administration concerns regarding Structural Safety. One of the legitimate concerns is the absence of structural certification from qualified structural engineers from either the Association of Structural Engineers of the Philippines (ASEP) or the Department of Public Works and Highways (DPWH) who must also be accredited by the Department of Health (DOH).

Some of the action plans in response to these concerns as suggested by the hospital representatives are to request and invite qualified structural consultants for their proposal and costing for the project and to request for structural plan and structural analysis computation. After consulting the engineers, request for funds and the request to fast-track the procurement procedure for retrofitting should then be part of their next steps. This is similar to the situation of government hospitals who are more concerned about structural and retrofitting (i.e. costs, funding, government support, etc.) when it comes to the structural disaster-readiness of the hospital.

The improvement of existing facilities, risk reduction in design and construction of new facilities, as well as the search for legislation and financial measures to retrofit critical facilities are also some of the other major concerns.

Since retrofitting is the most prevalent solution seen for structural safety concerns in hospitals, health facility engineers suggested furthermore that more detailed assessments of hospital structural risks should be made to arrive at feasible retrofitting solutions. In line with this, the drafting of generic terms of reference for structural assessment of hospitals as well as post-emergency rapid assessments should be done. Currently, a Memorandum of Agreement (MOA) is already in place and structural engineers are already being tasked in response to these measures.

Some of the other action plans suggested from this study in terms of government action, on the other hand, are to prioritize hospitals with higher risk scores in retrofitting, to raise awareness of the importance of retrofitting to policy makers and to disseminate public warnings on unsafe buildings. In terms of engineering and technologies, the funding and installation of accelerometers to assess seismic building performance is one of the suggestions being asked from the government. In terms of permits and compliance, old buildings lack space to comply with some building code requirements so alternative solutions are being sought. One of the problems is that hospitals are built without DOH approval. Authorities should adhere to existing policies and enforce it. Sanctions should be imposed on non-compliant institutions.

7.6.3 Non-Structural Safety

The study showed that based on the HSFDCBAT users‟ interviews, Non-Structural safety is easier to comply with as opposed to structural safety because most of these are already complied with and are being implemented in compliance with the National Building Code as well as the DOH requirements. These are more visible and are easier to mitigate since it is a major part of the Facilities, Engineering and Maintenance Head’s job responsibility in his day to day tasks.

7.6.4 Functional Capacity

Essentials during disaster emergencies are buildings (location, design specifications, materials), patients (increase during disasters), hospital beds, medical and support staff, equipment and facilities and basic lifelines and services. During disasters, demand for emergency care increases, while availability and supply of necessities and services decreases.

It was also noted during the interviews that there are more garbage, corpses, infections and diseases after a disaster and understandably so. This is one of the main reasons why a disaster management committee, an emergency operations center and operational plans for disasters are vital points in Functional Capacity.

7.7 HSFDCBAT Score

The study showed that data gathered from the sample hospitals using the HSFDCBAT served as a wake-up call and an eye-opener for the hospital representatives involved in the research study. Seeing numbers as ratings for the disaster-readiness of their hospitals made an impact on how they viewed the importance of being ready for disasters. Having a safe score report and recommendation report immediately after the assessment using the tool encouraged them as heads of their teams or departments to be proactive on the action plans to mitigate the checkpoints which were flagged as high risk areas.

The study also showed the common high risk areas among the health facilities based on their HSFDCBAT scores. In terms of location, being in Luzon where earthquakes, typhoons, storm surges and torrential rains are frequent, this was apparent as having the high risk checkpoints for all the sample hospitals although social phenomena and epidemics also passed as areas for concern.

Structurally, hospitals have different concerns. Most of the checkpoints in the module like structural history, structural standards and as-built plans and permits were all distributed across the lot as the major concerns for the hospitals. The most common high risk areas for them are adjacent structures and continuing check from ASEP and DPWH. Retrofitting as well as funds for it was also a major point of discussion during the assessment.

Telecommunication systems, equipment, movement outside the building and fire protection are causes of concern for the hospital representatives in terms of non-structural safety. But the absence of refuge rooms and redundant/open spaces are the most obvious high risk checkpoints among the sample hospitals.

Finally, the absence of Hospital Disaster Committee and Emergency Operations Center as well as operational plans for disasters highlights the Functional Capacity module. Other concerns are transport and logistics, absence of epidemiological surveillance committee and concerns on highly infectious diseases during and after a disaster.

7.8 User Satisfaction Score

Overall, the hospital representatives who used the HSFDCBAT Tool gave good reviews for the system. There were mixed reactions on the use of the tool but most of them are positive. The system had an average rating of **1.73**, with 1.00 being the highest, and 5.00 being the lowest, similar to UP‟ s grading system which is a relatively high rating. Security of the tool, together with the readily available reports and the recommendations was commended by the user. Also, the significance and relevance as well as the usability of the system were also lauded by the user. Other facets of the HSFDCBAT that were commended by the user are the innovation of the tool and its versatility and customizability.

Some of the concerns of the users, though, are completeness, functionality and relevance. General comments were to make the tool more detailed and more specific. There were also issues raised on errors or bugs encountered but these were just minimal. Concerns were also raised on the occurrence of minor glitches/bugs when the module is being saved and the comprehensiveness of the report.

7.9 Future Releases Of HSFDCBAT

For future releases of the HSFDCBAT, experts for each field/module can be surveyed and consulted so that the importance and relevance of each checkpoint can be correctly assessed and combined, and then come-up with mathematical models which will eventually result into accurate weight assignments. For now, all checkpoints are assigned a weight = 1.0, meaning all checkpoints have the same baseline weights. Involvement of these professionals is crucial in establishing these weight assignments. (An example of this would be to rate a checkpoint from 1 to 10 on what is more important/relevant based on the perception of the expert. But the concern here is to get a considerable sample population for the experts such as structural engineers, architects, doctors, hospital administrators, etc. which the researcher was not able to do in this study, thus the weight of 1.0 for all checkpoints. This would add another step to the methodology). The importance of checkpoints is based on experience, expertise and significance to the hospital site.

By using HSFDCBAT, designers will be guided and the design criteria will be more detailed in terms of making the hospital disaster-ready. Results are empirical, quantifiable and similar to expert systems. It can be noted from the research study that findings and analysis can be affected by perception of the interviewee, consciousness to the presence of the researcher and the interruption of the researcher from time to time.

HSFDCBAT can have commercial value (i.e. Hospitals, DOH, etc) and DOH can be the primary beneficiary and specific recipient of this system. It should be emphasized that the HSFDCBAT is for academic purposes only and that the quality of data being divulged by hospital representatives vary.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusion

The Hospitals Safe From Disasters Computer-Based Assessment Tool (HSFDCBAT) took off from existing assessment tools developed by PAHO/WHO and the DOH and addressed the need for a concise and quantifiable localized hospital safety index here in the Philippines whose primary goal is hospital disaster-preparedness and disaster-resiliency.

The execution of HSFDCBAT on selected private tertiary hospitals showed the disaster-readiness of these hospitals in terms of their location, structural safety, non-structural safety and functional capacity. Each health facility‟ s strengths and weaknesses were emphasized based on their scores acquired from the tool. The study showed that data gathered from the sample hospitals using the HSFDCBAT served as a wake-up call and an eye-opener for the hospital representatives involved in the research study. Seeing numbers as ratings for the disaster-readiness of their hospitals made an impact on how they viewed the importance of this initiative. Having a safe score report and recommendation report immediately after the assessment using the tool encouraged them as heads of their teams or departments to be proactive on the action plans to mitigate the checkpoints which were flagged as high risk areas.

The comparative analysis of the sample health facilities with the aid of the HSFDCBAT showed the common high risk areas among the health facilities based on their HSFDCBAT scores. Relationships between these scores and different aspects of the hospitals such as bed capacity, occupancy rate, location, trainings as well as their physical and structural characteristics were also established.

The applicability of such a tool in producing potential results which merit the same effects as the Hospital Safety Index initiative and the acceptability of such a disaster-readiness tool to the users in an effort to advocate safe hospital design and construction was also established from user satisfaction survey included in the HSFDCBAT.

The primary goal of HSFDCBAT is for hospital disaster-preparedness. Attaining the goal of safe hospitals requires the combined effort of all concerned agencies. Compared to other assessment tools, it is possible that they will have similar results but the difference is in the process and in the time these data were acquired. Aside from this, the potential in which these data can be analyzed would cover a lot more ground because of the filtering capability of the system and since all the data for all the hospitals are stored in a database. Time element of HSFDCBAT assessment and implementation of recommendations are very crucial based on the fact that much more can be improved with regards to hospitals safe from disasters.

8.2 Recommendations

For future releases of the HSFDCBAT, provisions for Green Hospitals can be added as another module. It should be incorporated in the Hospital Management System (HMS) for efficient data management. Provisions for HSFDCBAT to be web-based for further expansion and accessibility to other hospitals thru the web would also be beneficial to the users.

Also, other recommendations for the HSFDCBAT tool are to include specific Hospital Capacity details in the General Information module. Icons should be used and more “Infographics” should be incorporated in the system to have a more visual rather than text-based interface. In terms of the checkpoints, other disasters like ones caused by heat wave and extreme temperatures should also be considered.

In disaster mitigation, some key recommendations are to increase public awareness, have better warning systems, and better urban planning and facilities management.

8.3 Areas for Further Study

Areas for further study include some of the items which were discussed in the scope and limitations. The weighting system of HSFDCBAT, data from insurance companies and data from ISO certified hospitals can be considered. Experts from their respective fields can be gathered to assess which checkpoints are important and which can be given higher weight equivalents to give a much more comprehensive HSFDCBAT score.

Arrangements with insurance companies and ISO certification firms or ISO-certified hospitals can be made to gather data concerned with the disaster-readiness of hospitals which were not collected in this research because of confidentiality and proprietary concerns. Data gathered here can be compared to the data within the HSFDCBAT for further improvement based on their existing baselines and guidelines.

Lastly, comparative analysis can be further expanded to other types and other levels of hospital to have a wider range of data. Government hospitals would be a good jump off point for further studies in the utilization of the HSFDCBAT tool as a disaster-readiness assessment tool.

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STUDY ON THE RELATIVE IMPORTANCE OF GREEN BUILDING ATTRIBUTES IN PHILIPPINE URBAN SETTING USING ANALYTICAL HIERARCHY PROCESS

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Abstract: Along with the increase in the construction of buildings and infrastructure comes the inevitable adverse environmental effects. These effects are evident throughout the life cycle of a building from construction until its eventual closure and decommissioning. Green building practices seek to address these unwelcome environmental impacts by promoting environmentally responsible construction practices and building schemes that reduce the carbon footprint through energy and resource efficiency. LEED, an internationally recognized green building rating system, and BERDE, a locally developed one based on LEED, served as benchmarks for this study. The different green building attributes were identified and evaluated for relative importance using analytical hierarchy process. Respondents come from four distinct groups: engineers, architects, urban planners and end users. Energy and atmosphere, water efficiency and sustainable sites were the three most important green building attributes based on the survey responses while management and operation improvements, transportation and waste management practices figured in the bottom of priorities. Urban planners gave sustainable sites the biggest weight while the three other sectors tagged energy efficiency as the most important parameter. On a pie of 100, engineers would give a more or less equal points for the different attributes while the end-users would allot big fractions for energy and water efficiency and indoor environmental quality. This study finds its niche in the development of a locally calibrated green building rating system for the Philippines.

Key words: Green building, analytical hierarchy process

1 INTRODUCTION

1.1 Background of the Study

Buildings and infrastructure have inevitable adverse effects on the natural environment. Effects range in scale from local, such as displacement of ecological habitats, to global, such as greenhouse gas emission ultimately leading to global warming and climate change. Various effects arise throughout the life cycle of a building, from construction to operation and up to its eventual closure and decommissioning. Construction and maintenance impacts are mainly brought about by the consumption of natural resources. The operation of such, on the other hand, may also result to pollutants emission both directly and indirectly. Green building practices and technologies seek to address these foreseeable adverse environmental effects

The United States Environmental Protection Agency (2012) defines green buildings as the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and demolition. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building.

A sustainable green building can save our natural resources by reducing environmental impacts, lowering transportation costs, and decreasing water consumption. Not only do green buildings have environmental benefits, but they also have economic and social benefits. Green buildings create jobs, inspire growth and innovation in the local community, enhance occupant health and comfort, maintain a healthier indoor environment and air quality, minimize strain on public infrastructure and improve overall quality of life. Green buildings also have economic benefits. They reduce operating costs, improve occupant productivity, and enhance profits. Therefore, green buildings have the power to change our way of life and transform the future by being sustainable today.

1.2 Green Building Rating Systems

Leadership in Energy and Environmental Design (LEED), the most popular of the green building rating systems, was developed in the United States of America but is used internationally. Different building types in various places, however, have unique design and efficiency needs depending on their function and exposure to climate. The Philippine Green Building Council (PHILGBC) saw the need to find a viable and locally applicable solution that will help promote environmental conservation and protection in the Philippines. Hence, Building for Ecologically Responsive Design Excellence (BERDE), was developed. BERDE was designed to measure the environmental performance of buildings. According to PHILGBC, BERDE is a tool to measure, verify and monitor the environmental performance of buildings. It is consensus driven and was developed through a multi-stakeholder consultation and collaboration process. The certification is credible, unbiased and impartial because it is achieved through a third party process in line with international standards.

BERDE was developed using the United Nations Sustainable Development Indicators of Sustainable Development and other existing international green building tools including LEED by the United States Green Building Council (USGBC), Green Star by the Green Building Council of Australia (GBCA) and BRE Environmental Assessment Method (BREEAM) by the United Kingdom Building Research and Establishment (BRE). BERDE formulated two technical manuals, BERDE for New Construction and BERDE for Existing Buildings. The study conducted in this research will be patterned with the latter.

Furthermore, PHILGBC (2011), in its technical manual states that, BERDE was designed to certify the sustainability of ongoing operations of existing buildings. Buildings such as offices, retail and service establishments, institutional buildings (i.e. libraries, schools, etc.), hotels, as well as residential buildings (of four or more habitable stories) are eligible for certification. BERDE encourages owners and operators to implement sustainable practices and reduce the environmental impacts of their building.

The study conducted also uses the LEED 2009 manual for Existing Buildings Operations and Maintenance. In the USBGC (2009) technical manual, LEED 2009 for Existing Buildings is described as a set of performance standards for certifying the operations and maintenance of existing commercial or institutional buildings, and high-rise residential buildings. It was created to promote environmentally sound practices in existing buildings. As of 2013, there are five LEED-certified buildings in the Philippines, namely: Asian Development Bank, Nuvali One Evotech, Shell Shared Services Office, and Texas Instruments in both Baguio and Clark.

In 2009, the Quezon City Government passed its Green Building Ordinance No. SP-1917 (QCGBO). According to the Primer on the Green Building Program of Quezon City (2009), “It requires the design, construction or retrofitting of buildings, other structures and movable properties to meet minimum standards of a green infrastructure, providing incentives thereof and for other purposes.” Those who are planning to construct new buildings or retrofit existing structures in Quezon City are required to comply with the Implementing Rules and Regulations (IRR) of the Green Building Ordinance. The Quezon City Green Building criteria have specific mandatory requirements for a building to be considered green. These include specific actions undertaken for site sustainability, energy efficiency, water efficiency, materials and resources, indoor environment quality, sewage treatment plant, and for transportation.

The LEED, BERDE and QCGBO rating systems were created on the premise of the available technologies and innovations in the particular criteria. Having more of these advancements contributes to a bigger contribution to the weight appropriated to a particular criterion. The technical manuals of LEED and BERDE indicate the technologies available for use in their respective countries; it can be observed that more are available for LEED than there are for BERDE, which is an indication of the lagging of the Philippines compared to the United States and other first world countries in terms of these technologies for green building. On the other hand, an importance-based type of rating system is reliant on the opinions and needs of those who will use these green structures and systems. For a third world country like the Philippines, it is more beneficial to have this type of system due to the unavailability and/or costliness of said technologies. Implementing a needs-based system will surely encourage designers, as well as users to apply these green building practices in the Philippines. The structures would then, not have to suffer receiving lower ratings for not being able to comply with the preferred technological implements.

1.3 Problem Statement

There is a need for a green building rating system that is tailor fit for the Philippine setting, with each factor rated and calibrated for its local importance rather than on the availability of existing and practicable technologies. This study intends to achieve a scientific determination of the relative importance of each green building factor.

Specifically, this research aims to:

1. Compare and contrast the existing green building rating systems, both local and international
2. Identify the key areas and factors affecting the sustainability and greenness of a building
3. Conduct a multi-partite survey, involving architects, engineers, urban planners, and end users on the importance of the green building factors

This would be instrumental in the development of a locally-calibrated green building rating system, or possibly in the recalibration of existing tools in the country. The study is specifically conducted in the context of highly-urbanized locations, as in Metro Manila where ___% of the buildings in the country are situated.

2 RELATED LITERATURE

Green building rating systems are recognizably varied in methodology and criterion set, among the many other distinctions. Having been developed in different countries, the variability could be inferred to arise from the difference in the conditions in the countries where the rating systems were developed. In 2008, Ali and Al Nsairat conducted a study on developing a green building assessment tool for developing countries. The research studied internationally recognized green building assessment tools such as BREEAM, LEED, Japan's Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), GREEN STAR, among others. The outcome of the research was a suggested green building assessment tool that suits the Jordanian context. The research integrated criteria from different assessment methodological frameworks and built on the strength of each, and provided a more holistic assessment approach showing particular attention to local Jordan context.

The review focuses on the strengths and weaknesses, as well as the elements of success of implementation of these systems. It identified the local context of Jordan, its natural and physical conditions, and classified the current conditions as either positive or negative. The researchers used interviews with, and questionnaires and observations of stakeholders, investors, and builders of the private, public, and government agencies.

By benchmarking the established internationally used rating systems to the Jordan green building rating system, the items to be assessed were established. The three main assessment items are environmental, social and economic indicators. Analytical Hierarchy Process (AHP) was used to determine the relative importance of the items assessed. It was then synthesized into an overall rating system. Following are the results:

Table 1 Assigned weights to assessment categories based on the study by Ali and Al Nsairat in 2008

Assessment Categories	Index	Weight
Site	S	0.108
Energy Efficiency	E	0.231
Water Efficiency	W	0.277
Material	M	0.103
Indoor Environment Quality	IEQ	0.118
Waste and Pollution	W & P	0.064
Cost and Economics	C & E	0.099

The outcome of the study was a green building residential type assessment tool for Jordan called (SABA Green Building Rating System). This system is a powerful green building rating system for Jordan because it is based on scientific research and technical knowledge. In addition, the assessment framework suits the local context of Jordan—its culture, issues, resources, priorities, practices and institutions. From the table above, utmost priority is placed on water efficiency which is intuitively a result of Jordan being a desert country.

3 METHODOLOGY

3.1 Analysis of green building indicators

Three rating systems, namely LEED, BERDE and QCGBO were assessed based on their indicators or assessment categories. Distinct categories from each of the rating systems were defined, compared and contrasted. From this a definitive list of green building indicators was formed. The percentage weight of these indicators was computed for the three rating systems based on the ratio of maximum attainable score for the category and the maximum attainable total score. Following is the list of the identified indicators and their corresponding shorthand indices:

Table 2 List of green building indicators

Indicator	**Index**
Sustainable Sites	SS
Water Efficiency	WE
Energy Efficiency	EE
Materials and Resources	MR
Indoor Environmental Quality	IEQ
Management and Operations	MO
Transportation	T
Emissions	E
Waste Management	WM
Heritage Conservation	HC

LEED's category on Regional Priority Credits (RPC), which is not clearly defined for the Philippine context, was not included in the list. Further, Innovations in Operations, which is present in both LEED and BERDE was merged with BERDE's distinct Management. In LEED, Emission forms part of the Energy Efficiency criterion and waste management is under materials and resources. In BERDE, these were made distinct indicators. Heritage conservation criterion is also a unique feature of BERDE. The following shows the Venn diagram for the three rating systems.

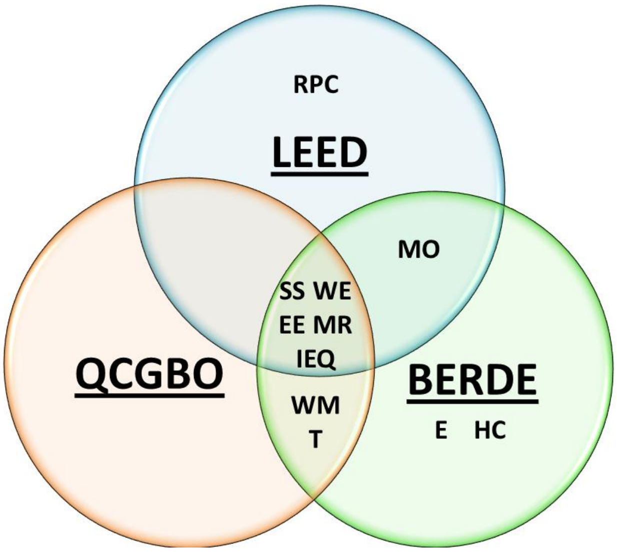

Figure 1 Venn diagram of green building assessment categories

3.2 Development of the survey tool

The study made use of a fieldwork approach—that is, using survey questionnaires and interviews—to arrive at the desired results. The questionnaire provided for the determination of the hierarchy of criteria was made in the form of a matrix, where the criteria were listed in both directions (i.e. column and row). The objective was for the respondent to use pairwise comparison, and provide weights for each of the criteria being compared. The values of the weights ranged from 1 through 5, and were in fraction and whole-number forms, which were indicative of the relative importance of each criteria with respect to another parameter. Table 3 shows the sample matrix provided for data collection while table 4 shows the possible responses and their corresponding interpretation.

Table 3 Pairwise comparison of green building indicators

	SS	WE	EE	MR	IEQ	MO	T	E	WM	HC
SS	1/1									
WE		1/1								
EE			1/1							
MR				1/1						
IEQ					1/1					

MO						1/1				
T							1/1			
E								1/1		
WM									1/1	
HC										1/1

Table 4 Possible responses to the survey questionnaire

Column is 5x more important than **Row**	1/5
Column is 4x more important than **Row**	1/4
Column is 3x more important than **Row**	1/3
Column is 2x more important than **Row**	1/2
Column is as important as **Row**	1/1
Row is 2x more important than **Column**	2/1
Row is 3x more important than **Column**	3/1
Row is 4x more important than **Column**	4/1
Row is 5x more important than **Column**	5/1

3.3 Conduct of the Survey

Survey respondents included stakeholders from different fields of expertise such as structural engineering, architecture, environment, transportation, water resources, and urban planning among others. Also surveyed were members of the general public whom the researchers determined had an influence on certain sustainable development practices. The survey also aimed to determine whether the different sectors had different opinions on the importance of the criteria being compared. The number of surveyed respondents totaled to 55, with 43.64% of the whole being engineers, 23.64% users, 16.36% architects, and 16.36% being urban planners. In some cases, interviews were also conducted prior to and/or after the participants answered the survey to gain more insight on the opinions and judgments of the respondents. Aside from the responses collected, the interviews provided clarification and supplementary understanding with regards to the manner of surveying, as well as to the response. Furthermore, the discussions with the experts imparted further knowledge and new ideas in relation to sustainability and in the design of green buildings. The use of the different existing rating systems such as LEED and BERDE locally were also discussed; this shed light on the merits and demerits of both system, and thus stresses the value of this study.

3.4 Analytical hierarchy process (AHP)

According to Saaty (1990), the most effective way to concentrate judgment is to take a pair of elements and compare them on a single property without concern for other properties or other elements. Judgments were used by the AHP to determine the ranking of the criteria of the rating systems; pairwise comparison was also conducted to compare the criteria from both systems. For the comparison, there were n criteria represented by A1, …, An, with weights given by w1, …, wn. The matrix was formed with the pairwise ratios whose rows were the weights of each criterion with respect to the others. The smaller of each pair was taken as the unit, and the larger was defined by multiples of the smaller unit. The eigenvector of the resulting matrix was then computed and normalized. This corresponds to the relative weights of each green building indicator.

Because the responses were sorted according to expertise (i.e. division into engineers, architects, users and urban planners), it was possible for the individual replies to be averaged. Consequently, from the 55 total responses, there were 4 averages that described the set of data. For the representation of the whole, the mean of the 4 values was taken and assumed to be descriptive of the opinion of the entire sample.

The rationale behind using this method was that the AHP was a mathematical technique which allowed the consideration of both qualitative and quantitative aspects of the decision. Furthermore, the AHP was less biased compared to the alternative—the study by Nguyen and Altan that was a simple evaluation and was subjective, which was why this method was more desirable. In a study by Kasperczyk and Knickel, it was noted that the AHP is a preferred method of multi-criteria analysis due to its flexibility and because users generally perceive this method to be straightforward. Moreover, it was chosen for its ability to decompose a decision problem into constituents and is able to build hierarchies of criteria. The AHP method was also able to make use of both subjective and objective evaluation measures.

3.5 Post processing of results

The responses obtained from the survey questionnaires were diverse—each of the respondents had a different opinion on which criteria was more important relative to another; however, each of the four sectors had a general response. In the analysis of the data, it could be seen that the respondents of a particular field of expertise held some criteria to be important than another, and the trend was observed throughout the responses of the entire sector. The analysis was performed per division, since the responses tended to be more similar.

Applying AHP to each of the respondent's surveys resulted to individual rating systems of each respondent. The average response of each of the groups was then taken. In order to analyze these results, a statistical analysis was conducted to compare whether there were significant differences between the ratings of the respondent groups. This was done by comparing each green building system criteria with each type of group respondent. For example, the results for sustainable sites between engineers, architects, users and urban planners were statistically analyzed to see if there are significant differences between the groups. Tukey's Pairwise Comparison Test was used to measure if the mean of each criterion differed. This test is used when confidence intervals are needed or sample sizes are not equal. Since the number of respondents differs between each group, Tukey's test is best used.

4 RESULTS AND DISCUSSION

The results of the analytical hierarchy process were expressed in percentages as shown below.

Table 5 Mean Weights of Green Building Criteria.

	Engineers	**Architects**	**Users**	**Urban Planners**
SS	11.92%	10.62%	9.06%	14.34%
WE	12.89%	13.10%	16.02%	11.58%
EE	12.90%	12.73%	16.98%	12.53%
MR	9.05%	11.82%	8.86%	10.21%
IEQ	9.26%	8.62%	11.02%	9.94%
MO	8.53%	11.03%	6.64%	9.75%
T	7.68%	7.56%	5.35%	8.41%
E	7.83%	7.47%	9.68%	7.73%
WM	9.60%	7.48%	9.74%	6.80%
HC	10.34%	9.55%	6.65%	8.71%

It can be observed that Water and Energy Efficiency are consistently among the top priorities of all sectors. Other than these two, Sustainable sites also figured in the top three of urban planners and engineers, materials is in the architects' top three and indoor environmental quality in the end users' top list.

Energy efficiency is the most important green building indicator for engineers and end-users while water efficiency is the foremost consideration for the architects. For the urban planners, sustainability of the siting took the foremost priority as was anticipated.

These values reflect the premium placed by each of the groups on the criteria that they perceive to be most important to their individual practice. The reason for WE and EA being most important for all groups may be that these commodities are more costly, and are thus perceived as highly important. Having innovations in these categories are thus beneficial to all stakeholders. It can be inferred that SS is most important to engineers and urban planners because their line of work focuses on the proper allocation and use of land. The priority allotted to land use and development is recognized by the engineers and urban planners. Similarly, MR is given importance by architects as their field deals with the use of the physical components of construction. In designing a structure, crucial to architects is the type of materials that go into the building. Lastly, IEQ is important to end users because they are the ones to occupy the structures once these are finished. Lighting, comfort, and air quality are among the things that users give a premium to when it comes to the structures. Having said these, it can be seen that the priorities of the respondents were taken into consideration in the completion of the survey questionnaires.

Also observable is the range of the weights given across the different sectors. The computed weights from the engineers, architects and urban planners are closely spaced as compared to that of the end users. For the end users, transportation takes less than a third in importance as compared to its highest ranked attribute, which is energy efficiency.

The results were statistically processed using Tukey's test to check for significant variability across sectors, as follows:

	N	Mean	Grouping
Urban Planners	9	14.340	A
Engineer	24	11.923	A
Architect	9	10.623	A
Users	13	9.058	A

Figure 2 Analysis of Sustainable Sites criterion using Tukey's Test

	N	Mean	Grouping
Users	13	16.025	A
Architect	9	13.101	A
Engineer	24	12.894	A
Urban Planners	9	11.578	A

Figure 3 Analysis of Water Efficiency criterion using Tukey's Test

	N	Mean	Grouping
Users	13	16.984	A
Engineer	24	12.897	A
Architect	9	12.733	A
Urban Planners	9	12.532	A

Figure 4 Analysis of Energy Efficiency criterion using Tukey's Test

	N	Mean	Grouping
Architect	9	11.824	A
Urban Planners	9	10.206	A
Engineer	24	9.050	A
Users	13	8.858	A

Figure 5 Analysis of Materials and Resources criterion using Tukey's Test

	N	Mean	Grouping
Users	13	11.023	A
Urban Planners	9	9.942	A
Engineer	24	9.263	A
Architect	9	8.619	A

Figure 6 Analysis of Indoor Environmental Quality using Tukey's Test

	N	Mean	Grouping
Architect	9	11.031	A
Urban Planners	9	9.750	A
Engineer	24	8.531	A
Users	13	6.636	A

Figure 7 Analysis of Management and Operations criterion using Tukey's Test

	N	Mean	Grouping
Urban Planners	9	8.410	A
Engineer	24	7.676	A
Architect	9	7.561	A
Users	13	5.347	A

Figure 8 Analysis of Transportation criterion using Tukey's Test

	N	Mean	Grouping
Users	13	9.680	A
Engineer	24	7.829	A
Urban Planners	9	7.726	A
Architect	9	7.474	A

Figure 9 Analysis of Emissions criterion using Tukey's Test

	N	Mean	Grouping
Users	13	9.743	A
Engineer	24	9.597	A
Architect	9	7.483	A
Urban Planners	9	6.800	A

Figure 10 Analysis of Waste Management criterion using Tukey's Test

	N	Mean	Grouping
Engineer	24	10.341	A
Architect	9	9.550	A
Urban Planners	9	8.715	A
Users	13	6.645	A

Figure 11 Analysis of Heritage Conservation criterion using Tukey's Test

As seen in the figures above, the results for all respondent groups for each green building criteria were the same. This implied that the means are not significantly different from each other. The engineers, architects, urban planners and users do not vary in their view of which green building criteria are most important. The results depended more on the country's environmental condition than their respective different professions. Since all the respondents were from the Philippines, their opinions of which criteria were important were similar. There are common concerns among the different rating systems; LEED and BERDE, such as emphasizing the consumption of energy in building, water efficiency, indoor environment quality, materials and resources, and sustainable sites. However, each rating system focuses on certain aspects more than others according to its country's local context.

The Green building criteria of the United States and the Philippines differ because of the contrast in environmental concerns of each country. Therefore, since the respondents from the survey conducted were all from the Philippines, their individual criteria have no significant difference between group of respondents.

The average weights across four sectors are as follows:

Table 8 Average green building criteria weights

Criterion	**Percentage**
Sustainable sites	11.49%
Water efficiency	13.40%
Energy efficiency	13.79%
Materials and resources	9.98%
Indoor environmental quality	9.71%
Management and operations	8.99%
Transportation	7.25%
Emission	8.18%
Waste management	8.41%
Heritage conservation	8.81%

The equality of percentages in the new rating system implies that most respondents do not highly prioritize a certain criteria from another. A slight difference is seen in both water efficiency and energy & atmosphere, which garnered the highest percentage.

Given that the Philippines is one of the countries that charges the most expensive electricity in the world, the respondents gave energy & atmosphere higher importance. Additionally, the air pollution of the country has worsen over the years, especially in Metro Manila, which is over congested. Since the respondents were all from Metro Manila, they gave energy & atmosphere higher importance. Likewise, the water pollution in the country has been covered in the news throughout the years. The current condition of Manila Bay and beaches around the Philippines has been degrading. Trash has been seen floating in Manila Bay recently and therefore making the bay dangerous to swim in. Water has been close to the hearts of the Filipinos given that the country is an archipelago, making the respondents give higher points to water efficiency.

Compared to LEED and BERDE, the calibrated rating system was based on the respondents' view of the importance of each criterion. On the other hand, LEED and BERDE are technology-based rating systems. LEED and BERDE rely heavily on technologies available in their respective countries. For example, as show in Table 9 below, BERDE only has 5.45 percent for water efficiency. Although based on the calibrated rating system, water efficiency had 13.40 percent, one of the highest percentages, which means that this criteria is important to the Filipinos. BERDE's percentage in water efficiency did not give due credit to the water crisis the Philippines is facing. The 5.45 percent from BERDE only means that there are few technologies which cater to the efficiency of using and saving water. Having a technology-based rating system will focus on the innovations available in the country and in cases where the technology is too expensive or unavailable, the rating obtained is lower than what is desired. On the other hand, the importance-based rating system takes into consideration what criteria is relevant to the place of application.

5 CONCLUSIONS

Energy and atmosphere, water efficiency and sustainable sites were the three most important green building attributes based on the survey responses while management and operation improvements, transportation and waste management practices figured in the bottom of priorities. Urban planners gave sustainable sites the biggest weight while the three other sectors tagged energy efficiency as the most important parameter. On a pie of 100, engineers would give a more or less equal points for the different attributes while the end-users would allot big fractions for energy and water efficiency and indoor environmental quality.

The average weights yielded in this study differ to those given by LEED and BERDE as the latter two are technology focused more than needs or context based. The setting for which LEED was developed is for the highly urbanized areas in the United States. Even in the Philippines, the importance of these weights will also vary if the setting was somewhere other than Metro Manila.

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SUSTAINABLE PUBLIC TRANSPORT: BRT DEVELOPMENT IN THE PHILIPPINES

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Abstract: Bus Rapid Transit (BRT) is now considered as an important urban mass transit option for different cities all over the world. It offers capacities and service levels that are comparable to those of urban rail systems but at a fraction of the cost. This paper presents the concept of BRT as a public transport system and compares it with other mass transit options for urban areas. It also discusses the factors that warrant the implementation of BRT in the Philippines, culling lessons from international best practices in Asia and Africa. These lessons underscore the importance of "soft" aspects of BRT planning and implementation which include political, governance and planning context, public transport system integration, operating arrangements, finance, branding, and communications. These factors significantly shape the viability and sustainability of a BRT system aside from its physical infrastructure components. The paper also presents the salient points of the Cebu BRT study completed in October 2012, focusing on its mains features and prospects for sustainability. The paper is capped by a discussion of the conditions and opportunities which are auspicious for the planning and implementation of BRT systems in cities of the country, in response to cities' needs for sustainable mobility or its people.

Key words: Bus Rapid Transit (BRT), Mass Transit, Urban Public Transportation, Modal Comparison, Institutional components of BRT

1 INTRODUCTION

Complex urban transport problems warrant a continuous search for solutions. People's need for mobility is a given in today's cities where commute trips tend to become longer as a result of urban sprawl and the growing mismatch between residential and employment locations. Consequently, more trips are made in terms of volume and distance. With a growing middle class whose tendency is to acquire and use private cars as the main mode of travel, traffic congestion worsens with its attendant economic and environmental externalities. As a result, dignity of travel, which the authors define as the ability of all people to travel using safe, reliable, convenient, and affordable means is lacking in many urban areas. Public transportation is ideally an alternative, but tends to cater to just its captive market or those who do not have access to the private car. But with worsening traffic congestion that results from uncontrolled growth in the number of private vehicles as well as the number of inefficient public transport vehicles, the viability and attractiveness of conventional road-based public transport is compromised thereby making it less and less attractive for choice travelers. This blackhole theory of public transport continues to compromise its prospects for functioning as an effective and sustainable travel alternative in the city.

Bus Rapid Transit (BRT) is fast becoming an important public transport option for developed and developing cities. Its cost effectiveness, rail-competitive passenger capacity, shorter construction time, possibility to absorb some of the existing public transport workers, and its potential to effect public transport reform are among the BRT's strengths. Others are its complementarities with existing public transport systems, environmental benefits, and inherent versatility and flexibility render it as a significant and viable mass transit option for today's cities.

The objectives of this paper are:
1. To present the concept of the BRT as a mass transit system;
2. To compare BRT with other mass transit options;
3. To draw lessons from international experience;
4. To present the factors that warrant the implementation of BRT systems in the Philippines;
5. To present the salient points of the Cebu BRT study; and
6. To discuss the prospects of BRT in the country.

Chapter 2 of this paper presents a definition of BRT, its components, features, and history. Chapter 3 discusses a comparison of BRT with other mass transit options. Chapter 4 discusses international experience and lessons learned in BRT planning and implementation, highlighting the importance of not only the hard infrastructure aspect of BRT but also its "soft" aspects. Chapter 5 discusses the warrants of BRT in the Philippines. Chapter 6 presents the salient points of the Cebu BRT study. Chapter 6 presents the prospects of BRT in the Philippines and Chapter 7 summarizes the paper.

2 WHAT BRT IS

2.1 Definition

The BRT Planning Guide (Sourcebook for Policy Makers in Developing Cities) defines BRT or Bus Rapid Transit as a bus-based mass transit system that delivers fast, comfortable, and cost-effective urban mobility. Through the provision of exclusive right-of-way lanes and excellence in customer service, BRT essentially emulates the performance and amenity characteristics of a modern rail-based system but at a fraction of the cost of rail.

2.2 Features and Components

BRT's philosophy subscribes to the essential attributes that are found in quality rapid transit systems. These attributes are speed, reliability, and image. These are attributes that are achieved by the BRT through the following system features that are found in most BRT systems in different parts of the world. These features are:

- Exclusive right-of-way lanes
- Rapid boarding and alighting
- Free transfers between lines
- Pre-board fare collection and fare verification
- Enclosed stations that are safe and comfortable
- Clear route maps, signage, and real-time information displays
- Automatic vehicle location technology to manage vehicle movements
- Modal integration and stations and terminals
- Competitively-bid concessions for operations
- Effective reform of the existing institutional structures for public transport
- Clean vehicle technologies
- Excellence in marketing and customer service

2.3 History of BRT

The continuous evolution of BRT as a mass transit system can be traced to these milestones:

- 1937: Chicago City outlined plans to convert 3 inner city rail lines to express bus corridors
- 1950s: BRT plans were developed for United States cities including Washington D.C. and St. Louis
- 1960s: High-occupancy lanes and exclusive bus lanes in the United States
- 1963: Express buses using counter-flow in New York City
- 1970: BRT plans were developed for Milwaukee
- 1972: Construction of a dedicated busway (7.5 kms) known as "Via Expresa" in Lima, Peru
- 1973: Busways were constructed in Runcorn, U.K. (22 kms) and Los Angeles, U.S.A. (11 kms, called the El Monte Busway)
- 1974: "Surface Subway" in the form of a BRT in Curitiba, Brazil, with 57 kms of exclusive busways and 340 kms of feeder services
- 1975: Sao Paulo, Brazil (now with 250 kms of exclusive busways), and Arlington, U.S.A
- 1976: Boiania, Brazil
- 1977: Porto Alegre, Brazil and Pittsburg, U.S.A.
- 1996: Quito, Equador opened its BRT system using electric trolley technology and now combined with clean diesel technology
- late 1990s: The BRT became more widely known with visits of technical and political groups from Bogota, Columbia and Los Angeles, U.S.A. to Curritiba, Brazil. This Bogota initiative resulted in its BRT system called the TransMilenio. The fruit of the Los Angeles inititive is a national BRT program that includes 17 cities in the U.S. The former mayor of Bogota, Enrique Penalosa, became an internationally prominent champion of the BRT concept.
- 2004: An initial 12.9 kms of exclusive busways opened in Jakarta. The system is called "TransJakarta". It has since expanded to 172 kms.
- 2008: Opening of BRT Lite in Lagos, Nigeria with 22 kms of majority-segregated lanes, only 18 months after inception. The system is currently constructing additional 22 kms of busways with more corridors in planning stage.
- 2010: Opening of the BRT in Guangzhou, China, known as GBRT, with more than 30,000 passengers per hour per direction. It currently has a network length of 22.5 kms.
- 2012: Opening of Janmarg BRTS in Ahmeddabad, India with 45 kms of busways and additional 41 kms in planning stage.

There are other BRT systems that are in the planning or implementation stage or already operational in different parts of the world.

3 MODAL COMPARISON

BRT is one of the urban transit systems that offer high line capacities, line capacity being defined as the product of passenger capacity of the vehicle or transit unit and the speed of the transit unit. High line capacities in urban areas can be achieved through the provision of exclusive rights-of-way. This may be in the form of tracks (elevated, at-grade, or subterranean) for rail-based systems, and exclusive road lanes for bus systems. The different mass transit options vary in cost, capacity, attributes, and others. A comparative analysis of different modes is presented here based on the following criteria: cost, construction time, capacity.

3.1 Cost

A review of various mass transit systems shows variation in capital or infrastructure cost on a per kilometer basis. BRT systems are the least expensive with Metros or subways being the most expensive. The most expensive BRT systems are just equivalent to the least expensive LRT system.

Table 1 Per Kilometer Costs of Mass Transit Systems

Mass Transit System	Investment Cost (in Million US$ per km.)
BRT	0.5M – 15M
Tram	10M – 25M
Light Rail	15M – 40M
Urban Rail	25M – 60M
Elevated Rail	50M – 100M
Metro	50M – 320M

The following table shows some mass transit systems and their unit infrastructure costs per kilometer.

Table 2 Units Costs of Urban Mass Transit Systems

City	Type of System	Kms of segregated lines	Cost per km (Million US$ per km)
Taipei	Bus rapid transit	57	0.5
Quito (Eco Via)	Bus rapid transit	10	1.2
Curritiba (1994 ext)	Bus rapid transit	57	1.5
Sao Paolo	Bus rapid transit	114	3.0
Bogota	Bus rapid transit	40	5.3
Tunis	Light rail transit	30	13.3
Lyon	Light rail transit	18	18.9
Bordeaux	Light rail transit	23	20.5
Los Angeles (Gold)	Light rail transit	23	37.8
Zurich (2005 ext)	Light rail transit	20	42.0
Bangkok (BTS)	Elevated rail	23	73.9
Madrid (1999 ext)	Metro rail	38	42.8
Hongkong	Metro rail	82	220.0
London (Jubilee)	Metro rail	16	350.0

Source: www.uncrd.or.jp/env/est/.../BRT.../1-2_Introduction_to_BRT.pdf

3.2 Construction Time

The required construction time of the transit system depends on its level of infrastructure requirements. BRT systems usually utilize existing road lanes which are improved and fitted with curbs or markings to achieve exclusivity. They are also usually at-grade. Rail-based systems, on the other hand, require the construction of tracks that are either elevated, at-grade, or underground. Construction time therefore for rail-based systems is generally longer than that for BRT.

Some BRT systems in various parts of the world have been constructed within 18 months as in the case of Lagos, Nigeria, while metros require 5 years or more to construct.

3.3 Capacity

Capacity refers to not just static capacity or the number of passengers that can be accommodated in a transit unit but line capacity which incorporates the speed of the transit vehicle. Line capacities are expressed in number of passengers per hour per direction (pphpd). Shown below are comparative statistics.

Table 3 Passenger Flows

Line	Type	Actual Capacity (pphpd)
Sao Paolo East Line	Subway	60,000
Santiago La Moneda	Subway	36,000
London Victoria Line	Subway	25,000
Guangzhou Metro	Subway	14,000
Bogota TransMilenio	BRT	45,000
Guangzhou BRT	BRT	40,000
Porto Alegre Assis Brasil	BRT	26,000
Curritiba Eixo Sul	BRT	15,100
Bangkok BTS	Elevated rail	42,000
Tunis	Light rail	13,400
Kuala Lumpur Putra	Elevated rail	7,000
Strasbourg	Light rail	6,000

Source: www.uncrd.or.jp/env/est/.../BRT.../1-2_Introduction_to_BRT.pdf

A US General Accounting Office (US GAO, 2003) study says that buses running on exclusive busways can achieve the same commercial speeds as urban rail systems. Full BRT systems achieve commercial speeds of 22-29 kph.

3.4 Other Criteria

Other comparison criteria include the transit system’s performance and impacts. Performance of the system is indicated by travel time or speed, frequency, reliability, comfort, safety, convenience, image and perception. Impacts include environmental, economic, social impacts.

4 INTERNATIONAL BEST PRACTICE AND LESSONS LEARNED

To develop a sustainable public transport system requires not only the planning and development of its physical infrastructure aspects such as segregated lanes, stations, vehicles and the like but also the so-called “soft” aspects of the system. These are political, governance and planning context, public transport system integration, operating arrangements, finance, branding, and communications (Kumar et. al, 2012). This looks at international experience in planning and implementing 5 BRT systems in Asia and Africa, specifically in Lagos, Johannesburg, New Delhi, Ahmedabad, and Jakarta.

Below are the salient points of the 5 cases studied presented in the World Bank report:

Table 4 Five Case Study BRT Systems

	Lagos, BRT-Lite	Johannasburg, Rea Vaya	Jakarta, TransJakarta	Delhi HCBS Busway	Ahmedabad JanMarg
Total System Length	22 Km, 20+ km under construction	25.5 Km, 300+ Km planned	135.11 Km, expanding	5.8 km, median transitway 8.7 km, curb lanes without enforcement	45Km 41 Km additional planned
Construction cost $US per Km	$1.2m+/Km	$14.2m+/Km	$1.3m/Km+	$5m/Km	$3m/Km
Percent segregated	60%	100%	90-95%	NA (<40%)	100%
No. existing stations	26	30	142	29	67

Vehicles	High Floor 11.7m	Medium Floor: 18m (trunk) 12m (feeder/ Complemntary.)	High Floor: 11.5m, Some 18 m	DTC: Primarily low floor, 12m; Some A/C Others: Variety of types and sizes	High floor 12m; testing 18 m
Average daily ridership on system (Approx.)	200,000	45,000	280,000	85,000	135,000
Max. Ld. Pt., Pk. Direction, Pk. Hr. Vol. (Approx.)	10,000/Hr.	3,500/Hr.	10,000/Hr.	10,000/Hr.	2,000//Hr.
Former mode of BRT passengers	Car (6%), PT (90%)	Not known	Car (14%) Motorcycle (6%) Public Transport (69%)	Not known	Bus (40%) Auto Rickshaw (35%) Taxi, Auto (13%)
Av. Rev. Spd. (Km/Hr)	20 for local service			18 on median transitway	25
Travel time savings from previous	29% over length of corridor		40-50% over length of each corridor	30% over length of median transitway	20-30% over length of each corridor

4.1 Political, governance, and planning context

Among the important but non-infrastructure factor which can have a significant impact on the success of BRT planning and implementation is institutional in nature, pertaining to the political, governance, and planning context in which the BRT as an intervention is pursued. The issue of weak institutions is a major stumbling block for BRT since BRT is not just an infrastructure intervention but an attempt at public transport reform. There may be no government entity with a public transport policy, planning, and oversight capability or authority. Or the existing public transport entity may not have the ability to plan, implement, and operate a BRT.

There may be a need to strengthen the institutions during BRT planning and project preparation. It is also possible to change the structure of institutions or establish new, multi-modal authority or one that has the authority to cooperate with other authorities in the planning, implementation, and operation of BRT.

An almost constant and expected response of incumbent PT operators particularly the informal sector is one of opposition because of the perceived threat to their livelihood. BRT planning and preparation should be mindful of this issue.

Another challenge is the absence of a well-prepared and valid master plan which identifies mass transit corridors. The potential of achieving synergy between land use and transport planning is sometimes overlooked. BRT can provide a high level of accessibility to destinations along a corridor and if coupled with clear and focused land use planning can not only push property values but also enable the city to achieve the kind of development it wants to pursue.

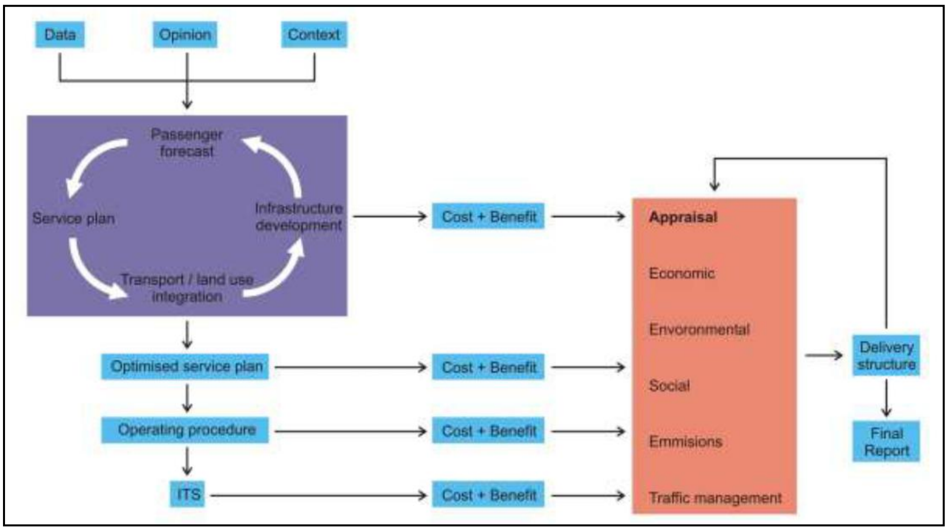
Lastly, the need for champions who will advocate BRT as a sustainable public transport solution in the government, private sector, academe, and various circles cannot be overemphasized. Ahmedabad, Jakarta, and Lagos all had strong and determined political leaders supported by academic and technical experts who collectively were the agents of change that broke through conventional and traditional thinking.

4.2 Public transport system integration

Because a BRT system uses at-grade physical space, its interaction with the rest of the road users is inevitable. Public transport integration has always been an issue in the cities where BRT is introduced. There were problems when the rest of the public transport network is not integrated with BRT in terms of fare and service. Such integration could be achieved in doses and not without political challenges. In the case of Ahmedabad, it was easier to integrate the BRT with the rest of the public transport system in terms of connections, fares, etc.

The potential for NMT (non-motorized transport) could be harnessed in BRT implementation through the treatment of walking and the use of bicycles as important access modes. As such, the improvement of sidewalks and the provision of bicycle storage facilities at BRT stations are important.

Another lesson learned is the importance of having a full understanding of the local needs and travel demand first, followed by a service plan, and then the hard infrastructure. If not done in this sequence, it is possible that the design of BRT elements could be inconsistent with the demand. There can be missing passing lanes at critical points, or lack of level, no-gap boarding, or limited vehicle capacity, less than ideal interior layout, door width and placement. What is needed is a clear identification of local user needs and travel demand prior to the planning and design of the physical infrastructure elements.



Source: C. Brader

Figure 1 BRT Planning Process

4.3 Operating arrangements

The prevalent success among cities that adopted BRT is having an independent public special purpose vehicle (SPV) or authority that implements and manages competitively procured operation contractors and service providers as in the case of BRTs in Latin America. There are multiple operators that are contractually engaged by the BRT SPV and paid on a gross-cost contract, either on per bus-km or bus-hr basis, with proper performance incentives and penalties. Some of these operators are companies formed from incumbent minibus operators as in the case of Lagos, Jakarta, and in later phases, Johannesburg.

4.4 Finance

BRT infrastructure is mostly financed by the government, with buses purchased and operated by private companies on a gross cost contract, either per km or per hour of service provided. Revenue accrue to the SPV or BRT management entity. The table below shows the nature and scope of financing made for the BRT of the different cities.

Table 5 Financing of BRT Components

City	Financing of Infrastructure	Financing of Vehicles	Infra operating & maintenance costs
Ahmedabad	Municipality, State of Gudjarat, National Government of India	Private sector	Farebox and other revenues
Johannesburg	National Government of South Africa	City Government of Johannesburg	With government subsidies
Jakarta	Province of Jakarta	Government for some lines, Private sector for the others	With government subsidies
Delhi	Municipality financed the busway	Private sector	Advertising revenues
Lagos		Private sector	Farebox and other revenues

The variation in nature of financing across cities depends on the scale of the public transport market, institutional structures, nature of contracts with operators, fare levels, and competition from informal public transport operators.

4.5 Communications and Branding

BRT as an intervention needs to be understood, made acceptable, and supported by the different transport stakeholders both from the government and private sectors. Communicating to various audiences the concept, benefits, as well as challenges faced by BRT is therefore crucial in the success of BRT. Lack of information, as in the case of Delhi, can hurt the BRT advocacy.

Communication is important in making people understand the concept of BRT. People will only be supportive of anything new if they understand its benefits and if their mindsets are changed. Traditional thinking is that it is only rail-based systems that can solve urban transport problems. Openness of mind is needed for people to consider other options, better options in terms of responsiveness to needs, costs, implementation times, etc.

Part of communications is the crafting of clear and focused messages meant for different audiences. There is no one-message-fits-all in communications. A specific message will be suitable for a particular stakeholder group. The message on travel time and convenience of the BRT will matter to the commuters. The opportunities for BRT operations will interest the existing public transport operators. The environmental benefits of BRT will be valued by environmental groups. The land development potential associated with a high-quality mass transit system like the BRT will excite businessmen and property developers.

Branding plays the role of a symbol that represents what the BRT system promises to deliver. Effective and catchy brands are important for people to associate the BRT with reliable and safe service. Brands also become part of the image that the city wants to project. Branding is meant to evoke in people's mind their aspirations and needs and how these can be met by a particular product or service. Branding also helps in communicating the benefits that BRT stands for.

5 WARRANTS OF BRT IN THE PHILIPPINES

Cities in developing countries such as the Philippines face the consequent challenges of urban transport that go along with development. These challenges or externalities are traffic congestion, air pollution, rising transport costs, road safety, rising national government subsidies, and other issues. These are discussed below.

5.1 Traffic Congestion

The high number of both private and public vehicles on the road leads to traffic congestion with its attendant economic and environmental consequences. Vehicle ownership in the country is growing rapidly. In 1990, the total number of registered vehicles was 1.6 million; in 2007 this was 5.5 million. Since 2005, motorcycles/tricycles (MCs/TCs) have grown the fastest with an average annual increase of (10.77%), followed by SUVs (10.55%) and trucks (2.75%).

For the National Capital Region (NCR), vehicle registration between 1997 and 2007 shows an average annual increase of 2.70%. For Cebu City, the number of vehicle registration has shown an annual growth rate of 7% for the period 1994 to 2000 and 4% for the period 2000 to 2006. The share of trips using the private modes increased from 9.7% in 1979 to 20.6% in 1992 while the share of trips using public transport decreased from 90.3% in 1979 to 79.4% in 1992. It is anticipated that the Metro Cebu will experience an increasing rate of person-trips due to rapid population growth and urbanization.

It has been estimated that the annual cost of traffic congestion for Metro Manila is 140 Billion Pesos. More recent estimates put this at 2.4 Billion Pesos per day (JICA 2013). This is attributable to lost man-hours, additional fuel consumption health costs, and opportunity costs of lost investments.

5.2 Environment

Transportation or mobile sources have been identified as the major contributor of many air pollutants. The following table shows a national inventory of various pollutants and the contribution share of the three (3) sources: stationary, mobile, and area sources.

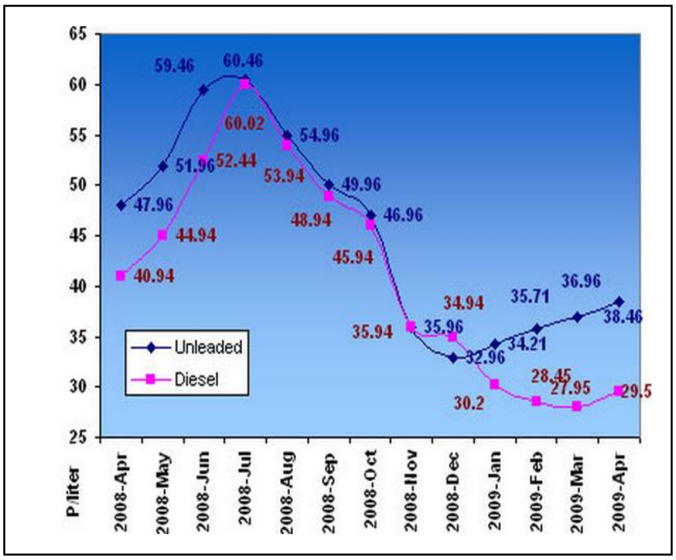
Table 7 2007 National Emission Inventory According to Air Pollutants (DENR)

	PM (%)	CO (%)	NOX (%)	SOX (%)	VOC (%)	Total Share (%)
Stationary	14.13	10.26	30.82	97.35	6.48	20.87
Mobile	31.44	85.03	38.26	2.33	87.42	65.13
Area	54.42	4.71	30.92	0.32	6.10	14.01

According to the Cebu City CLUP (2000), air pollution is now an increasing problem in the city. In the absence of heavy industries or thermal and coal fired plants in the city, the deterioration of air quality is mainly attributed to emissions from motor vehicles as with the national figures. Severe air pollution is now observed in many areas of the city particularly in major roads.

5.3 Fuel Price

Fuel prices have been unpredictable in the past two years as a result of complex confluence of factors such as growing demand in emerging economic powers, uncertainties in production, foreign exchange fluctuations, and others. The chart below shows the oil price trend for unleaded and diesel fuel between April 2008 and April 2009. The erratic behavior of fuel prices result in uncertainties and pressure in public transport provision, furthermore underscoring the importance of quality and reliable public transport systems in the midst of oil price ambiguities.



Source: (http://www.alternat1ve.com/biofuel/2008/05/15/average-philippine-gasoline-prices-2007-2008)

Figure 2 Philippine Oil Prices of Unleaded and Diesel, 2008-2009

5.4 Road Safety

Road safety has been an important issue that cities face today. The national cost of traffic accidents has been estimated to be 105 Billion Pesos equivalent to 2.6% of the country's GDP. The occurrence of traffic accidents is correlated to volume of vehicles, and a number of vehicles involved are public transport vehicles and motorcycles. Metro Manila's Commonwealth Avenue has been notoriously dubbed as "killer highway" as a result of frequent accidents, both fatal and non-fatal. This arterial road also serves in Metro Manila as an important bus corridor.

The number of accidents in Cebu City in 2000-2006 ranged from a level of 14,000 in 2000 to around 10,000 in 2006. The number of accidents is quite high considering that Metro Manila recorded a maximum of 11,185 accidents in 2005 in its 2002-2005 data.

5.5 Rising government subsidies for rail transit systems

Due to the high investment costs of rail-based systems and the need to keep fares at socially-acceptable levels, the required national government subsidies for rail systems have been growing rapidly. For example, the national government subsidizes the EDSA MRT passengers at close to 48 Pesos each, based on the proposed 2011 General Appropriations Act. This amounts to an MRT subsidy of P7.3 billion in 2011, which is P2.2 billion or 43 percent more than the P5.1 billion subsidy to train riders in 2010 (Manila Standard Today, Sept 6, 2010).

Issues of affordability and equity are raised here. The national government which is already faced with financial difficulties have to provide huge subsidies to an expensive system. Furthermore, there are equity and fairness issues because the rail subsidies come from taxpayers' money from all over the country and are earmarked solely for Metro Manila commuters.

5.6 Others

Road-based public transport in the Philippines is in the hands of private operators who are guided by their own compartmentalized perspective of market demand and supply and fundamentally driven by their profit motive as investors in the industry. Consequently, public transport provision is highly fragmented and there is practically no semblance of full systems operation and management, "systems' referring to the whole public transport system. As a result, there is erratic, inefficient, even unsafe provision of public transport, rendering captive passengers no choice but to take the low-quality services and the choice passengers the propensity to use their private cars. A high-quality and systematically organized, managed, and provided public transport system is therefore warranted.

6 BRT STUDIES IN THE PHILIPPINES, WITH FOCUS ON THE CEBU CITY BRT

BRT studies have been and are being conducted in various cities in the Philippines including Metro Manila, Cebu City, and Davao City. These are studies conducted by international development organizations including the USAid, ADB, and the World Bank as well as private companies like the Ayala Corporation.

The following sub-sections present and discuss the salient points of a BRT study that has been conducted in Cebu City, Philippines. This is the World Bank's feasibility study of a BRT system for Cebu City conducted completed in October 2012 and as of this writing awaiting national government approval. A study is currently being conducted for Metro Manila, and is in its final stages. Presented here are the highlights of the study including the environmental and social benefits of BRT.

6.1 Overview of the proposed BRT system for Cebu City

6.1.1 Project Definition

The Cebu BRT project includes:

- A segregated busway between Bulacao and Ayala Mall
- Stations and terminals along the segregated busway route
- A depot for the garaging of buses designated to operate as BRT services
- An Area Traffic Control (ATC) System to facilitate priority run times within the corridor and give city wide benefits of improved traffic flow
- An open service plan that ensures that while infrastructure is limited to that between Bulacao and Ayala, BRT services operate beyond this. Specifically in the case of Ayala Mall to Talamban where bus passage will be facilitated by bus priority measures where required and where achievable within the confines of the roadway.
- Traffic management measures to improve traffic flow outside of the corridor that are seen to complement the BRT and maximize its impact
- Parking management measures that will similarly complement BRT and improve traffic flow
- Interchange improvements to offer enhancement to the level of service received by all public transport passengers irrespective of whether they use BRT or not
- Urban planning improvements consisting of public realm enhancements and enhanced integration of transport and land use.

6.1.2 BRT Route

The diagram shows the proposed BRT route which consists of segregated operation between Bulacao and Ayala, as well as within SRP, and buses running with some priority between Ayala and Talamban. In segregated sections BRT will run in its own lanes in the center of the road. There will be gaps where it crosses signalized intersections. At signalized junctions BRT will receive priority by interaction with the central computer housing the Area Traffic Control System.

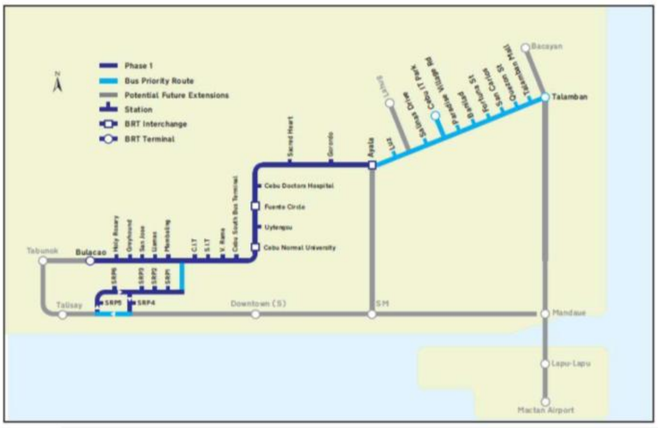


Figure 3 Proposed BRT Network for Cebu City and Environs

6.1.3 User-oriented design

The scheme has been developed through a deep understanding of the needs of travellers within and through Cebu City. As part of the Feasibility Study over 5000 people have been engaged with more reached through newspapers, TV, radio and the project's Facebook and web site. In addition meetings and presentations have been given to interest groups and stakeholders.

The understanding of need and context has been supported by large scale data collection to understand the scale of movement in and around the city. Data has been used to create a sophisticated forecasting model that enables the development team to understand in some detail the potential patronage and revenue to be achieved by the scheme, the revenue it will bring and its impact upon existing transport providers. Forecast future years of 2020, 2025, 2035 and 2040 have been considered in addition to a 2015 opening year. Applying projected growth to the transport network shows that travel conditions in Cebu will deteriorate significantly in the future. The implementation of BRT between Bulacao and Talamban together with an improved ATC system will offset that deterioration to a certain extent but will not protect the City entirely from the negative effects of growth. Further transport interventions will be required

6.1.3 Branding

A BRT brand was developed by discussing colours, images and feelings associated with proposed BRT travel within the Barangays fronting the BRT route. The output from these focus groups was interpreted by a graphic designer to produce a whole series of names with different means of portrayal and brand colours. These options were tested through quantitative assessment of the general public in SM, Ayala and City Hall. The output of this process was a clear preference for the name, TransCebu, with a dominance of the colour green and use of a sunshine motif.

Figure 4 Cebu City BRT Branding

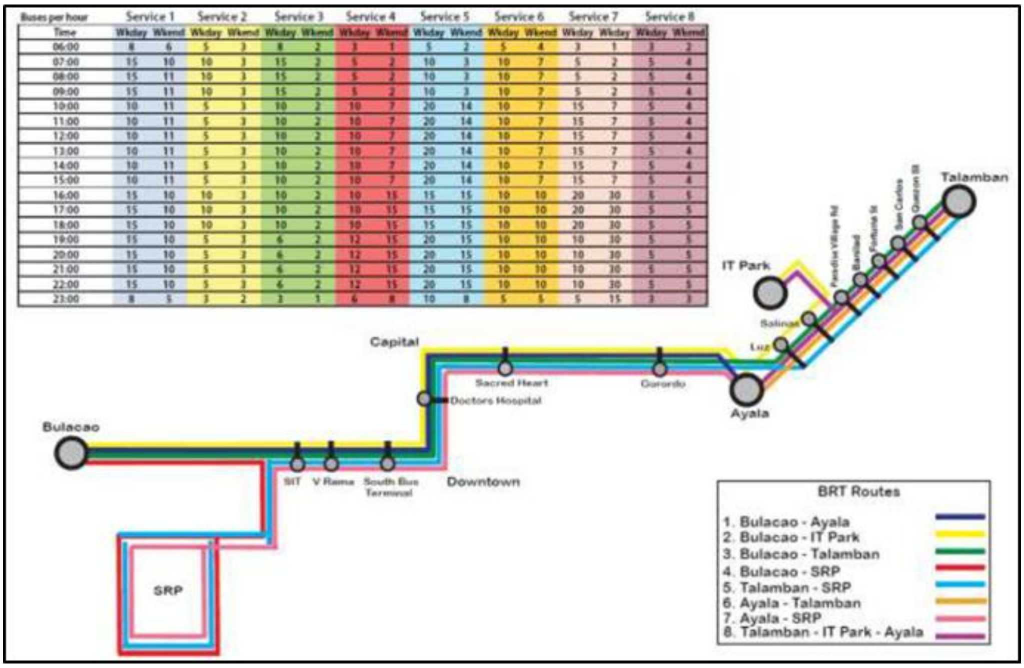
6.1.4 Passenger Forecasts and Service Plan

A summary of the passenger ridership forecast for target opening year 2015 is shown below:

Table 8 Forecast Passenger Ridership

AM peak passengers	26,100
Daily passengers	330,000
AM peak link loading (pphpd)	5,300
AM peak boardings	
Bulacao – Ayala service	5,800
Bulacao – IT Park service	3,500
Bulacao – Talamban service	8,500
Bulacao – SRP service	500
Talamaban – SRP service	3,600
Talamaban – Ayala service	1,800
Ayala – SRP service	2,000
Talamban – IT Park – Ayala service	800

These passenger forecasts are used as basis for developing the service plan shown below.



Buses per hour	Service 1		Service 2		Service 3		Service 4		Service 5		Service 6		Service 7		Service 8	
Time	Wkday	Wkend	Wkday	Wkend	Wkday	Wkend	Wkday	Wkend	Wkday	Wkend	Wkday	Wkend	Wkday	Wkday	Wkday	Wkend
06:00	8	6	5	3	8	2	3	1	5	2	5	4	3	1	3	2
07:00	15	10	10	3	15	2	5	2	10	3	10	7	5	2	5	4
08:00	15	11	10	3	15	2	5	2	10	3	10	7	5	2	5	4
09:00	15	11	10	3	15	2	5	2	10	3	10	7	5	2	5	4
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16:00	15	10	10	3	10	2	10	15	15	15	10	10	20	30	5	5
17:00	15	10	10	3	10	2	10	15	15	15	10	10	20	30	5	5
18:00	15	10	10	3	10	2	10	15	15	15	10	10	20	30	5	5
19:00	15	10	5	3	6	2	12	15	20	15	10	10	10	30	5	5
20:00	15	10	5	3	6	2	12	15	20	15	10	10	10	30	5	5
21:00	15	10	5	3	6	2	12	15	20	15	10	10	10	30	5	5
22:00	15	10	5	3	6	2	12	15	20	15	10	10	10	30	5	5
23:00	8	5	3	2	3	1	6	8	10	8	5	5	5	15	3	3

Figure 5 Cebu BRT Service Plan for 2015

6.1.5 BRT Vehicle

Alternative vehicle types were investigated and a 13.7m twin door rigid vehicle powered by an ultra-clean diesel engine is proposed. This vehicle could be bought as a chassis from a number of international suppliers to be assembled in the Philippines.

6.1.6 Infrastructure

In general terms, the BRT running way can be built without ROW acquisition except at its stations, terminals and depots. At stations, widening is required to accommodate a median station. To support BRT, sidewalks will be improved to provide access and ground level pedestrian signals will be provided. Spaces for jeepneys to drop off passengers will be provided at interchange stations. Jeepneys will only be allowed to stop at these designated areas and will not travel along the corridor for more than one stop. A general station layout is shown below.

Figure 6 Typical Station Layout

Passengers will pay by smartcard to enter the station to ensure that boarding the vehicle will be swiftly executed. Stations will have a ticket kiosk and turnstiles. Station personnel will be present to ensure a secure environment. Outline station designs have been developed with respect to forecast passenger capacity, to meet the needs of the number of buses that will serve them, offer a pleasant waiting environment and have a low environmental footprint.

6.1.7 Area Traffic Control and Traffic Management

The existing Area Traffic Control (SCATS) system is old, not maintained and largely dysfunctional. BRT requires control along its corridor to offer preferential journey times to its passengers and minimise its impacts upon other travellers. As such a new city wide traffic control system has been investigated and proposed that will bring significant benefits across the whole City.

To complement BRT and make it more effective, ATC, parking management and jeepney organisation/routeing has been examined in the Downtown area, together with accessibility improvements between BRT and Downtown.

6.1.8 Managing PUJ Sector Impacts

Along the route of the BRT, Jeepneys will be affected. They will however continue to play an important role within the future public transport network. The diagram below shows how some Jeepney services will act as 'feeders' to the BRT. This will significantly enhance people's travel opportunities and travel experiences.

Some will be replaced. It is estimated that approximately 1,300 jeepneys will be affected. A companion study to the Feasibility Study has been undertaken that held extensive discussions with the jeepney industry to understand how individuals and groups might be motivated to be involved in the delivery of BRT. A BRT operator, or operators, will be required that are trained and capable of offering the required service levels. There is much international experience in the engagement of existing, informal, operators becoming active in BRT operation.

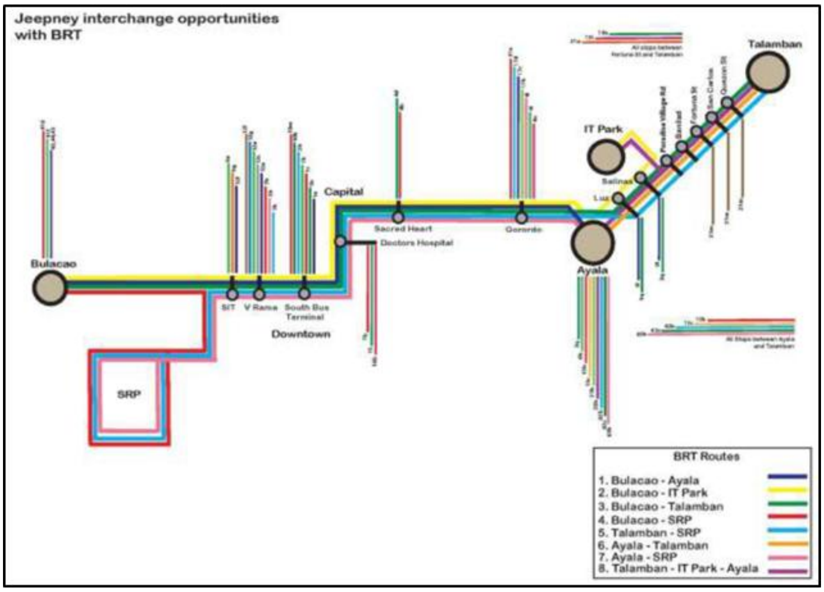

Figure 7 Jeepney Interchange Opportunities with BRT

6.1.9 Environmental and Social Benefits

The operation of the BRT should have beneficial effects on the surrounding environment overall. The introduction of the BRT will allow faster more efficient mass public travel and improved traffic flow on the adjacent traffic lanes and smoother asphalt pavement and improved road side gutters and drainage can be expected to reduce the accumulation of road side dust and therefore air pollution from disturbed dust should also be controlled. The improvement of the road will be within the existing corridor and will use existing flyovers where necessary keeping BRT vehicles away from roadside sensitive receivers such as places of worship and schools. The residential areas are generally set back from the roadway. Gaseous and particulate emissions from the expected traffic flows will be well dispersed from the road and under the new arrangements there will be insufficient additional traffic to increase noise above the acceptable standards. Overall the Project may result in increasing vehicle speeds but additional future traffic should be better organized and there will be additional signage and pedestrian controls so that community safety issues are unlikely to arise. The overall conditions for efficient BRT travel by the public, the segregation of traffic and the enhanced road facilities will mean driving conditions improve. Routine safety measures, signage and road markings will be introduced to reduce pedestrian and driving risk further.

GHG Emission Benefits

At present, around 474,000 tonnes of CO2e are currently being produced by some 893 million vehicle-km of travel across the Cebu City road network. For the proposed BRT corridor, 120,000 tonnes of CO2e are being produced by 205 million vehicle-km. In terms of GHG emissions per person-km, 135.6 grams CO2e are being produced per person-km across Cebu City by passenger transport and 131.1 grams CO2e per personkm in the BRT corridor. Current urban transport greenhouse gas emissions across Cebu City per GDP per capita are 323.1 tonnes of CO2e per US dollar4 GDP per capita.

For the future, implementing the BRT-ATC scenario in Cebu City would give significant greenhouse gas emission benefits over the baseline scenario against the three main performance indicators. In particular, it would:

- Yield annual savings across Cebu City by comparison with the baseline scenario of 115,000 tonnes of CO2e by the year 2020 and 192,000 tonnes by 2025 (equivalent to 24% and 41% of the current total annual GHG emissions from urban transport in Cebu respectively).
- Save a total of 3,867,000 tonnes of CO2e over a 20 year period from 2015 by comparison with the baseline scenario - the equivalent of saving over eight times the current total annual GHG emissions from urban transport in Cebu.
- Reduce GHG emissions per person-km below current levels and in the BRT corridor keep them below those levels for the 20 year period from 2015. Across the city, GHG emissions per person-km would be kept below current levels for around 9 years from 2015. Under the baseline scenario by contrast, emissions per person-km would exceed current levels within 3 to 4 years from 2015 and then continue to rise throughout the 20 year period.

6.1.10 Economic and Financial Appraisal

The economic appraisal defines the project's viability from a social perspective. The financial appraisal defines the project's viability from a business and commercial perspective. The table below presents opening year (2015) revenue against opening year recurring costs. Total opening year financial benefits are estimated at approximately 880 million Pesos. This covers all recurring costs including direct operating costs including vehicles, operational control, systems management, infrastructure maintenance and technical support consultancy and leaves a net surplus of approximately 25 million Pesos. Overall, opening revenues cover approximately 103% of all recurring costs assuming a fare of 9 Pesos. It is estimated that increasing BRT fares to 10 Pesos would allow opening year revenues to cover 114% of all recurring costs.

Over an appraisal period of 2015-2042 economic viability is proven using both World Bank and NEDA discount factors.

Table 8 Cebu BRT Economic Appraisal

Economic Benefit Cost Ratio (EBCR)	8.0
Economic Net Present Value (ENPV) (millions of Pesos)	81,439
Economic Internal Rate of Return (EIRR)	39%

7 PROSPECTS FOR BRT IN THE PHILIPPINES

Conditions are ripe for the planning and implementation of BRT in the Philippines. For one, BRT has officially been recognized as belonging to the menu of Environmentally Sustainable Transport (EST) strategies of the country. Hence, it is officially recognized as a potentially viable option. Second, climate change funds are available to finance studies and implementation of BRT systems in Metro Manila and Cebu. Thirdly, the Cebu BRT has been identified as one of the top PPP undertakings of the current national government.

7.1 EST Framework

Efforts to implement BRT in the Philippines have been officially included in the Environmentally Sustainable Transport (EST) Framework for the Philippines. The Presidential Administrative Order No. 254 issued in January 2009 mandated the DOTC to develop the EST Framework for the country. The National EST Strategies, Indicators, and Action Plans were submitted by the DOTC to the Office of the President and the NEDA in November 2009. The EST strategies include the BRT as a environmentally sustainable mass transit option, officially recognizing it as an option for cities in the Philippines.

7.2 Climate Change Funds

There are funds that are being made available for BRT studies and implementation courtesy of Climate Change funds. At present, 350 Million US$ consisting of 250 Million US$ from the International Bank for Reconstruction and Development, 50 Million US$ concessional loans from the Clean Technology Fund, and 50 Million US$ Philippine government counterpart funds for 50 kms of BRT in the Philippines (PPIAF Update).

7.3 Public Private Partnership

BRT implementation is an opportunity for private-public partnership with official development assistance, ensuring the barest Philippine government exposure. As a PPP undertaking, the BRT infrastructure (busways, stations, terminal and depot, ITS) may be paid for by the government through Official Development Assistance while rolling stock or buses and their operations and maintenance may be invested in by the private sector. The Cebu BRT project has been identified as one of the 16 top PPP projects of the current administration (The Freeman, 2010).

8 SUMMARY

This paper presents the concept of BRT as a public transport system and compares it with other mass transit options. The paper also discusses the factors that warrant the implementation of BRT in the Philippines. It also presents the highlights of the Ceby BRT study. The paper is capped by a discussion of the conditions and opportunities which are auspicious for further BRT planning and implementation in the country.

APPENDIX

[1]Lloyd Wright quoting Levinson et al. Bus Rapid Transit, Volume 1: Case Studies in Bus Rapid Transit, TCRP Report 90. Washington, DC, USA. Transit Cooperative Research Program

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THE SKYCOURT AND SKYGARDEN: TOWARDS A VERTICAL URBAN THEORY

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Abstract : Population increase, advances in technology, and the continued trend towards inner city migration through economic progress has transformed the traditional city of spaces into the modern, high rise city of objects. This has necessitated alternative spatial and technological solutions to replenish those environments that were once so intrinsic to our day-to-day interactions and communal activities. This paper considers the skycourt and skygarden in terms of their social, economic, environmental and spatial benefits that they provide to the urban habitat. The paper argues that they have the potential to be 'alternative' social spaces that can form part of a broader multi-level open space infrastructure that seeks to replenish the loss of open space within the urban habitat. It starts to illustrate how semi-public spaces can be incorporated into high-rise structures, and be suitably placed into a hierarchy of open spaces that supports the primary figurative spaces on the ground or, in their absence, create them in the sky. It also advocates for a new hybrid that harness the social characteristics of the public domain, but placed within buildings as an alternative social space for the 21st century. The paper aims to educate the reader of the socio-spatial functions and the broad socio-economic, environmental, and psychological benefits of sky courts and sky gardens as an additional component within the architectural and urban vocabulary of the city. Beyond social and transitional space, psycho-physiological wellbeing, economic generation, biodiversity enhancement, and environmental filtration, the paper argues that the skycourt and skygarden can potentially be a forum surrendered for cultural good, and therefore become public beacons and cultural foci for the 21 century city.

1 The skycourt and skygarden: an historical overview

There have been notable historical precedents that suggest the skycourt and skygarden are not phenomenon only known in our lifetime, but can be found in the urban habitats of antiquity and the immediate past. We can trace the skygarden back to ancient civilisation's quest to integrate greenery into cities at height. The *Hanging Gardens of Babylon,* built by Nebuchadnezzar II for his wife Amyitis, were documented by the Greek historian Diodorus Siculus in the 6th century BC as being a series of planted terraces that were supported on stone arches 23 metres above ground. The Syrian King reputedly built the hanging gardens in an effort to please his homesick wife of Persia, who longed for her homeland. Trees were embedded into tiered stones terraces, with permanently green foliage made possible by a mechanical irrigation system from the Euphrates River.

Al-Fustat, an Egyptian city known for its shaded streets, gardens and markets that today forms part of Old Cairo, similarly incorporated skygardens. Modern archaeologists have recovered relics that came from as far as Spain, China, and Vietnam, providing evidence of the city's importance as a trade hub as well as being a production centre of Islamic art and ceramics. It was reputedly one of the wealthiest cities in the World and had an estimated population of 200,000 people (Mason, 1995). The Persian poet and philosopher Nasir Khusraw described the city as having a number of 14 storey high-rise residential buildings that were surmounted by recreational roof top gardens that were customised by its inhabitants and irrigated by ox-drawn water wheels (Barghusen and Moulder, 2001; Behrens-Abouseif, 1992).

In Italy, hill towns such as Urbino and San Gimignano manipulated the natural topographic levels of its location to create urban settlements that were protected given its elevated position (figure 01). During the Renaissance, steeply terraced gardens and green roofs were common in the city of Genoa. Raised piazzas, interconnected by steps to traverse the changes in level permitted surveillance of the land beneath but also environments for public events to take place (Peck et al, 1999). At the private scale, the *Villa Giulia,* built between 1550 – 1555 by the architects Ammanati and Vignola for Pope Julius III, manipulated the natural topographic and man-made levels in order to allow the Pope and his entourage to enjoy views of the surrounding landscape from its raised terraces and three-tiered covered loggias (Watkin, 2005).

By the 19th century, the ability to glean panoramic views was no longer the realm of the privileged few. The democratisation of view from ever increasing heights, made possible by the invention of the elevator, further challenged any exclusive preconceptions of elevated levels by providing opportunities for society to survey the city as a means of recreation and delight. The *Eiffel tower* of the Paris exposition of 1886 stood as a testimony to human ingenuity and technological advancement in an industrial age. It provided a platform from which people could marvel the Paris skyline for an entrance fee, and remains the most visited paid monument in the World. It's ability to provide a panorama as a sellable commodity and thus a means of income generation has since become a template for many an observation gallery in tall buildings within cities around the World.

By the 20th century, the influence of Le Corbusier and his manifesto of celebrating the rooftop as a further means of supplementing those open recreational spaces on the ground further spawned examples of planted and unplanted sky rise social spaces within an increasingly object driven modern city. Architects such as Ken Yeang went further to adopt the skycourt as an interstitial open space within buildings for its environmental as well as socio-economic benefits, and has become an increasingly important part of a new architectural vocabulary within high-density urban environments (Pomeroy, 2012) (figure 02). Norman Foster's *Commerzbank* in Frankfurt was conceived as three 'petals' of triangular office floor plates, grouped around a central 'stem' formed by a full height atrium (figure 03). Sealed sky courts, four storeys high, provide a social dimension for the office employees to use as places of meeting, events, lunches or remote working.

The skycourt and skygarden continue to be part of the urban habitat today, and exist for the very same reasons that they did in antiquity. They are places of recreation for the individual or group, can afford a memorable view and vantage point, and can offer environmental as well as socio-physiological benefit. Yet despite such historical precedents and the important role that they play, little has been done to define the skycourt and skygarden in terms of their spatial, social, economic, environmental, technological or cultural contribution, or the increasingly diverse role that they play within the urban habitat. The following sections will seek to define their multi-faceted nature.



Figure 01 *San Gimignano,* Siena: a lush and steeply terraced hill town in Italy with public spaces at multiple levels

Figure 02 *Unité d'habitation,* Marseilles: recreational space on the roof to supplement open space on the ground

Figure 03 *Commerzbank,* Frankfurt: an exemplary environmentally responsive building that incorporates skycourts to form a vertical working village

2 The skycourt and skygarden: spatial morphology and perceived density

In urban terms, 'density' often carries the negative spatial and social connotation of the close proximity of buildings in one constrained location, or of cramped living conditions where there is a heightened proximity between individuals. According to the academic Vicky Cheng, perceived density refers to 'the interaction between the individual and the space, and between individuals in the space', which requires the concepts of spatial density ('the perception of density with respect to the relationship among spatial elements') and social density ('the interaction between people') to distinguish between the two different aspects of the former (Cheng, 2010). She points out that these definitions demonstrate how perceived densities straddle different disciplines under different contexts and how urban density is intrinsically associated with the shaping and densification of urban morphology.

Societies aversion to urban density given pre-conceived notions that such environments lack space for interaction, or are homogenous environments that lack character, therefore requires careful consideration – particularly as there are a myriad of case studies of high-density environments that embody such attributes but are celebrated urban settings for its inhabitants and visitors alike (OECD, 2012). Hong Kong and Paris demonstrate this, and also how high-density urban habitats need not relate to just high-rise. An investigation into the spatial morphology of Hong Kong and Paris demonstrates that the iconic high-rise developments of the former may be perceived to be higher-density than the lower-rise developments of the latter, and yet the reality is that Hausmann's 6-7 storey districts are in fact denser than a Hong Kong neighbourhood of 20 storeys. When comparing the 2 cities in terms of floor area ratio (FAR), Paris has an FAR of 5.75, whilst Hong Kong's is 4.32, demonstrating that higher densities can be achieved by alternative building forms to the high-rise typology, which can similarly reduce perceived densities (OECD, 2012) .

It perhaps comes as little surprise that the skycourt has become an increasingly important element within the architectural vocabulary of the worlds' tallest buildings and the densest environments as a means of reducing perceived densities. A skycourt can be initially defined in terms of their spatial morphology and how they can reduce the perceived densities of a tall building, or high-density development, by breaking the mass and potential monotony of repetitive floorplates by the juxtaposition of solid and void (Pomeroy, 2005; 2007). They have the ability to evoke the human scale and proportion of the traditional street by presenting themselves within high-density urban habitats and tall buildings as interstitial open or enclosed spaces that balance the figurative (semi-public) void within the solid of the (private) object.

As the word 'court' suggests, a sense of enclosure can be created by the void space being bordered by other buildings within the immediate urban context, or formed by its own internal facades. Skycourts are often located to the perimeter of buildings and are commonly 3 stories or more to allow the benefit of greater light and ventilation to penetrate deeper into the structure – thus enhancing the internal environment. Such proportions also permit, depending on orientation and climatic factors, the incorporation and growth of trees or extensive landscaping to further enhance their aesthetic, socio-physiological and environmental properties of these social spaces.

A rooftop garden has been defined as a landscaped environment built on the roof of a building that is strong enough to support the load, and is ideally suited to reinforced concrete and steel structures (Osmundson, 1999). A skygarden, on the other hand, tends to refer to an open or enclosed landscaped open space that can be dispersed through the higher levels of the urban habitat or tall building, and has become a generic term that occasionally substitutes the terms skycourt and rooftop garden. As the name suggests, emphasis is often placed on the aesthetic qualities of the garden setting and its appeal to occupants. Just as one normally finds a proportion of open space to built-up area in ground scraping mixed-use developments, skycourts and skygardens start to vertically balance open space to built-up area ratios within the tall building (Pomeroy, 2010).

Stephen Holl's *Linked Hybrid*, in Beijing, explores the de-densification of urban centres by the incorporation of skycourts, skygardens and skybridges and acknowledges Beijing's change of urban morphology (figure 04). The Linked Hybrid conceptually seeks to reconcile the city of objects with a city of spaces by interlinking 8 towers via a 20th storey ring of skybridges that include sports facilities, education, bookshops, cafes, exhibition space, healthcare, postal and management services. The typically repetitive nature of the high-density residential development in the region is discarded in favour for a diversity of apartment configurations and sizes that are further spatially deconstructed by the presence of the skycourts that help reduce the perceived densities.

Figure 04 (left to right): *The Linked Hybrid*, Beijing: skycourts, skygardens and skybridges seek to reduce perceived densities

2.1 The skycourt and skygarden as a social space

The academic Ulrich Struver's notion of critical spatial identities acknowledges relationships between groups as opposed to boundaries (Struver and Best 2002). Groups may have different spatial interpretations of a given space which sets up power struggles, requiring one power to be dominant (appropriating the space in such a way that would be perceived as conventional); the others subservient (often perceived as unconventional). For instance, what may be used as a transitional space between buildings (as governed by an institution and perceived as the conventional) may also be used as a skateboarding area appropriated by a subculture (as appropriated by society and perceived as the unconventional).Such an interdependence of dominant and subservient powers creates a formative tension that can be used as an instrument of power; the enforcing of such, whether by a private corporate body, council, individual, group or association being the device to control, maintain or manage.

The skycourt and skygarden can act as social spaces in the sky that help replenish the loss of open space potentially surrendered through urban densification. Like its public space counterpart, these skyrise spaces can permit communal group's to form and disband, and in so doing potentially present the contestation of its space amongst social groups as to its function that meet regularly. For instance, students may gather within such spaces outside of school hours to share notes before disbanding; office workers may meet with fellow workers from different departments for coffee or lunch breaks, before returning to their respective departments within a working day; residents may populate these spaces during the weekend and / or in evenings to meet with neighbours and friends before retiring to their home, and tourist groups may gather to observe a panoramic view but will similarly disband upon closing time. It's continual use by a dominant individual; group or association can imprint an element of informal territoriality on a place that may implicitly restrict the use of the space by others.

Unlike its open space counterpart on the ground, which tends to be governed by public interests and permit a spontaneity and freedom movement, speech and action, the skycourt and skygarden are often semi – public and are governed by private interests. This in turn imparts particular social restrictions that are more formal. Despite bearing public domain characteristics that allow the user a particular freedom of movement or the ability to appropriate the space as a place of recreation, amenity and social interaction, they're nevertheless managed spaces that are physically constrained by the very structure that retains them and are controlled by the institution, company, association or group that governs the tall building (Pomeroy, 2012). This inevitably leads to limitations on the patterns of speech and action of the individual, group and association appropriating the space give the dominant (private) parties control of the space. The resultant social spaces are often highly classified environments that often have explicit rules of exclusion that may be time-based (i.e the operating hours of the corporation and the levying of an entrance fee) or implicit rules of inclusion that are social activity based (i.e to be part of a studying community; an office community; a residential community or a tourist community).

The *Pinnacle*, in Singapore, demonstrates such an approach in its ability to use 12 sky gardens to interconnect its seven, 50 storey high-density social housing blocks comprising of 1848 family units (figure 05). The intermediary gardens at the 26th floor serve the residents only, whilst the 50th floor roof top garden is accessible to the public in addition to residents. The 26th storey intermediary gardens have explicit rules of governance as to who can enter and who cannot – they are ultimately privatised spaces for the sole use of its residents and are thus encoded with explicit rules of exclusion, despite being deemed public by State. It's 50th storey sky garden, again deemed public, also has explicit rules of governance but are encoded with implicit rules of exclusion with the proposed levying of an entrance fee to gain access to it as an observation deck. Those who can afford to pay for a view will enjoy a panoramic skyline; those who will not or cannot will be excluded by their own choice or economic circumstance (Pomeroy, 2012).

Figure 05 (left to right) *The Pinnacle*, Singapore: explicit rules of governance that negate particular freedoms of speech, motion and action , an example of how skycourts can act as new social spaces for residents to enjoy

2.2 The skycourt as a transitional space

When inner cities become denser and pedestrian movement increases, the two dimensional plane of the city reaches its elastic limit. It forces the city to move to a second stage of development whereby it can take no more growth without incorporating auxiliary systems and layers, such as transit, parking and subways, to facilitate choice and freedom of movement (Siksna, 1998). This inevitably thrusts itself into the third dimension in order to cater for increased density and movement. A city like Hong Kong, with its myriad of skyways, bridge links and multi layered movement systems above and below ground cannot reach such a threshold of movement needed to expand into the third dimension unless it has the prerequisite urban density of its centre to sustain an increase in population. Without such infrastructure, the compact city would run the risk of accessibility suffocation due to its own success (Gabay and Aravot, 2003).

Similarly, the tall building typology cannot reach its threshold needed to expand skywards into the third dimension unless it has the prerequisite sky courts and auxiliary systems (i.e the deployment of underground trains, parking structures, sky bridges and other technical facilities) to sustain an increase in occupancy or pedestrian flow. Without such infrastructure, the compact city of objects would similarly run the risk of accessibility suffocation. The need for improved circulatory methods to facilitate an ease of pedestrian movement at height, is as pertinent in the tall building typology as it is to the urban environment at grade, and reinforces the importance of ensuring an equality of movement for civil society in the sky as well as on the ground.

The skycourt can act as a transitional space in its ability to be a circulatory interchange in super-tall buildings, whereby lift car capacities, waiting times and floor plate efficiencies, necessitate the stacking of local lift cores to enhance the economic viability of the development. Just as civil society is provided with both choice of route and mode of transport on the ground (the ability to walk, cycle, drive, or take public transport through a variety of axes), the occupant or visitor is faced with a multiplicity of circulation routes and modes in the sky, making the skycourt not only a destination place of recreation and planned meeting, but also a transitional space of movement and chance meeting (Pomeroy, 2008). Consequently, the incorporation of skycourts can facilitate the occupants' onward transition from one part of the tall building to another, by linking the disparate vertical circulation modes, and even to other buildings and their skycourts (Wood, 2003). The skycourt acts as a pseudo-vertical arcade by its ability to link primary, secondary and tertiary modes of vertical circulation.

The incorporation of retail compounds the analogy further – the skycourt being the (vertical) arcade; the lifts, escalators, staircases, ramps and other (vertical) circulation means being the hierarchical orders of boulevards, streets and passageways. It begins to ameliorate the risks of visual disconnection and separation from the activity of the street at ground level, as the horizontal and vertical means of circulation within a complex of tall buildings serves to create *new eyes on the street in the sky* which can serve to aid security through the recognition of who is a stranger and who is not. Furthermore, it presents an opportunity to escape from one tall building into another via skybridge. Post the September 11 terrorists attacks, there has been a radical re-evaluation of mass evacuation procedures from tall buildings – thus ameliorating the need for phased evacuation which can not only compromise life safety but may be economically unviable due to the increase in escape stairs required and the consequent reduction in net-to-gross floor efficiencies (Wood, 2003).

The *Shard* London Bridge demonstrates how skycourts can be incorporated at mid-level as a transitional space (figure 06). The 72 storey tower is the tallest mixed use structure in Europe - standing a little over 310 metres tall. The first 26 floors above the public piazza houses modern high – specification office space with winter gardens. A five star hotel with 200 rooms from the 37th to the 51st floors, and residential apartments from the 52nd to the 63rd, completes the programme. Separating the working from the living spaces is a three-storey skycourt that acts not only as the community space that gels the disparate functions together, but also a means of transition between them – an interchange point amongst different social functions that starts to imprint a 24-hour city quality. Such a space is designed to provide memorable views of London for its 800,000 visitors per year, and contains retail, bars, restaurants, leisure, and performance and exhibition activities as well as social spaces for the tower's inhabitants and the broader community. It effectively becomes a new square in the sky – a place of orientation, chance or planned meeting and onward journey to one's destination.

Figure 06 (left to right) *The Shard*, London: its mid-level skycourt acts as a transitional space as well as a destination space

2.3 **The skycourt and skygarden as an environmental filter**

Natural light and ventilation are essential for the survival of living organisms. Builders of traditional buildings understood the importance of harvesting natural light and ventilation before Man's technological ingenuity led to inventions that ameliorated the need to rely on proximity to perimeter windows. As noted by the academic Rayner Banham in The Architecture of the Well-Tempered Environment, the architect by the turn of the 19th century had ceded such environmental considerations to the consulting engineer (Banham, 1984). Today however, both academics and professionals alike have returned to the basics of passive design, in order to enhance internal comfort levels and reduce consumption in buildings. We see such considerations of filtering the benefits of natural light and ventilation through open spaces such as arcades and atria, though arguably this requires heightened glass performance and / or shading devices to counteract the potential heat gain through direct solar exposure.

The incorporation of greenery to skycourts and skygardens can counteract such issues given the ability of plants to reduce external climatic factors. Greenery to the horizontal and vertical surfaces of skycourts and skygardens can help reduce urban heat island effect, the absorption of heat in the building fabric, and its subsequent re-radiation by harnessing the biological properties of plants – such as photosynthesis, respiration, transpiration and evaporation. Planted surfaces can help cool the environment by between 3.6-11.3 degrees centigrade, with wall surfaces being reduced by as much as 12 degrees centigrade (Alexandri and Jones, 2008; Wong et al, 2009a). When trees are positioned at the perimeter of skycourts, they can act as a shading device, with light tree canopies intercepting between 60% and 80% of sunlight and dense canopies intercepting as much as 98% (Johnston and Newton, 2004). They can also help act as a wind-break and thus reduce loading to structural frames whilst also helping to act as an acoustic buffer to urban noise.

Planted skycourts and skygardens can also improve air quality and help reduce respiratory illnesses by acting as a 'sponge' to noxious pollutants and carbon dioxide in the atmosphere, with climbing plants showing a particular susceptibility to absorbing and filtering dust particles. Urban settings with trees may reduce dust particles to 1000-3000 dust particles per litre whilst an environment with no trees may contain 10,000-12,000 dust particles per litre (Johnston and Newton, 2004). They also have the added ecological benefit of retaining storm water, thus helping reduce run-off into drains and the occurrence of flash floods during extreme rain periods. Studies in Berlin showed that green roofs absorb 75% of precipitation that falls upon them, reducing immediate rainwater discharge by 25% of normal levels whilst helping remove impurities. The filtration properties of plants can remove over 95% of cadmium, copper and lead from rainwater and 16% from zinc, whilst Nitrogen levels can also be reduced (Johnston and Newton, 2004).

Yeang's *Singapore National Library* aptly demonstrates the incorporation of planted skycourts for such environmental benefits (figure 07). The library has over 8,000 square metres (or 10 per cent of the total gross floor area) of designated green space that acts as an environmental filter to the low angled east and west orientated sun – thus helping reduce solar heat gain and providing an effective shading device. There are two main areas situated on the fifth and tenth floors. These contain 12 metre high trees that increase bio-diversity, help retain water on site, and can also help regulate the ecosystem by acting as a respiratory system and filter of noxious pollutants. The provision of the skycourts, its greenery and bio-climatic design considerations also helps enhance the indoor thermal performance and its energy efficiency. When compared with a typical Singaporean commercial building's energy consumption of 230kWh / sqm / annum, the library has been able to reduce its consumption by 78 kWh / sqm / annum to give an energy consumption of 152 kWh / sqm / annum – making it one of the most energy efficient buildings in Singapore (NLB, 2008).

Figure 07 *(left to right): National Library,* Singapore: the skycourt as an exemplary environmental filter

2.4 **The skycourt and skygarden: their economic benefits**

In a time of increasing global environmental and social consciousness, the need to challenge the preconceived ideas of the 20th century tall building has led to a paradigm shift in tall building design that re-evaluates structure, envelope and the functional programme of uses, in order to minimise consumption and preserve the natural and built environment for future generations. Such a shift has economic benefits, and celebrates the skycourt and skygarden as increasingly important components within the architectural vocabulary of the sustainable tall building typology that can help reduce energy loads within buildings as well being an income generating source that can draw people to it as a destination not normally associated with the development.

The environmental properties of greenery incorporated into skycourts and skygardens can reap benefits in terms of reduced energy consumption and therefore running costs. Roof top gardens and their greenery have been shown to reduce ambient temperatures given plants ability to absorb solar radiation. Studies have demonstrated that the exposed area of a black roof can reach 80 degrees centigrade, whilst an equivalent area beneath grass reaches only 27 degrees centigrade (Gotze, 1988; Kaiser, 1981). Gravel roofs have been shown to have temperatures of 30 degrees centigrade in comparison to 26 degrees centigrade for a green roof (Kaiser, 1981). The insulation properties of green roofs can reduce room temperatures beneath the structure by as much as 10%, thus helping to reduce artificial cooling and therefore running costs. When we also consider the shading properties of vertical planting within skycourts, Envelope Thermal Transfer Values (ETTV) can be reduced by 40 percent in comparison to a conventional building with no greenery (Chiang and Tan, 2009).

Yet the skycourt and skygarden can also extend beyond their energy reducing benefits to embrace direct income generation through its space provision. With continued urbanisation, the need to utilise available space becomes paramount.

The ability to 'future-proof' developments by incorporating skycourts and skygardens provide opportunities to extend into the voids of skycourts, and into the airspace above skygardens in order to increase buildable area and therefore locally increase density. Such an approach optimises existing structures and can potentially increase sellable and lettable areas of development whilst negating the need to demolish existing buildings and to rebuild – a process that can be potentially detrimental to the natural and built environment aswell as existing communities (Pomeroy 2011).

Their social function of providing a source of amenity can similarly offer economic benefits if incorporated midpoint within the building, as they can be a useful source of convenience, recreation and amenity that can negate the need to travel ground-wards for the grocery run, gymnasium visit or relaxation in open space. The critical mass of social and recreational activities, freed from the conventional setting of the ground plane, can enhance the footfall of the buildings occupants at height, thus providing opportunities for passing trade and income generation (Pomeroy 2012). Just as research has shown how public space on the ground enhances property values, so too can sky rise social spaces command a premium.

Given rooftop skygarden's elevated position at the pinnacle of tall buildings, they can also function as observation decks, bars and restaurants that can be income generating. The *Empire State building* famously weathered the storm of financial crisis in the great depression through its 86th floor observation deck that drew tourist receipts of 2 million dollars in the first year of opening – as much money as was taken in rent that year (Tauranac, 1997). At the turn of the 21st century, there has been an unprecedented number of tall buildings of over 200m that has allowed Man to satiate his appetite for cityscape view in the form of observation decks that can be found in the World's tallest buildings. Rooftop skygardens therefore provide an opportunity to observe memorable skylines and panoramic views and the ability for people to pause and orientate themselves within both building and urban context. In doing so, they can potentially become a source of income by levying an entrance fee.

The *Marina Bay Sands,* Singapore is a contemporary success story of the income generating attributes of skycourts and skygardens (figure 08). The 1.2 hectare park is the World's largest public cantilever and hosts a variety of amenities, including the longest elevated swimming pool of 146m amongst a lush tropical landscape setting. The skygarden is open daily from 9:30am to 10pm and can cater for up to 3900 people at any one time. It has become an income generator through the levying of an entrance fee of between 10-20 SGD dollars per person to gain panoramic views of Singapore's skyline from its observation deck, generating an income of 54,600-78,000 SGD per day (4). It also includes a number of roof top bars, restaurants, and shops that have become a popular alternative environment for locals and tourists alike to socially interact during the course of the day and night.

Figure 08 *Marina Bay Sands*, Singapore: the 1.2 ha skypark is the world's largest public cantilever

3 Towards a Vertical Urban Theory

3.1 The skyourt and skygarden: evolutionary observations

Today, technology further reduces the need for co-presence in space, as society can glean the very same commodities of transference virtually via the internet. This effectively renders public, and even semi-public space increasingly obsolete in their roles of being able to bring people together in exchange. Our sense of being social in public therefore becomes deliberate and planned, as opposed to being the result of daily casual social interaction that is spontaneous and unplanned. We pass through an increasing number of privatized transitional social spaces that permit movement in order to visit the retail mall, the cinema, the café, or the museum that are the privatized destinations that society plans to meet in.

The skycourt and skygarden has become another social space within the architectural vocabulary of the urban habitat, and currently remains predominantly managed by the corporation or landowner that controls them. They are differentiated by the fundamental truth that they can never be truly public unless they become ceded to state ownership and permit the individual, group or association the freedoms of speech, action and movement that one normally finds in the public domain of the street and the square. The skycourts and skygardens that we have seen similarly demonstrate this. These semi-public realms are, as the academic and architect John Worthington describes new social spaces, 'seismic creations' – created in an instant, highly classified to their correlating building function, socially controlled by the dominant (private) power, and spatially constrained by the structure that retains them. To this end, they have not necessarily promoted a social spontaneity, and their immediate creation is arguably the antithesis to the public realm that incrementally evolves with time and is the result of a continuous contestation of its space by its users, which, in itself, creates interest through the unplanned and unpredictable. Despite the reasons why they are currently not public spaces, we have started to see their evolution given changing social, spatial, environmental, cultural, economic and technological needs that permit the nurturing of public domain characteristics. This may bode well for society's co-presence and may enhance urban life quality as well as the natural and built environment.

We can see in the earlier completed examples that the skycourt and skygarden were little more than private terraces, very occasionally planted, and often accessed from the occupied internal areas of the building that retained them. They were often imprinted with the function and control of the dominant power that occupied the habitable space within. Their privatized nature often reduced chances for spontaneity; and the occupants within generally imprinted an implicit control on the skycourt's social use through their observation of such spaces by others. Their control therefore permitted only the occasional use by the worker or resident, which was often dependent on the familiarity of others within its proximity. Their use was predominantly one of the occasional lunchtime visit, or coffee break, and did not necessarily sustain regular patterns of use or heightened social interaction amongst groups (figure 09).

However, examples completed more recently showed the promise of more 'public' orientated environments, and their greater usage as an environment for transition as well as social interaction. Unlike their mono-functional predecessors that were less integrated with circulatory patterns, newer skycourts and skygardens formed both internal and external spaces that became more integrated into the cores of tall buildings – spatially linking vertical methods of circulation and facilitating transition; and socially linking occupants through the heightened probability of chance meetings and opportunities for spontaneity. As tall buildings continued to soar higher and embrace an increasingly mixed-use programme, the skycourt adapted to cater for a greater multiplicity of function. The skycourt, as an interstitial space within the mixed-use tall building, started to become a 'spatial gel' that glued together the disparate series of land use components within the tall building as well as beyond via the skybridge. This fostered greater usage and a sense of community amongst people from different backgrounds, groups and associations from different parts of the development and city. With society's heightened environmental awareness, the incorporation of greenery within skycourts and skygardens also became more prevalent in the acknowledgement of its environmental, ecological, and socio-physiological benefits.

In line with such social, spatial and environmental development, the examples under construction have been the product of an era when alternative social spaces have started to be placed into a hierarchy of urban spaces in terms of scale, use, and classification that support existing public spaces, and arguably start to blur boundaries between what is public, semi-pubic and private. What were once slender viewing balconies have become skycourts and terraces for individuals, families and groups to enjoy as individual private spaces with a greater multiplicity of function. Larger, more neutral skycourts positioned in prominent and easily accessible parts of the buildings have started to serve as broader circulatory interchanges that allow the casual interaction on an almost vertical neighbourhood level. When coupled with skybridges, they have become nodes of activity that further heighten social interaction by the presence of both income generating and recreational opportunities. In some countries such as Singapore, the progressive development of skycourts and skygardens has been enabled through economically incentivised legislation in the interests of promoting the cultural identity of a 'greener' city. Such legislative power, with the promise of enhanced permissible developable area and therefore enhanced return on investment, has allowed such skyrise social spaces become an increasingly popular addition to the urban architectural vocabulary of the urban habitat.

Banham's comment that 'no architect who considers himself worthy of his craft can bear to stand by and see his design destroyed, especially grand designs in the scale of the city' (Banham, 1976), is having to be re-evaluated given a rapid urbanization to cater for 70 per cent of the global population living in cities by 2050. The re-birth of the megastructure, an all encompassing framework that can house the functional parts of the city, not only explores porosity by the erosion of the building fabric to create social space, but also the counterbalancing of objects to create the very same. Arguably, this can be viewed as the space left over following form creation and may be conceived spatially as a 'vertical modernism' (figure 10). This is where counter-poised, object-driven blocks are left freely to float in undifferentiated sky space, and places the skycourt and skygarden as secondary to the blocks, and thus challenges the idea of containing social space as seen in previous examples.

The works on the drawing board embrace and develop both the concept of the point block tower and the interlinked series of tall buildings as megastructures. This could be in part attributed to population increase, the migration to city centres and the consequent urbanization, which necessitates an increase in density, scale, and multiplicity of uses within developments. This consequently requires a greater ratio of sky rise social spaces to built-up area. These environments – loftier to permit light and ventilation to percolate deeper inside the floor plates, greener and appropriately orientated to maximize climatic responsiveness, more integrated with circulatory patterns within the tall building and the city to permit an ease of movement, and activated by communal as well as economic uses to encourage greater social interaction within the development, may well prove to bear more public domain characteristics than its predecessors.

The future city is almost Utopian in nature, and arguably once again follows Banham's observations of how the perceived future often has elements of reality that can be found within the existing habitat (Banham, 1976). The visions appear to be unfettered by the realities of today and may be mistaken for being influenced by the celluloid machinations of directors such as Fritz Lang, Ridley Scott, or Luc Besson; or the vertical edifices on paper by architects such as Yona Friedman, Archigram or Super Studio (figure 11). Some of the case studies have demonstrated how the theoretical solutions of student's are heavily influenced by the issues that beset the city of tomorrow and are underpinned by more radical technologies and ideas that seek to address densification, space replenishment, social re-engagement, climate change, fossil fuel depletion, food and water distribution. The future city therefore must be utopian and challenging to safeguard against complacency and to continue the line of development of how visions can become a reality.

Figure 09 *Menara Mesiniaga,* Kuala Lumpur: the skycourt as an extension of the internal office function that is used for the occasional informal meeting

Figure 10 *Interlace,* Singapore: a megastructure that can be viewed as a vertical modernism with the skygardens floating in undifferentiated skyspace

Figure 11 Work from students of the Nottingham University MArch in Sustainable Tall Buildings

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TOWARD SUSTAINABILITY & RESILIENCE, FACING MAJOR RISKS, THROUGH PROFESSIONAL TRAINING & MEANS DEVELOPMENTS

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Abstract: The study proposed here intends to provide South-East Asia an efficient training system regarding prevention measures and right behaviors to adopt in order to educate populations (children, adults, students, professionals, craftsmen, shop tenants, civil servants, hotel staff and tourists) and avoid beforehand, unpreparedness, negligence and vulnerability increase, and then, in case of a major hazard's impact, dangerous reactions, disorder, injury worsening or panic. A good education, combined with appropriated prevention policies, is very efficient and can reduce disaster's socioeconomic impacts, injuries and death tolls by more than 80%. And it is also a great catalyst for local economic growth.

We aim here to improve populations' knowledge regarding major risks mitigation including professionals, such as architects, engineers, craftsmen, civil servants, facilities' staff, university professors, school teachers and others, by proposing to each trade some adapted training means. This may provide South-East Asia, with much higher "culture of the risk" and therefore, much higher preparedness level all over the region on very long term, especially regarding the six main striking natural and anthropic hazards which are: tropical storms, floods, coastal erosion, undesired soil effects, earthquakes, tsunamis and industrial accidents, plus the so called "secondary" or "associated" such as : fire, landslides, pollution, corrosion, etc.

Regarding to students' population, a close collaboration with most universities and pedagogic institutions, will afford specific pedagogic contents inclusion into existing programs, to provide students the most complete training and knowledge possible.

Key words: major risks, hazards, mitigation, sustainability, resilience, training, education, sustainable buildings, prevention

1 - INTRODUCTION

To consider only risks known as natural, Mother Nature, as we use to call it, is not, or not anymore, our original matrix. Jean-Jacques Rousseau precisely noticed that we are “society animals”, orphans of a world where we must learn to cohabit with an environment, which is not always favorable to us even if it brings us the necessary resources to our survival; therefore we must respect this environment, but also often have to protect us from it.
From of the moment our prehistoric ancestors placed a roof of branches above their nests, architecture was born. Because architecture, beyond any aesthetic, conceptual, social, economic or functional consideration, is made for enabling us to evolve in this poorly adapted environment, and has for ultimate aim, to provide a roof, a protection, above each one’s head.

Last 30 years’ experience shows that, at the time of the impact of an exceptional hazard, more than half of the undergone damages to structures, which most often are responsible for the heaviest losses in human lives, are due to errors of conceptual nature rather than non-observance or non-respect of safety, civil engineering or city planning requirements and rules. Therefore, it is essential to educate building designers, from graduate architects to simple craftsmen responsible for self-construction.

As a matter of fact, regarding to safety, prevention always prevails on cure. This concept initially applies to the “facing and behaving knowledge” which can be acquired only by experience and by training (education).
Furthermore, in Europe, but also especially in the countries of the ASEAN, tourism stands as one of the greatest economical growth’s factors. In some countries it is even the most important one. Therefore, in order to insure sustainable development by avoiding any severe impact of major risks on the main economical activities, it is essential to maintain constant tourism activities development by ensuring safety and proposing, in each country, adapted services to its own population, of course, but also to tourists regarding to major risks prevention and assessment, either before, during or after an eventual hazard’s occurrence, especially in areas prone to such impacts.

On the other hand, in most of the countries of the ASEAN, hotels are, with scholar, health and some public equipments, the only equipments able to propose wide gathering facilities and safe shelters in case of major hazards striking. Thus, as we will talk about later on, it appears that in most big cities they stand as best “shield” to protect and/or to welcome surrounding populations in case of need. It is obvious that, as a consequence, these structures have to be adapted, but their staffs have also to be properly trained.

It is fascinating to observe a 6 years old Japanese child acting with such coolness and maturity at the time of a strong earth tremor. Soon he feels the very first jolts, he quickly stands up and move in order to turn off gas and electricity, to open doors and windows, to cap his invalid grandmother with a protection and to finally take refuge under a table, without the smallest sign of panic. The same applies to the reactivity of Japanese population during tsunami alerts, which are always seriously taken, even after many previous alerts not followed by real consequences.
It has been evaluated that with good and adapted education of the populations regarding to major threatening risks, it could be possible to reduce socio-economic damages of more than 60% and losses in human lives of more than 80%. Thus, we are considering here one of the most essential matters regarding to major risks mitigation.
That applies as well to the youngest children, as to the whole population, including building majors professionals, but also all others (as security aids, public authorities, the various gathering facilities staff, adults at home, etc.), whose better adapted behaviors and knowledge will help perpetuating local economic growth.
Lastly, after approaching training of our professionals, tourists safety improvements and education of our populations, it is also essential to coordinate all carried out actions by endeavoring tools developments, allowing effective collaborative work between local public persons in charge and the different experts from the far-flung multidisciplinary field that covers the major risks mitigation responsible community. A necessary and essential collaboration (regarding human, technical, material, economical and political means), without which, no policy of mitigation would be effective.

Therefore, if here I will only focus on professional training, in fact, our actual intentions through the several researches programs we are coordinating today, in collaboration with many worldwide institutions, are to bring efficient solutions to the four following quoted fields:
- children education
- training of the professionals
- tourism guideline and information
- development of specific collaborative tools for the local persons in charge

2 - GENERALITIES

It is obvious that pedagogical and sensitizing intentions are common to the four quoted fields of investigation, playing an essential catalyst role within the whole nebulous project developed here. Because one of the first existing reason of a science, as technical as it could be, is its popularization, so that everyone can understand its principles and its aims and prides himself for belonging to those who learned, to those who know, to those who argue for their future, to those with whom an optimistic future could be shaped, by force, by perspicacity and by solidarity.
Architects, scientists, engineers, civil servants, contractors, craftsmen, but also professionals of tourism, education, industrial business, as well as the entire population, including children, major risks mitigation should be everyone's duty. Because we may be able to obtain a real improvement of the situation only by gathering our efforts, whether in Southeast Asia or anywhere else.
Earthquakes, tsunamis, hurricanes, landslides, floods, fire, industrial accidents, etc, are not isolated events, and we will always face this kind of hazards. It is then necessary to accept this fate and to work in such ways so that, from now on, these fatalities would cause less damages to our societies.
In fact This project of education, sensitizing and assistance, based on an international experience which extends from the country of the rising sun to the hard climate of the Sahara, will be, I hope, a great catalyst for innovative, effective and responsible policies, carried out for everyone and by everyone.

But before going any further and beyond any technological, legislative, social or economic thought, it is necessary to remind us the four "golden rules" of any major risks mitigation policy.
A greater rigor implies a larger responsibility of all the concerned people (architects, engineers, town planners, industrialists, professionals of tourism and education, rescues, public services, political leader, etc). It initially consists in including in their education a rigorous learning of elementary principles, taking into account the risk factor and sensitizing them to the need for their engagement in respecting, as previously said, the four following elementary rules of any preventive policy's finality, which are:

1 • To prevent human injury from the disaster resulting from the event **2** • To minimize the damages to property	***Physical damages***
3 • To ensure the continuity of vital services such as water supply, communication, rescue abilities and eventually electricity, gas, etc. **4** • To ensure the continuity of regional development and economical growth by minimizing the impact of an eventual hazard on its main activities	***System damages***

It is interesting to quote that these four "golden" rules are valuable for any major risks (natural, anthropic or accidental) and applicable to all the concerned majors. Regarding to architecture, for example, those rules must imperatively been taken into account during the entire necessary period to consider a project, from the conceptual phase to the completion of the project. And for any construction of public utility, in a risky environment, these four elementary rules should be imperatively included within the program and be quoted as a priority.

In France, a "damages' scale" has been produced by the ministry of Ecology and Sustainable Development. It makes it possible to classify the events among six different classes, from the slightest incident to the major catastrophe.

Class		human damages	material damages
0	incident	no injured people	bellow 0,3 M€
1	accident	1 or more injured people	from 0,3 M€ to 3 M€
2	serious accident	1 to 9 people killed	from 3 M€ to 30 M€
3	very serious accident	10 to 99 people killed	from 30 M€ to 300 M€
4	catastrophe	100 to 999 people dead	from 300 M€ to 3000 M€
5	major catastrophe	1000 or more killed people	over 3000 M€

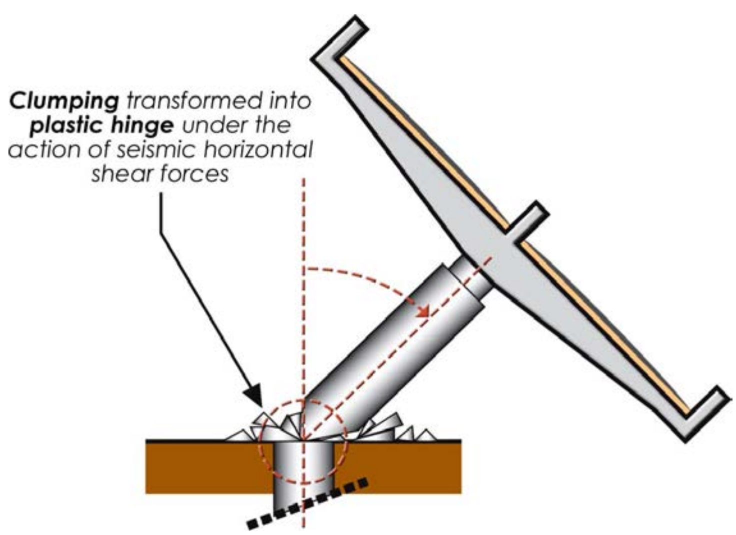
Nevertheless, the mega seism of Sumatra of December 2004, and the tsunami which followed it, generated more than 230,000 deaths and considerable socio-economic damages, still very difficult to evaluate today, thus far beyond the 1000 deaths and the 3000M€ of material damages of the class 5 defined above by the French authorities. The same applies to the Katrina Hurricane in

August 2005 or the North Japan seism in March 2011… It shows the extreme complexity of the phenomenon and the great difficulty we still have today to foresee such catastrophes. Because in the Indian Ocean, at the Mediterranean circumference, around the Caribbean sea, in South-East Asia, in the USA or in Japan, if the frequency, the type of risks and the threatening stakes can vary from place to place, there is no safe area, where populations would not be threaten by such catastrophes. However, to tackle this problem we have to build our policies according to our common memory, which is still far too insufficient today to enable any precise evaluation of "the probable", or to enable us to estimate the precise vulnerability of our societies.
On the other hand, we can already protect us and reduce vulnerability by preparing us for such impacts. It is what we call *major risks mitigation*. However, no mitigating policy can be applied without initially sticking to educate populations, to train persons in charge and to bring to our societies the necessary tools and means for the accomplishment of effective and adapted preparedness.

Recently, with the great progresses made in the field of the Information and Communication Technology (ICT), many new opportunities of improvements of our major risks mitigation policies are rising, especially in all the very specific fields concerned here.

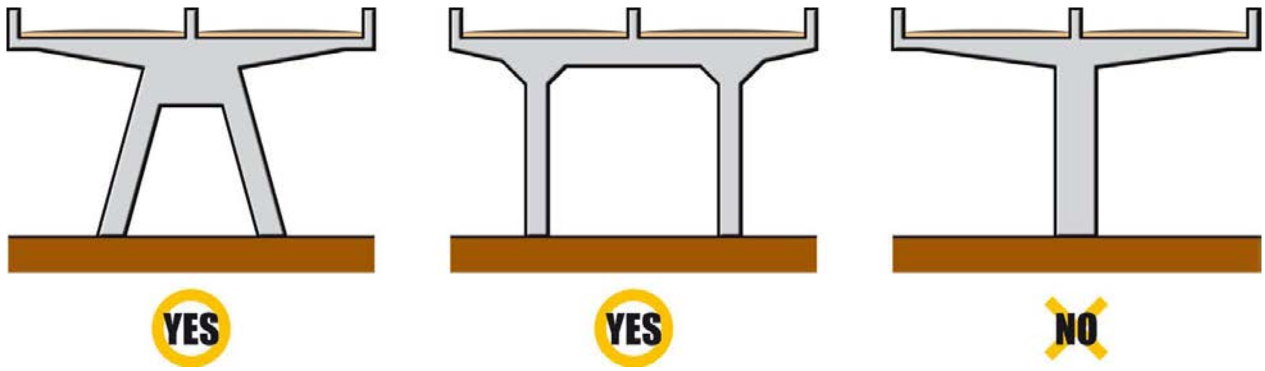
3 - TRAINING OF THE PROFESSIONALS

This research field concerns, at first, the development of training tools intended to master-builders. Our aim is to palliate many lacunas in the usual professionals training of master-builders in Southeast Asia, but also in Europe as in most countries in the world. By this project, we intend to offer innovating tools (adapted initially for France, England, Romania, Thailand, Malaysia, Philippines and Japan), which will facilitate the necessary "knowledge improvement" of idea men regarding to major risks issues.
Because, as we have underlined it before, and it is not exclusive to the ASEAN's countries and France ; "the last 30 last years' experience shows that, at the time of the impact of an exceptional hazard, more than half of the undergone damages to structures, which most often are responsible for the heaviest losses of human lives, are due to errors of conceptual aspects rather than non-observance of safety, civil engineering or city planning requirements".
In the field of paraseismic construction, for example, much before getting into the problem of any structural reinforcement, or having recourse to the use of some particular response control devices, the design of a structure must be carefully elaborated in order to reduce to the minimum possible any conceptual weaknesses, which could have disastrous consequences on its resistance, in the event of severe jolt, and that, even at the price of a conscientious reinforcement using paraseismic engineering rules. It should be also known that these engineering codes are more based on our passed experiences than on highly improved physical realities. In addition, paraseismic engineering is far from being an exact science. Proposed calculations, even within the strictest codes, are established theorems, which are extremely simplified. For example, let us quote that all the calculation methods suggested by today's codes, are mostly based on simple static physics axioms, describing a vertical distribution of theoretical forces along a structure, whereas reality can only be explained by a complex phenomenon of dynamic physics characterized by energy absorptions where the structure acts as a gigantic shock absorber. These paraseismic rules, can help the engineer to dimension and reinforce various structural elements, but will never enable us to propose real simulations of the phenomena, according to the type of jolts, especially on complex architectural projects or projects showing too many conceptual defaults.



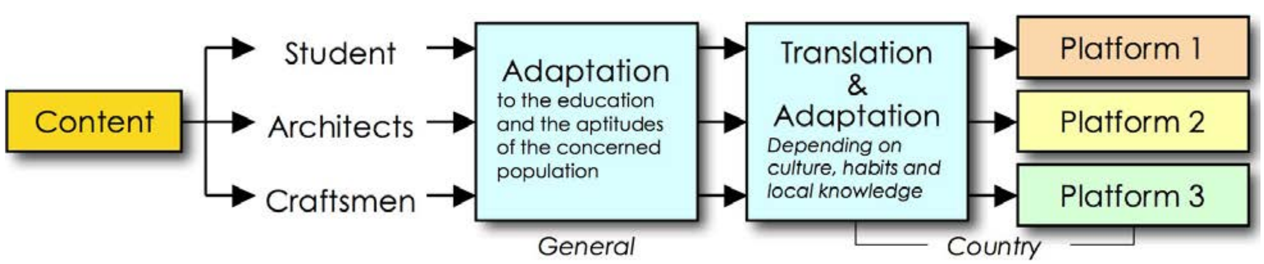
A famous case of conceptual error, simple to understand even for non-initiated persons, was the expressway of Kobe city, in Japan, which broke down on more than 500 meters during the seism of January 17th, 1995.
Though, the reinforced concrete pillars, which supported this expressway, had been the objects of thorough studies, which would have theoretically protected the structure against much higher earthquake intensities.
Under the effect of the seism (of 6.8 on JMA Intensity Scale), each pillar's clumping has been changed into "plastic hinge", offering no more resistance to horizontal loads. However, beyond some poor implementation reasons (due to construction period shortening), this phenomenon could have been easily avoided if the design of these pillars had been different. It would have even solved the problem without having recourse to excessive, expensive and, obviously, useless reinforcements.

If, from the very beginning, the designer had drawn these supporting structures by taking into account seismic risk factor, it would have reduce specialized civil engineers intervention and would have been certainly more effective.
The three following schemas show three different types of very simple structures, supporting an expressway of the same type than Kobe's one.



The third diagram shows the structure used in Kobe. If the first two structures, by their design, offer quite good resistance qualities to horizontal loads, obviously, it appears that the third does not offer a suitable conceptual solution and will require much higher dimensioning and reinforcements for the same resistance.
And the same applies to many other conceptual rules for all other types of structures.

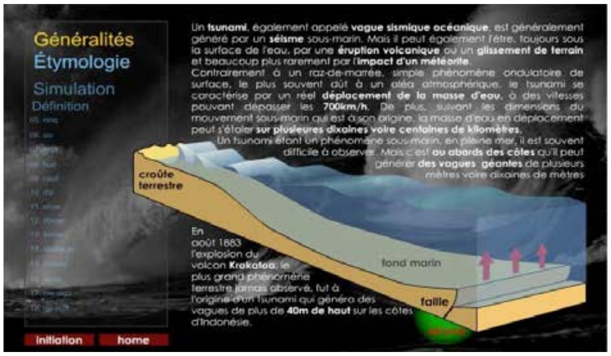
Thus, it is urgent to improve the training of the persons in charge of the design, who are the architects, but also of all the actors responsible for the building carcass, for the simple reason that many countries of the ASEAN (like others), especially in the field of individual housing, are subjected to *self-construction*, without resorting to any monitoring or expertise from an architect or a specialized engineer.
It is obvious that the teaching contents developed here will differ, at least in the way of communicating them, according to the comprehension level and the aptitudes of each targeted population. Thus, the created platforms will vary accordingly, depending on who are the targeted interlocutors : from graduate architects to simple craftsman, often without any real educational background (sometimes presenting reading difficulties and even inapt to use a keyboard, etc.).

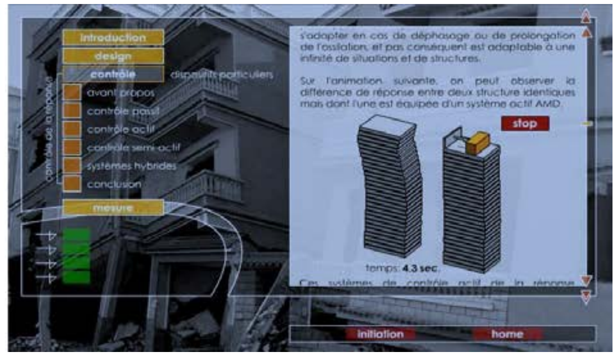


Lastly, in order to adapt the platforms accordingly to the targeted interlocutors, we must distinguish the professionals from the "future professionals" of the project management majors, who are the students in architecture and civil engineering.

If the resulting platforms will rather greatly vary according to the aptitudes and the "knowledge" of each targeted population : students, project management professionals already in exercise or self-educated craftsmen, the contents of the formations, regarding to elementary rules of design, structural engineering, implementation and sensitization to environmental risks prevention necessity would only slightly vary. Because it is essential, for knowledge improvement, to offer the most completes training possible to everyone. Beyond the general appearance and pedagogical tool itself, the platforms differ especially in their containers. Only certain themes, like, for example, "the structural response control” in paraseismic and paracyclonic design (reserved for university education and for graduated architects) or some practical developments with a glance of implementation (reserved to the “men at work”, generally craftsmen of the *self-construction*), will be able to differentiate the contents themselves.

• The platforms intended for students in architecture (and possibly in civil engineering) will be used as a lecturing basis by professors. Thus, they must propose a complete formation built according to a strict hierarchy, an organization and a suitable progressiveness to adapt this teaching to its integration into already existing pedagogical programs in order to improve them. They must also allow non-initiated professors to be self-trained by integrating particular notes reserved for them.





Teaching interface sample of platforms already developed and used in France, at the ENSAPVS (National Graduate School of Architecture Paris Val de Seine), within the framework of master courses specialized training.

These platforms have to propose a “lectures” part, a “discovery” part and a “practical work” one, dispatched over several years (according to the studies level of the students), while keeping in mind that these courses will be mainly handled by the professors themselves and projected onto a screen. Therefore, they must be, of course, theoretical, but also conclusive, attractive and offer the most complete contents possible adapted to a long period of training, from the “undergraduate courses” till the end of the “master courses”. It is obvious, that the platforms intended for the students will be by far the most consequent ones regarding to their contents.

• Platforms intended for project management body’s professionals, architects in exercise, will be, as far as their final aspect, rather similar to those proposed to the students, except that they will be much more practically than theoretically oriented and must be much more concise, since they will be used during quite limited time periods (one or two weeks of intensive formation, cumulated through several local specialized seminars).
With the assistance of specialized monitors, professionals themselves could directly handle them, during formation sessions, using several workstations (PC), or they could be used, when necessary, by “lecturers”. They will be, in fact, directly built according to the precise programs of each specialized local “seminars” and may be partially printed out.

• The platforms intended for project management’s self-employed craftsmen, will be developed and adapted according to the areas in which they will be used by taking into account the aptitudes of the concerned populations and their qualifications’ levels. In particular cases, those platforms could even allow interlocutors with reading difficulties.
Most of the contents would be able to be printed and all other ways to diffuse those contents have to be carefully selected in order to be adapted to local means without requiring excessive investments (tactile panels, video-projection…), either from teaching organizations or local communities and remain fully accessible to targeted populations.
Furthermore, these platforms will propose a much more practical training, with only some simple theoretical developments aiming at sensitizing the populations with various threatening risks, allowing comprehension, and focusing on practical work (materials, building processes, quality, conformity...) especially in the field of individual housing, small structures (shops, shelters, hangars, housing extensions, etc.) and rehabilitation.

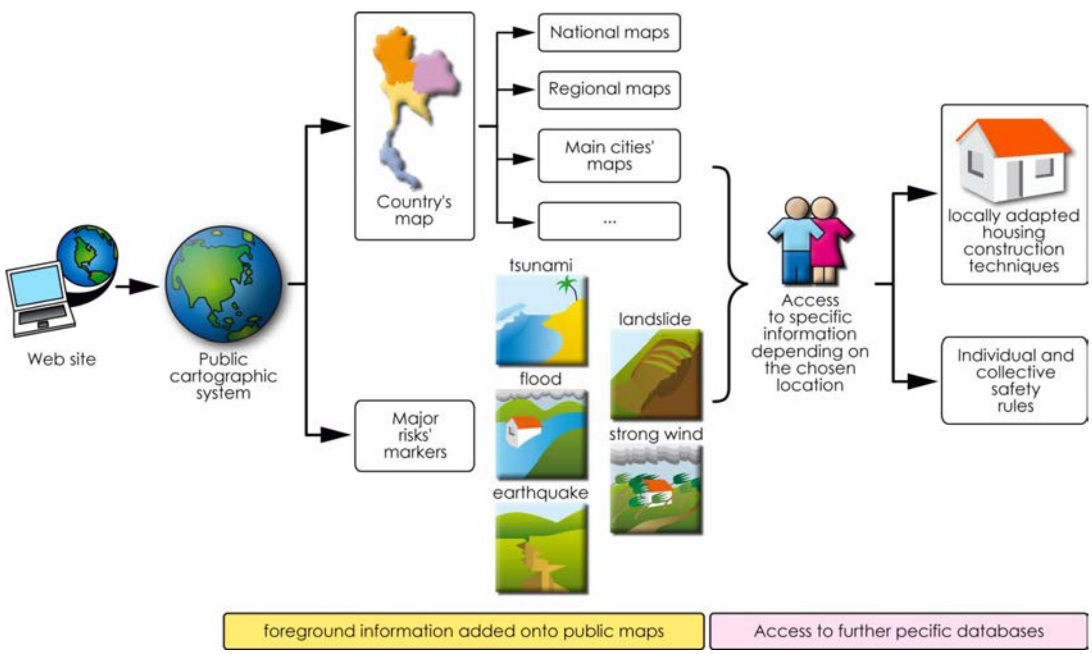
• An essential aspect to quote regarding to all these training platforms, for students, architects or craftsmen, is that beyond the teaching, allowing the targeted populations to acquire the necessary knowledge in design, structural analysis and practical work adapted to major environmental risks, these formations will intrinsically propose a strong awareness and many economic and ecological orientations, thus a wide sensitization to sustainable development ; The couple “major risks mitigation and sustainable development” being nowadays obviously indivisible.

But below project management majors, we have to consider another essential way of preventing natural hazards, before their occurrences. We reach here the "just before" period of an impact, in case of an alert, for example. To reduce hazards' impact we need, of course, to improve safety by durably reinforcing constructions and offer great shields to the threaten populations. We also need great detection, alert and communication systems, in order to anticipate the impact, then to inform the populations as early as possible and ask them to react the right way. But during an alert, we still have to control and manage populations' reactions, in order to avoid any random, unwanted or wrong behaviors, which could aggravate the situation. For that, we need to organize people confluence before hands, taking inventory of all available gathering places and existing shelters, which, in most of the ASEAN's countries, happen to be mostly main hotels, scholar equipment and several public facilities. Therefore, it is necessary to train a last professional body which is composed of this facilities' staffs, whose roles, in case of an alert, are essential to the whole population's survival (population, which includes local inhabitants and a varying toll of tourists, depending on the location).
For that, these facilities' staffs training will be concretized by interactive computer platforms, which specific contents will be sent to each ICT equipped facility and stocked into digital libraries, in order to be used during special monitored training sessions and/or self-used by any new recruit in case of need. The training content will more or less concern exclusively disaster prevention, people's first aid, emergency situation management and equipment maintenance. But these staffs should also be able to answer all eventual questions, regarding to emergency situation's eventuality, from usual hotel's customers (local or not) or any local citizen, at any time.
And as all this structures are not always including ICT abilities, mostly for smaller structures, some training contents would be also available through specialized TV channels and printed material.

But to provide efficient built environment resilience, beyond professional training it is necessary to inform populations, regarding to behaviors to adopt in case of the impact of an exceptional hazard, but also considering that in most of South-East Asian countries, for example, most of inhabitants use to take care themselves about their own house (or small collective housing), and even sometimes built it themselves. Therefore, even not being "professional", they have to be carefully informed regarding to proper behaviors to adopt but also regarding several construction, maintenance and upgrading techniques. A last type of informative and pedagogical platforms is then considered here.

3 - SPECIFIC PUBLIC TOOLS FOR CARTOGRAPHY, INFORMATION AND EDUCATION

The first tool consists of collecting, analyzing, managing and setting up a wide database regarding to major risks (in Thailand, in Philippines, in Malaysia, in Japan and in France…). Data base, which is consultable through a graphic interface proposing an interactive cartography by country, then by region, by city, etc., according to the same principles of zooms and information scaling than several current public cartography engines.



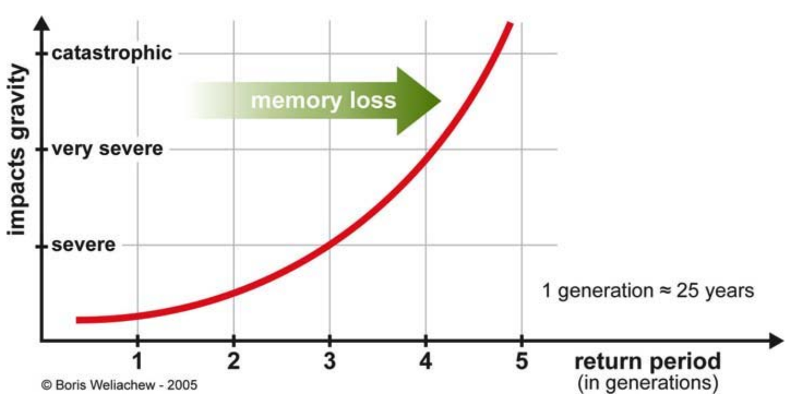
In fact the proposed interface allows, from the standard cartographic engines, commonly used nowadays, to index all the most important risks of tsunami, flood, earthquake, landslide and storm types, then to highlight them with the use of interactive "markers" making it possible to access, not only to information concerning the indexed risks, hazards' history and today's local situations, but also to additional information related to regional essential safety and construction rules.
This public tool makes it possible to get a precise history of disasters within a particular area (and thus to evaluate hazards' return periods, etc.), but also to apprehend the current threatening risks and to obtain all necessary information regarding to hazards prevention, to individual and collective safety measures and behaviors, and to the social and economical activities durability (rather than only at constructive, material and behavioral levels). The concept proposes a system with references to a double database : one on the history of the catastrophes in each area and the other quite similar to the previously quoted contents for professionals training, but this time intended for a larger public, initiated or not.
Starting from a precise Internet gate, according to each countries' wish (choice accrue to the national and/or local authorities), users navigate through familiar cartographic interfaces on which appear, in double exposure, colored markers pointing towards areas, precise administrative districts, cities, villages, housing blocks, etc., according to the scale of the zoom; precision of the markers being directly related to the scale of the map. Then, by pointing markers, small windows pop up, giving information regarding to major risks threatening the area, as well as links toward precise history of disasters recorded locally and toward various construction, professional and behavioral rules that are essential for individual and collective prevention and safety.

4 - TOWARD EXTENDED PARTNERSHIP

To bring to completion such a training and prevention program that intends to reduce our societies' vulnerability, especially regarding to our built environment, we started research programs since several years now, in the frame of a worldwide scientific and pedagogical collaborative work gathering many different institutions (university laboratories, professionals and industrials). Our collaborative consortium today extends from France to Japan and many South-East Asian countries such as Malaysia, Indonesia, Vietnam, Thailand, Cambodia, Singapore and Philippines. But it stays true that for instance, if in France, in Japan, in Malaysia and in Thailand developments and researches are rather effective, for most of the rest of the South-East Asian countries, participation stays until today more or less at a simple "contact level". Therefore we still need your effective enrolment in this project. Furthermore, in the framework of its "Asian specialized pedagogical and scientific studio", of which I am the director, my own institution (the National Graduate School of Architecture Paris Val de Seine, Paris, France) is still open to any eventual new pedagogical and scientific exchanges agreements, especially with institution from South-East Asia.

In Japan, we are particularly collaborating with one of worldwide most active laboratory regarding to major risks mitigation, crisis situations' management and pedagogy, which is the Professor FUKUWA's Laboratory, of the Environmental Sciences Department of Nagoya University. Laboratory which is since years now, one of the leading institution in these field and even provide today, many pedagogical, training and technical tools such as all the "bururu" ones (http://www.sharaku.nuac.nagoya-u.ac.jp/laboFT/bururu_english/index.htm), etc. In France, I personally provide many specialized training courses and coordinate research, mostly at the ENSAPVS, but also in few other institutions from undergraduate level to post doctoral research.

These programs are funded for part locally but also by wider institutions such as the European Commission, the Monbukagakushõ (Japan), the ANR (France), etc.



At last, to conclude this paper let me remind you that as being in building business, architects, civil engineers and contractors have a main role to play in preserving the "memory" of our societies, one of the major catalyzer toward an ideal "culture of the risk", which, if as in Japan, for example, was really engraved into our societies' characteristics, could greatly help in preventing us from disastrous fatality threatening our so fragile social, technological and economical development and therefore guaranty great resilience and sustainability for all of us.

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TOWARDS SUSTAINABLE DEVELOPMENT OF BEACH COASTS - ENGINEERING DESIGN METHODOLOGY FOR LOW ENVIRONMENT-IMPACT INFRASTRUCTURE FOR COASTAL TOURISM

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Abstract : Nearshore infrastructures to mitigate beach erosion without limiting the view of the sea horizon or causing flow stagnation are desirable from the viewpoint of coastal tourism. A submerged breakwater with "invisible" low crest is known to be a good alternative to the traditional emergent type. Measured data of waves around an existing artificial reef shows that porosity plays a crucial role in the infrastructure's wave energy-dissipative action. A fully nonlinear wave model for permeable bed is presented and its important features summarized to carry out the analysis the wave damping effect. Numerical simulations based on the model quantify the functional effectiveness for a number of submerged porous structures. Wave performance simulative analyses indicate that the model can be used to determine suitable values of hydraulic properties such that the low-impact advantage of the infrastructures is not realized at the expense of reduced protection of the beach.

Key words : beach erosion, tourism, infrastructure, submerged breakwater, permeable beach

1 INTRODUCTION

Tourism is an important economic contributor in terms of GDP share and source of employment for the Philippines. In 2010, with 3.52 million foreign visitors, tourism contributed 5.8 percent to the Gross Domestic Product and 10.1 percent of the total employment of the country (NSCB, 2013). The Department of Tourism is projecting the number of foreign tourist arrivals to hit 10 million by 2016, and tourism in general to contribute 6.8 percent to the GDP and provide employment to 6.5 million in the labor force. The contribution of domestic tourism to the national economy is also projected to hit all-time high values as airfares become attractive and transport infrastructure projects in the pipeline are completed.

Natural sceneries, sun and beaches are significant contributors to tourism destinations. While the proportion of beach visitors in the tourists is not available in the national statistics, beach tourism is known to be a significant portion of these destinations. The Philippine archipelago is endowed with excellent tropical beaches and coasts that are a constant magnet for both domestic and foreign visitors. Its tropical coasts are a valuable resource not only for recreation and global tourism, but also for economic activities that are important for many municipalities and regions of the country. After all, the country has more than 36,000 km of coastlines that rank fifth in global coastline length.

In addition to requirements of affordably good accommodation and efficient transport infrastructure, coastal tourism also requires that beach infrastructures are planned and implemented in consonance with environmental preservation and aesthetic enhancements. Fixed structures that tend to block the view of the sea from the beaches are less preferred over low crested ones that allow virtually unobstructed view of the sea horizon. Beach development and management are now faced with challenges associated with climate change and sea level rise, usually leading to coastal erosion.

Coastal structures are built to protect beaches from the damaging action of uplifted sea levels, nearshore currents, storm surges and waves. In the past two decades, the use of submerged beach protection structures that are invisible from inland has resulted in increases of tourist arrivals in major beach destinations in Asia. In the Philippines, recent interest in the use of such "invisible" breakwaters is increasing due to their low or virtually zero impact on beach erosion. This feature has become attractive to beach resort planners whose guests are mainly on marine eco-tourism or beach recreation. This development compels engineers to review design methodologies for coastal protection and to quantify their real effectiveness. It is clear that by placing the breakwater crown lower than the mean sea level, there is the real danger of waves propagating unbroken or un-dissipated over the crown and thereby causing beach erosion.

It is imperative for engineers to have a reasonably powerful wave transformation prognostic tool to determine not only the environmental conditions under which such invisible breakwaters are effective, but also the various engineering parameters that will allow engineers to design them properly. This paper reviews known wave damping characteristics of submerged breakwaters based on field data for an actual structure. It also presents a wave transformation model suited for such low-crested breakwaters and takes up its important features, including capabilities and limitations. The paper discusses some results of numerical simulations of waves on common coastal structures in a beach, with the primary view to developing a prognostic and design tool in their performance analyses and engineering design.

2 EMERGENT AND SUBMERGED COASTAL TOURISM INFRASTRUCTURES

Depending on wave conditions, seabed topography and shore morphology, various coastal structures have been used to mitigate erosion along a beach coast. Along coastal Niiigata, Japan, part of the long coastline was protected by segmented nearshore breakwaters of the emergent type (Figure 1) by 2003. Around 2004, the construction of two pairs of submerged porous breakwaters was completed. After 5 years, the evolved shoreline showed various degrees of beach accretion and erosion (Figure 1, 2009). The coasts fronting the submerged breakwaters generally accreted, whereas the coast near the westernmost emergent breakwater, which is not protected by the submerged breakwaters, experienced erosion. Later, after analyzing the nearshore currents induced by waves and considering the observed longshore sediment transport, a coastal groin was placed near the western end of the emergent breakwaters. For this coastline, the resulting wave-induced nearshore currents and littoral drift made the prediction of long-term effects of each structure type quite complicated.

Traditional breakwaters are of the emergent type, with a cross-section following a typical trapezoidal embankment and a crest that pierces the water surface. This protrusion of the crest forces the waves to break on the seaward slope which induces a considerable reduction of wave energy that would otherwise be spent on the beach face that leads to sediment loss. A submerged breakwater has also a trapezoidal cross-section but a low or submerged crest that is invisible from the shore. Since the crest allows the transmission of wave energy, a wide crest is normally necessary to damp wave energy by porous action and turbulence in the structure’s body.

Both types of breakwaters are placed at some offshore distance from the shore, determined based on the required stability condition of the beach sediments against waves and currents. This distance is typically about 100 to 300 m, depending on seaward slope, which would normally limit a free circulation of sea water in the foreshore area. Transverse gaps in the structures are usually provided to afford better circulation and rejuvenate the seawater.

Figure 1 Coastal structures along the coast of Niigata, Japan (source: Google Earth)

3 FUNDAMENTAL CHARACTERISTICS OF WAVES ON SUBMERGERGED COASTAL STRUCTURES

One type of low-crested breakwater that has been used successfully is an artificial reef, which is a man-made reef with a wide crest that extends to the shore and whose porous body consists of stones and armor units that make them habitable by marine fauna. Two such reefs are placed about 75 m offshore of a reclaimed land along coast of Yugawara, Kanagawa Prefecture, which is roughly 70 km southwest of Tokyo (Figure 2). The reefs were built to protect the bulkheads of the mixed-use reclaimed land against storm waves that reach Sagami Bay from Pacific Ocean. Sloping revetments with concrete armor units were damaged from historical storms that penetrated Sagami Bay. Wave data were obtained from field measurements to analyze the wave deformations and assess the effectiveness of the reefs.

Figure 3 shows the layout, plan-forms and profile of the southern reef, as well as the locations of wave gauges and current meters on and around this reef (Aono and Cruz, 1996). Since storm waves approach the coast orthogonally, the instruments were placed along the centerline of the reef. The profile of the seabed and reef are also shown. The reef crest is 70 m wide and 170 m long. Incident wave conditions that were used to analyze field data and carry out numerical simulations were based on Station 0, located offshore at a depth of 22 m.

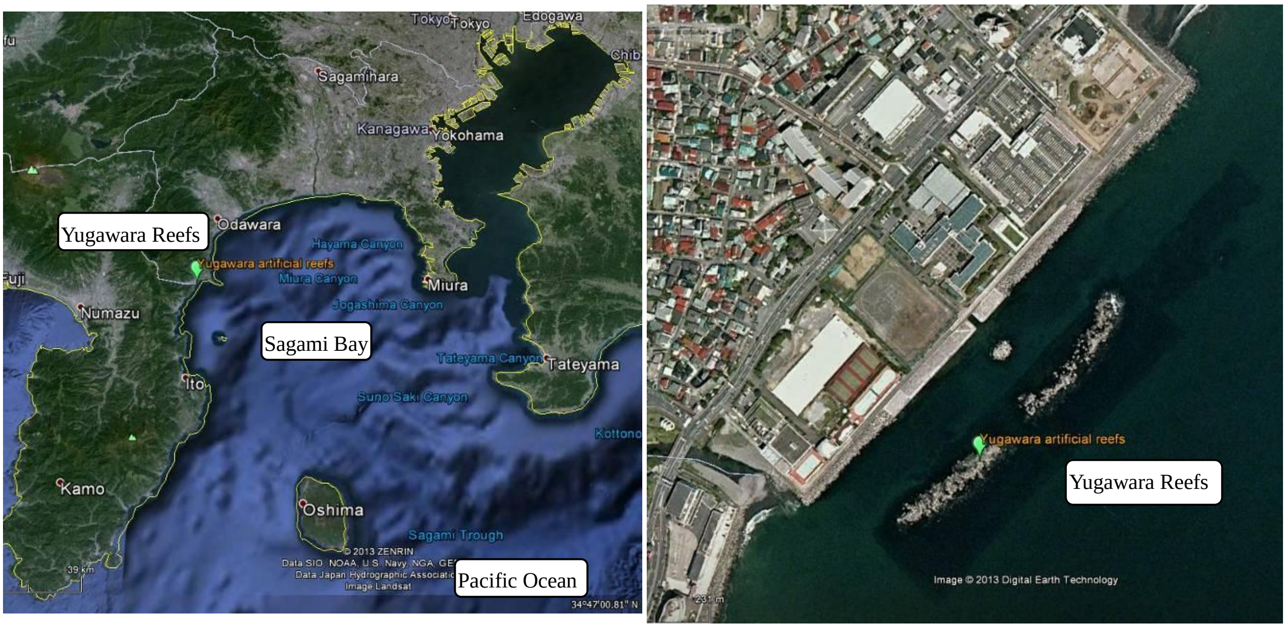


Figure 2 Location and aerial photo of Yugawara Reefs (source: Google Earth)

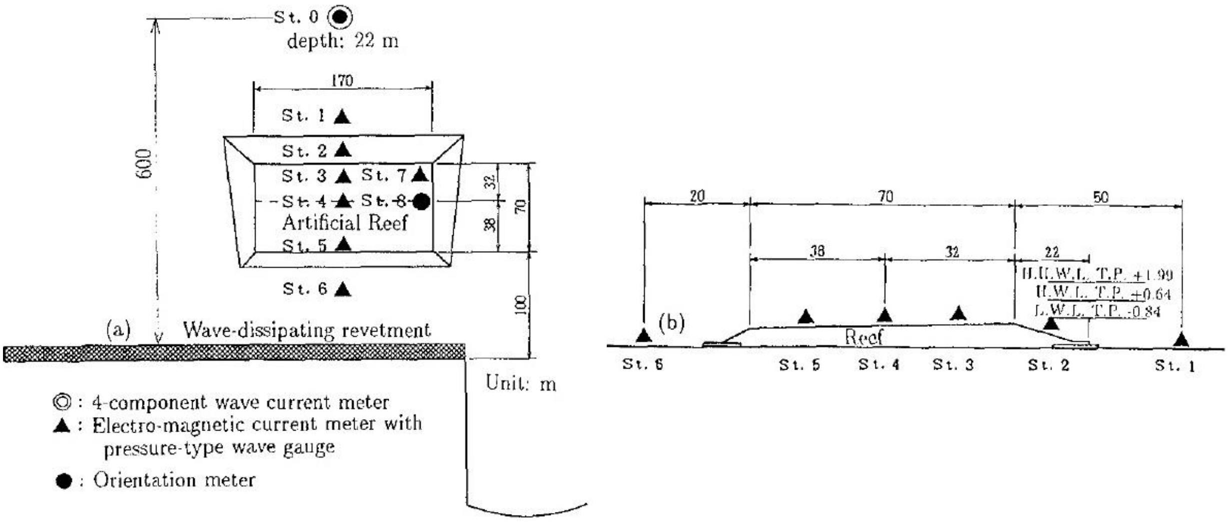
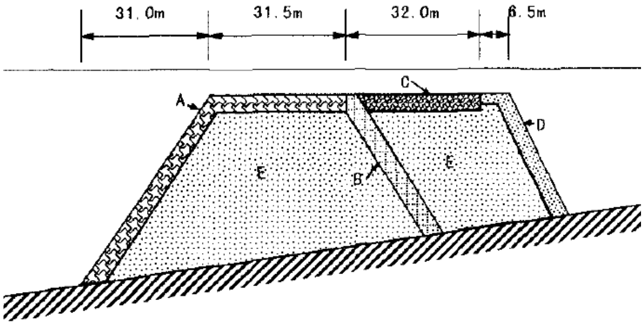


Figure 3 Yugawara Reef plan-form and profile (from Aono and Cruz, 1996)

Figure 3 shows the cross-section of completed reef. The reef crest was widened from the original 32 m to render it more effective in dissipating wave energy over a wider range of incident wave periods. The slopes are 1:3 and 1:2 on the seaward and shoreward faces, respectively. The armor layer consist of 10-ton X-block concrete units in the seaward 31.5 m of crest and of 250-kg rocks in the shoreward 32 m. The core consists of medium-sized rocks.



Zone	Material	Weight
A	X-Blocks	10tons
B	armor rocks	250kg
C	armor rocks	2tons
D	armor rocks	500～800kg
E	medium-size rocks	30～200kg

Figure 4 Yugawara Reef cross-section design and material composition

Figure 5 shows representative distributions of significant wave height along the reef centerline for breaking wave conditions. It is seen that the height first increases towards the reef crest due to wave shoaling, then abruptly decreases on the crest edge due to wave breaking. Along the crest, the wave height continues to decease due to the damping effect of the porous body, although the rate of decrease is lower than that due to breaking. Leeward of the reef, the wave height increases again due to the depth increase. The field data reinforces the results of theoretical analyses that indicate the damping effect of the porous interior on waves passing over the reef crest.

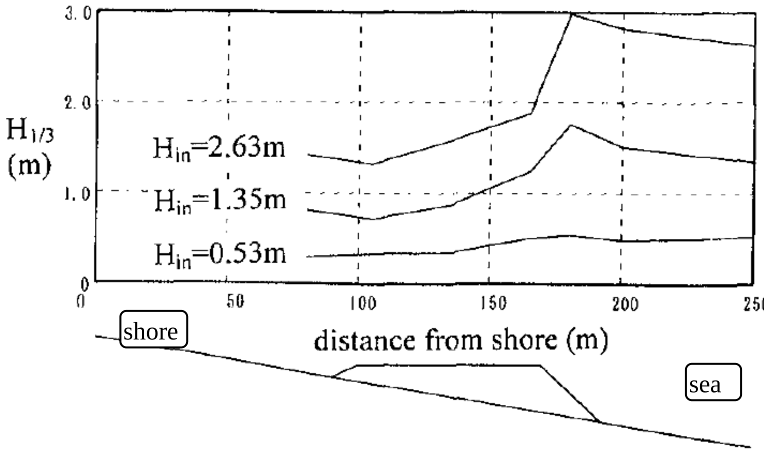


Figure 5 Distribution of measured wave heights along reef centerline

4 DEVELOPMENT OF WAVE MODEL FOR SUBMERGED COASTAL INFRASTRUCTURES

In order to assess the protection afforded by a breakwater with a low crest, it is imperative to quantify the wave transformations over and around the infrastructure. The model must be able to incorporate at least five important conditions. The first is wave nonlinearity, which is ratio of the wave amplitude to the water depth, which increases rapidly on the crest. The second is frequency dispersion, which is parameterized by the depth to wavelength ratio and is dominant in the deep offshore area and past the seaward slope. The third is the porosity of the structure, which is paramount to the dissipative action of the submerged structure on incident wave energy (proportional to the square of wave height). The fourth condition is the co-existence of waves with currents; nearshore currents are induced by wave deformations near the shore. The last condition pertains to the ability of the model to account for arbitrary bottom slopes, which can be very high for actual engineering embankment structures.

Models of waves on porous beds have been proposed in past three decades by Kobayashi (1986), Rojanakamthorn et al. (1990), Flatten and Rygg (199), Isobe et al. (1991), Kioka et al. (1994 and Cruz et al. (1997). The assumptions invoked in the derivation of the model equations, however, impose conditions on the regions of validity of these models. The most limiting of these are the assumptions of weak dispersivity in the water layer and weak nonlinearity of wave motion. The second limitation was relaxed in the model of Hsiao et al. (2002). However, their assumptions on wave motion restricted their application to wave-current fields with weak vertical vorticity. Chen (2006) developed a set of fully nonlinear Boussinesq-type model, discussed below, that conserves the potential vorticity to second-order in the frequency dispersion parameter. Succeeding theoretical analyses in Cruz and Chen (2006) showed that the model equations reproduce the fundamental wave properties of permeable beds of relative porous thickness, or ratio of permeable-bed thickness to water depth, as high as 10, which has not been achieved by past models. Numerical simulations also showed that the model equations are also accurate for a wider range of porous-layer grain size, and for porous beds with strong spatial variation in the porous resistance (Cruz and Chen, 2007).

With the aim of simulating wave-current interactions in the nearshore area, Chen (2006) developed a set of model equations for fully nonlinear waves propagating on a porous seabed. For studies involving cross-shore propagation of waves from deep to shallow waters, the one-dimensional version of the full model equations is applied. The continuity of fluid mass is expressed by Eq.(1) and conservation of momentum in the water layer and permeable bed by Eqs.(2) and (3):

$$\eta_t + M_x + \left(nM^s \right)_x = 0 \tag{1}$$

$$u_{\alpha t} + u_\alpha u_{\alpha x} + g\eta_x + V_1 + V_2 = 0 \tag{2}$$

$$u_{\beta t} + u_\beta u_{\beta x} + g\eta_x + R_\beta u_\beta + V_1^s + V_2^s + \Lambda_1 + \Lambda_2 + \Lambda_3 + \Lambda_4 = 0 \tag{3}$$

where t denotes time, x the spatial coordinate, $\eta(x,t)$ the water elevation from mean water level, u_α , u_β the seawater particle horizontal velocities, respectively, at $z = z_\alpha$ in the water layer and $z = z_\beta$ in the porous layer, $n(x)$ the local volumetric porosity, and g the gravity acceleration. Subscripts t and x denote partial derivatives in time and space and t s denotes quantities in the porous bed. The mass flux terms M in the water layer and M^s in the permeable bed are given by Eqs. (4) and (5):

$$M = (h+\eta)\left\{u_\alpha + \left[\frac{1}{2}z_\alpha^2 - \frac{1}{6}(h^2 - h\eta + \eta^2)\right]u_{\alpha xx} + \left[z_\alpha + \frac{1}{2}(h-\eta)\right]\left[(hu_\alpha)_{xx} + (n h_s u_\beta)_x\right]_x\right\} \tag{4}$$

$$M^s = h_s\left\{u_\beta + \left[\frac{1}{2}z_\beta^2 - \frac{1}{6}(h^2 + hh_b + h_b^2)\right]u_{\beta xx} + \left[z_\beta + \frac{1}{2}(h+h_b)\right](h_b u_\beta)_{xx}\right\} \tag{5}$$

where $h(x)$ is the local water depth, $h_s(x)$ the local porous layer thickness, and $h_b = h + h_s$ the depth to the impermeable boundary (Fig.1). V_1 and V_2 are the dispersive Boussinesq terms in the water layer. Similarly, $V_1{}^s$ and $V_2{}^s$ are the dispersive Boussinesq terms for the permeable layer. The resistance R_β of the porous medium to wave motion is expressed as a combination of a steady-flow component A_β, consisting of a linear viscous part a_p and a nonlinear turbulent part b_p, and an unsteady inertial component that is proportional to the wave-induced acceleration, as follows:

$$R_\beta = A_\beta + C_A\frac{\partial}{\partial t} \qquad A_\beta = a_p + b_p\left(u_\beta^2 + \left[z_\beta u_{\beta x} + (h_b u_\beta)_x\right]^2\right)^{1/2} \tag{6}$$

in which C_A is the added-mass coefficient. Λ_1 in Eq.(3) is the second-order dispersive porous-damping term, while Λ_2, Λ_3, and Λ_4 are the higher-order porous-damping terms, collectively called the β_3 terms. The model parameters α and β define the vertical location z_α and z_β of the fluid particle horizontal velocities within the respective layers, as follows

$$z_\alpha = \alpha h \qquad z_\beta = \beta h_s - h \tag{7}$$

and thus have range of values (-1,0). Values of the model parameters are optimally determined so that wave properties are virtually coincidental with those of linear wave theory in the range of relative depth from deep to shallow water.

5 WAVE DAMPING EFFECT OF POROUS STRUCTURES

The fundamental properties of wave celerity and porous damping rate based on the optimized values of the model parameters α and β are shown as dashed lines in Figure 6 as functions of the relative depth h/L_o. These properties are normalized by the shallow-water celerity C_S. The upper plots are for a nominal layer thickness ($h_S = h$) and the lower ones for very thick porous layer ($h_S = 10h$). The model properties are compared with the exact solution (solid line) based on the linear wave theory for constant permeable thickness and water layer.

It is seen that the model yields fundamental wave properties that are virtually coincidental with theory for both layer thicknesses. The optimized properties of the model with $\beta_3 = 0$ (dashed curves), i.e. higher-order porous damping terms are neglected, reveal that the wave celerity can still be optimized to match linear theory, but the porous damping rate deviates considerably from theory for a thick porous layer if the higher-order porous damping terms are excluded.

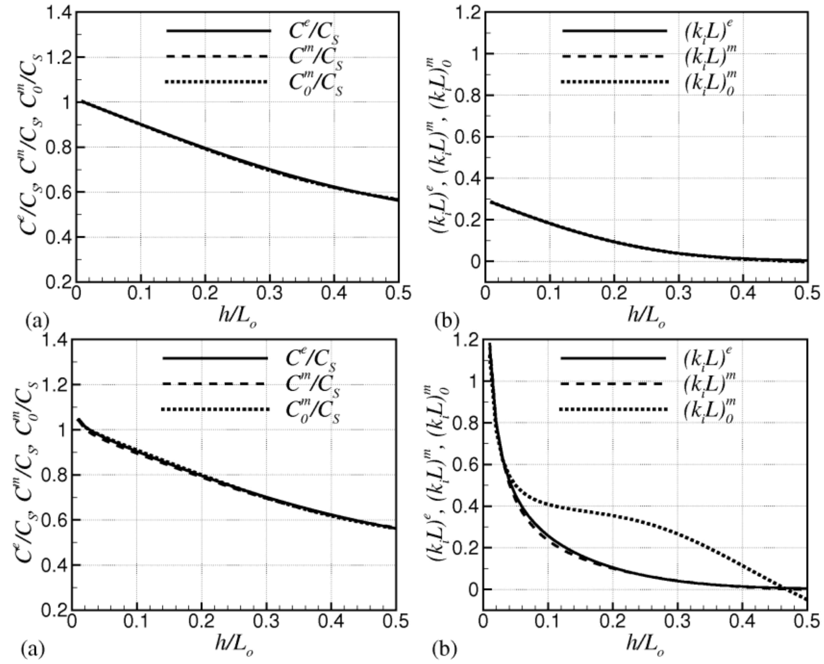


Figure 6 Comparison of wave celerity (a) and porous damping rate (b) of model equations (dashed line) and linear wave theory (solid lines) for a nominal porous bed $h_S = h$ (top), and for a thick porous bed $h_S = 10h$ (bottom). The model properties with β_3 terms excluded are shown by dotted curves.

The full model equations (i.e. β_3 terms included) have been discretized into a numerical model using the finite difference method. To better understand the effect of breakwater porosity on wave propagation, numerical simulations on solid and porous trapezoidal breakwaters were performed. Figure 7 summarizes the simulated spatial profiles of the water surface, water layer velocity u_α and the post-processed wave heights on a solid breakwater and on a porous one. To exclude the effects of water depth and wave breaking on the wave transformations, a horizontal seabed and non-breaking incident wave height are chosen. Prototype incident wave conditions are inputted into the model and the hydraulic resistance coefficients were calculated using the empirical formulas for prototype granular material of van Gent (1995). The simulation results show that the porous breakwater significantly reduces the wave height on the crest to about 0.6 of the height on the seaward slope over a crest distance of 2 wavelengths. This reduced wave height, when transmitted to shore, is less damaging to coastal sediment stability. Such damping effect is attributed to the combined dissipative action of friction, turbulence and inertial damping on the fluid momentum that penetrates into the porous body, as indicated by the scaled plot of u_β . It is clear that from the point of view of coastal erosion, a porous submerged breakwater is more effective than a solid one.

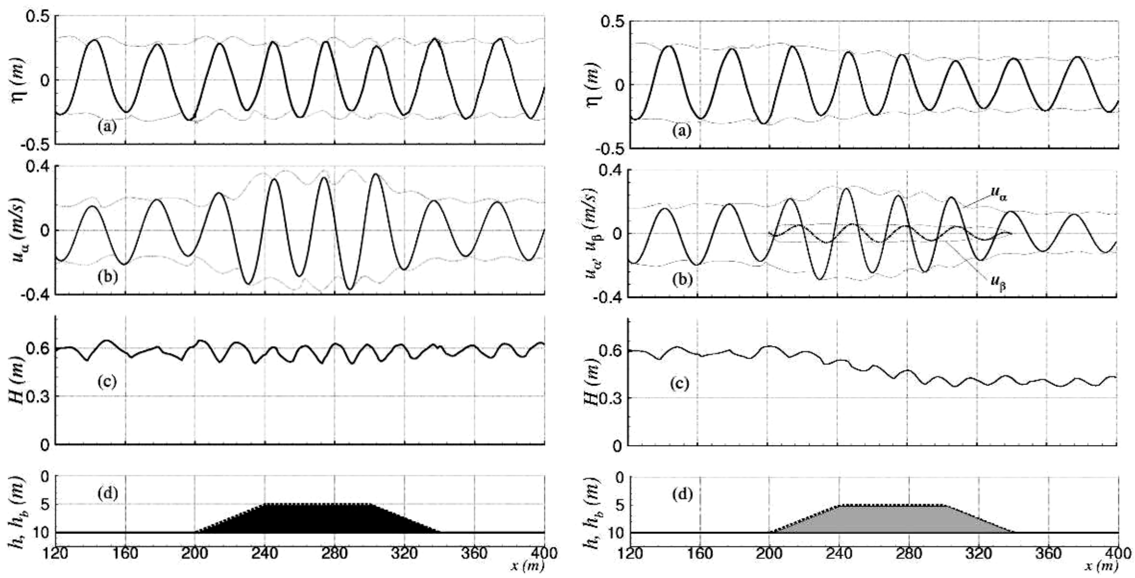


Figure 7 Wave fields on (left) solid breakwater, and (right) porous breakwater. Incident wave: T =5 s, H_i = 0.6 m. Hydraulic parameters of artificial reef: n = 0.4, d_{50} = 0.2 m, a_p = .056 s^{-1}, b_p = 0.026 m^{-1}, C_A = 0.26.

6 TOURISM-ORIENTED COASTAL INFRASTRUCTURE DESIGN METHODOLOGY

One important application of the model is the study of the wave evolution on a beach slope. In Figure 8, 50 cm-high waves are introduced from the left side at depth of 8 m, which then propagate shoreward over a sandy beach of uniform thickness with 2-mm mean grain size, as shown in Figure 8(a). The minimum depth onshore is 1 m. Figure 8(c) shows the evolution of the wave train on the sandy beach. For comparison, the wave profile on an impervious beach in Figure 8(c), simulated using the numerical model, is also shown plotted. The waves on the impervious slope continue to shoal until around x = 630m, then breaks and decays up to the 1-m depth bed junction. In comparison, the presence of the 2-m thick porous layer causes early dissipation of the wave energy at around x = 465m, retards shoaling, and effectively reduces the wave energy close to the shore. It is also evident that the porous damping acts more effectively on the high-frequency wave components. The presence of the porous layer can also postpone wave breaking to a location closer to shore, depending on the hydraulics parameters and incident wave conditions. Finally, the waves approach the shore with lower celerity compared to the solid beach.

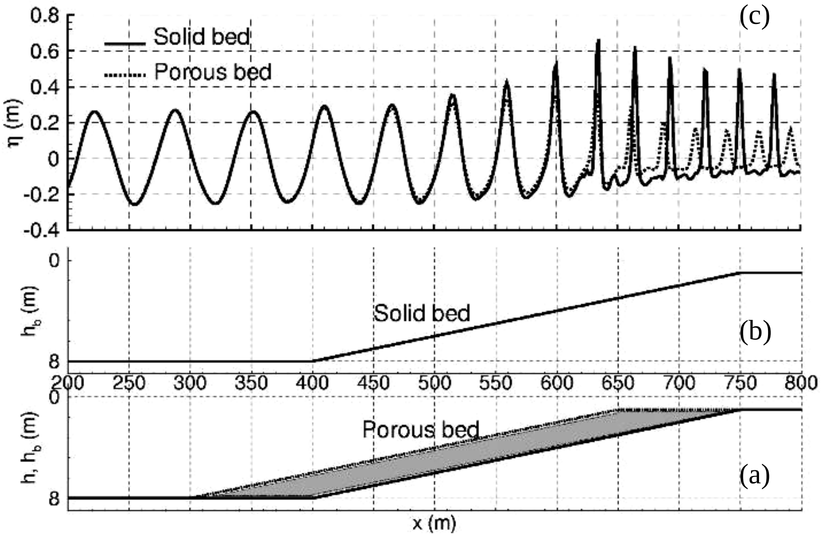


Figure 8 Wave transformation on: (left) porous beach (a) versus impervious beach (b); Incident wave: T = 8 s, H_i = 0.5 m. For porous beach: n = 0.5, d_{50} = 2 mm, a_p = 562.5 s^{-1}, b_p = 5156 m^{-1}, C_A = 0.46.

Numerical simulations provide useful information on the performance of porous slopes as dissipative beaches. For example, the model results suggest the shoreward limit where the porous layer becomes ineffective, which is at around x = 465 m in Figure 8; at this location, the sand virtually does not influence the surface waves. Such information can be utilized to optimize the placement location and volume of sand on an otherwise impervious slope so that waves reaching the shore are low already and hence will not cause beach erosion.

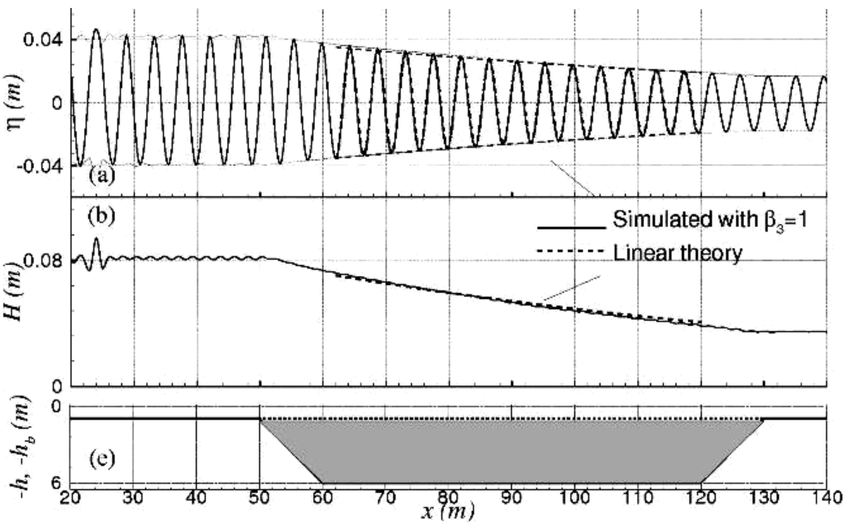


Figure 9 Wave energy dissipation by a porous coastal trench; incident wave: T = 8 s, H_i = 0.5 m. Hydraulic parameters: n = 0.25, a_p = 22.6 s^{-1}, b_p = 0, C_A = 0.

Figure 9 shows the simulation results for a 5-meter thick coastal trench below seabed one-meter deep so that $h_s/h = 5$. To be consistent with the linear analytic solution shown plotted for the constant-thickness portion of the trench, only the linear component of porous resistance is set to a non-zero value. The simulation results where the full-model is used (i.e. where β_3 =1) show very good agreement of the wave height H with the analytical solution, which further buttresses the importance of the higher-order porous-damping terms for modest values of the porous thickness ratio h_s/h.

The numerical model was also applied to simulate the wave fields around a low-crested porous mound breakwater. The bathymetry is shown in Figure 10 left (c) where the mound has mean rock size of 0.5m and porosity of 0.4. To study the relative importance of the porous resistance components, the nonlinear part b_p and inertial component C_A were initially set to zero. The resulting wave fields are shown in Figure 10 left (a-d). For reference, the damped wave heights of linear theory for constant water depth and permeable-bed thickness are superimposed (dotted line) with the simulated (solid line) wave heights in Figure 10 left (b); the theory is based on water depth and permeable-bed thickness at the location of the seaward edge of the crest. It is seen that, while the actual porous thickness is varying within the crest, the slope of the trend line of wave height agrees with linear theory within the crest. Figure 10 right (a-d) shows the corresponding results when the nonlinear resistance term, i.e nonzero coefficient b_P, is considered. It is clear that the wave damping effect is dramatically stronger and its rate deviates considerably from linear theory. It is then concluded that the turbulent dissipation of fluid power in the porous interstitial space dominates the damping action of the structure on wave energy. It should be noted that the known process of wave decomposition at the deep lee side of a submerged structure, due to the release in deeper water of the bound higher harmonics on the crest, is seen in Figure 10 right. The damping effect on wave energy and the wave decomposition processes effected by the submerged porous breakwater are desirable from the viewpoint of beach erosion mitigation.

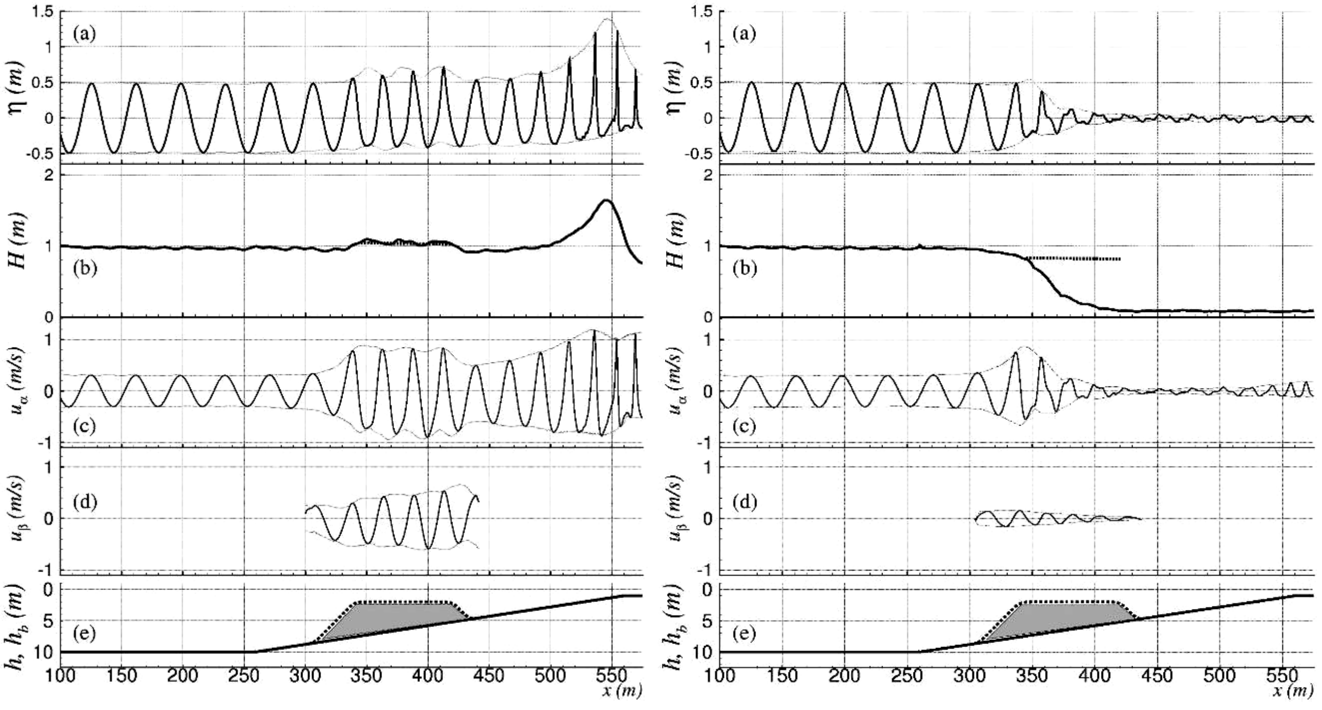


Figure 10 Wave field around low-crested rubble mound. Incident wave: $T = 5$ s, $H_i = 1.0$ m. Hydraulic parameters: $n = 0.4$, $d_{50} = 0.5$ m, $a_p = 0.009$ s^{-1}, $C_A = 0$; nonlinear resistance coefficient: $b_p = 0$ (left), $b_p = 2.06$ m^{-1} (right).

Figure 11(a) shows the wave heights from a third simulation, now with the inertial component C_A determined from van Gents' (1995) empirical formula. The results show that the inertial resistance component decreases the damping effect of the porous mound, resulting in relatively higher waves on the lee side. This is consistent with the theoretical results for shallow water with $h/L_o = 0.051$ (Cruz and Chen, 2007) on the breakwater crown (L_o is the deepwater wavelength for impermeable bed).

The model can be used to carry out a hydraulic design of porous structure involving, for example, determining the mean stone size of the submerge breakwater above. This is the point demonstrated by a fourth simulation, which was run with conditions identical to those in Figure 11(a) except that the stone size is now smaller at $d_{50} = 0.25$ m. The resulting wave heights in Figure 11(b) indicate that a smaller stone size is more dissipative for this particular set of incident wave conditions. The decrease of wave height due to smaller d_{50} would be more pronounced for a smaller incident wave period. Similar simulations can be performed for different porosity values. The model can be run several times to optimize the hydraulic design for prescribed ranges of incident wave conditions and bathymetry. For beach erosion mitigation purposes, the proper size and cross-section proportions of the submerge breakwater can be determined by iterative simulations to make sure that the transmitted wave with damped height and shorter period are not able to further erode the sediments on the beach face or along the coastline.

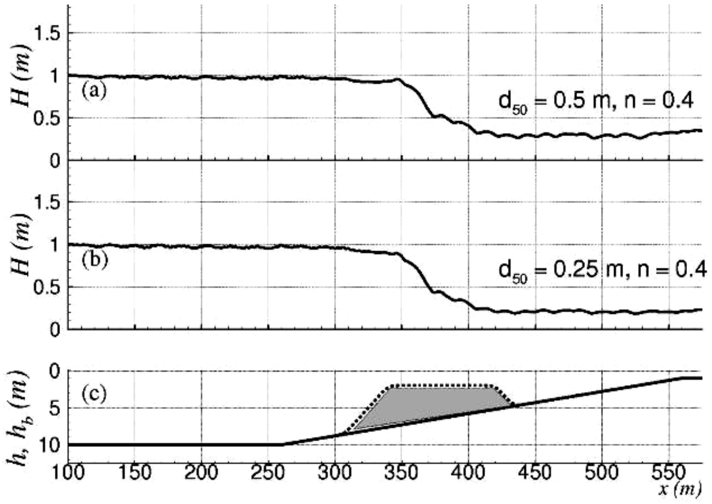


Figure 11 Hydraulic design performance prediction for a submerged porous nearshore breakwater: hydraulic properties and wave conditions are similar to those in Figure 10 except C_A = 0.51; Case (b) is identical to Case (a) except that the core stones are smaller (d_{50} = 0.2 m).

7 CONCLUSIONS

As shown by measured field data of waves at various locations on an existing artificial reef in Yugawara, submerged porous structures can effectively decrease the wave height over the crest and past the lee side. It is found from this study that while submerged breakwaters, coastal trenches and permeable beaches allow incident waves to pass over the submerged crest, they can be effective mitigating structures against beach erosion by inducing wave energy dissipation through frictional damping of the fluid, turbulent dissipation of wave energy within the porous interstitial spaces of the structure's interior, and wave breaking on the crest or porous slope.

A model of nonlinear dispersive model for wave transformation on a submarine porous bed is presented and discussed in terms of its features that are useful in the numerical analysis of the wave damping action. It is found that the model reproduces the fundamental wave properties from deep to shallow waters and for a wide range of the relative porous thicknesses when compared with the analytical solutions from linear wave theory on permeable beds.

The connection of structure porosity to the wave damping property of the set of model equations is verified by comparison of simulation results of wave height on a solid submerged breakwater and on a porous one under identical incident wave conditions and hydraulic properties. The importance of the nonlinear turbulent porous resistance on the porous damping rate is elucidated on by simulation results for prototype submerged breakwater, namely, that inclusion of this resistance term amplifies the energy dissipative action of the porous structure. Taken together, these findings imply that prototype submerged porous breakwaters can make up for the reduction of their wave damping action on account of their low crest by forcing these same waves to be damped by the structure's porous interior as they pass over it.

Numerical simulations of wave transformation on common coastal infrastructure such as permeable beaches, coastal trenches and artificial reefs clearly show that incident waves can be damped significantly by their passage over these infrastructures. This means that these submerged porous structures significantly can decrease the wave energy propagated towards shore, thereby mitigating the beach erosion hazard. It is thus possible to reduce the adverse environmental impact of an offshore structure on a beach coast by lowering its crest elevation and still meet the required protective function of the structure.

Finally, the model equations can be used to evaluate the potential functional performance of a low environment-impact infrastructure by determining the appropriate hydraulic properties of the structure based on simulative analyses of the resulting wave conditions around the structure and shore. Through the simulative use of the model, the hydraulic design of submerged porous infrastructures can be optimized.

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VTT's ECOCITY CONCEPT FOR SUSTAINABLE COMMUNITY AND NEIGHBORHOOD REGENERATION AND DEVELOPMENT

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Abstract: Based on the wide expertise accumulated, and building on recent experiences carried out in different parts of the world (China, Russia, Finland, Kenya) which can be somehow considered the origin of the new formulation of the concept developed by VTT in line with its Research and Innovation Vision 2020, EcoCities provides a framework for sustainable community and neighborhood regeneration and development focusing mainly on developing countries and emerging economies. EcoCity Miaofeng (China), EcoGrad in St. Petersburg (Russia), EcoDrive (Finland) or UN Gigiri in Nairobi (Kenya) are the main references prior to the launch of the EcoCities concept presented in this paper.

Key words: sustainable community development, neighborhood regeneration, developing countries, emerging economies

1 INTRODUCTION

VTT Technical Research Centre of Finland is the biggest multi-technological applied research organization in Northern Europe. VTT provides high-end technology solutions and innovation services to enhance its customers' competitiveness, thereby creating prerequisites for society's sustainable development, employment, and wellbeing. VTT can combine different technologies, create new innovations and a substantial range of world class technologies and applied research services thus improving its clients' competence.

VTT has done research on different aspects of sustainable building since decades. There's a continuous stream of international research projects related with sustainability metrics and building performance, indoor climate and energy efficiency, product development, sustainability assessment and decision support tools. The focus is nowadays increasingly stretched towards sustainable neighborhoods covering also infrastructure and economic and social assessment. At present VTT has 50 to 100 experts doing research on sustainable built environment.

2 VTT'S ECOCITY CONCEPT

2.1 Background and references

The main examples from Finland that preceded the development of VTT's EcoCity concept were Tapiola Garden City (1950s, Espoo), Otaniemi High-Tech Park (1960s, Espoo) and Eko-Viikki (1990s, Helsinki). Tapiola Garden City is one of the most internationally recognized residential areas in Finland. Based on the concept of Garden City proposed by Ebenezer Howard, it was built as a response to the big post-war demand for housing and social reform.

Figure 1 Finland's most energy-efficient office building, Eko-Viikki, Helsinki. © Pekka Huovila

Since it was built, Eko-Viikki has attracted a lot of attention both nationally and internationally. The local plan for the area was developed through an architectural competition (1994-1995) that specified that the proposals had to be ecologically sustainable through minimization of the use of non-renewable energy sources and rapidly diminishing raw materials; reduction of the levels of pollution, noise and waste; minimization of the strain on natural resources and local eco-systems; residents empowerment and awareness raising on ecological sustainability. (Hakaste et al., 2005)

PHASE I

The first phase of VTT's EcoCity concept development started in 2002 in two projects under the EC 5th Framework Programme.

PHASE II

Experiences from and knowledge gathered in these activities led into second phase neighborhood development projects in Finland and also in China, Kenya and Russia. Ecocity Miaofeng feasibility study presented features of 17 socially, ecologically and economically sustainable villages in Miaofeng Mountain Town North-West of Beijing (Nieminen et al., 2010).

Figure 2 One of the villages in Miaofeng, not far from Beijing. © Pekka Huovila

EcoGrad presented a design concept of eco-efficient districts in the city of St. Petersburg including dense city development, a minimal need for travel, a maximum use of public transportation and light vehicles, and minimum power consumption (Nystedt et al., 2010). In Gigiri (Kenya), VTT studied how a new office building can become energy neutral in Nairobi. In Peltosaari (Finland), the value increase of a declining neighborhood through sustainable regeneration was studied including social and economic studies.

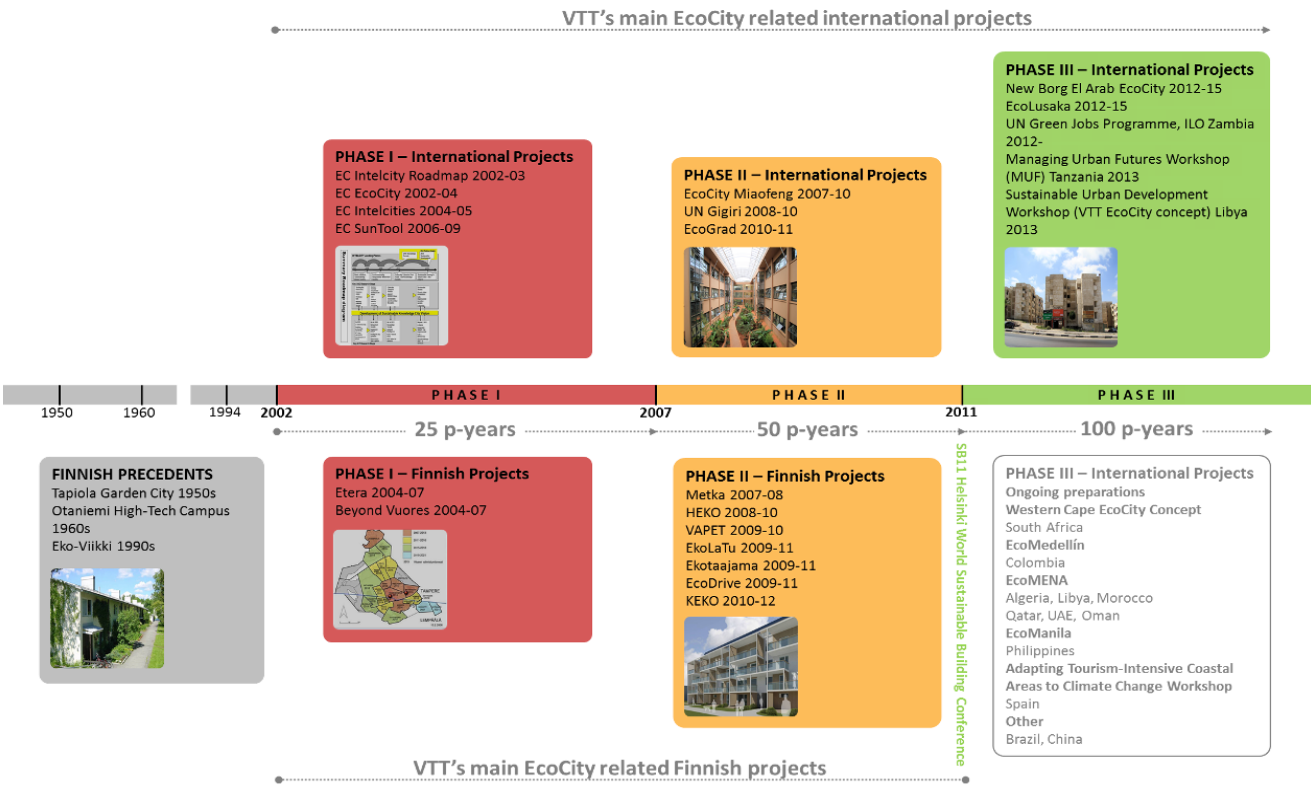

Figure 3 VTT's EcoCity roadmap showing the evolution of the concept through the main related projects. © Pekka Huovila & Carmen Antuña, August 2013

PHASE III

The third phase in the evolution of VTT's EcoCity concept starts after the 6th World Sustainable Building (SB) Conference that took place in Helsinki from 18th to 21st October 2011. One of the main objectives of SB11 Helsinki was *"to expand the international research community's focus to consider people and their needs, particularly those in the developing world"* (Huovila & Antuña, 2012a).

The wide network of experts from around the world established during the conference, and the knowledge gained then, served as a springboard for further development of VTT's EcoCity concept into an international framework for sustainable community and neighborhood regeneration and development. In line with VTT's Research and Innovation Vision 2020, EcoCities focuses mainly on developing countries and emerging economies. This phase is the main focus of this paper therefore its main related activities will be commented more in detail below.

2.2 Challenges addressed by EcoCities

At present more than half of the world's population, over 3 billion people, is living in towns and cities. By 2030 this number will increase to 5 billion people, with urban growth mainly concentrated in Africa and Asia (World Urban Forum, 2012). Urbanization is perceived as synonymous with modernization, industrialization and development, but it also presents a dark side: proliferation of slums and squatter settlements, inadequate infrastructure, poor access to social services and environmental degradation among others (UN-HABITAT, 2008). Very recently, the UN General Assembly has endorsed the outcome document of the United Nations Conference on Sustainable Development (Rio+20) where climate change is acknowledged as "a cross-cutting and persistent crisis" affecting all countries and challenging their ability, in particular that of developing countries, to achieve sustainable development, as well as threatening the viability and survival of nations (UN, 2012).

Therefore, among the main challenges addressed by EcoCities are:

- Climate mitigation and climate adaptation
- Sustainable urbanization
- Affordable housing
- Integrated planning and funding availability
- Capacity building for local solutions and services
- Citizen empowerment and participation
- Cross-cutting themes: gender issues, etc.

To respond to these challenges, EcoCities is built around a strong collaboration with reliable local partners in order to answer to local needs previously identified and discussed with them. The flexibility of EcoCities' approach allows the implementation of expert solutions depending on local conditions and customized to varying socio-economic realities worldwide.

2.3 EcoCities' approach and main components

VTT's EcoCities' approach developed to respond to the abovementioned challenges in collaboration with local partners can be summarized as follows:

- Best combination of technologies and services that form sustainable solutions providing the users and inhabitants a high quality of life and indoor and outdoor comfort
- Applicable EcoCity solutions depend on local conditions and need to be customized to socio-economic realities
- There is not one solution that fits all, but a number of possibilities that need to be studied to find the right solution for each case
- Require knowledge of local traditions, perceptions, available materials and competent partners. (Huovila & Antuña, 2012b)

3 ECOCITY PROJECTS

What follows is a more detailed description of both ongoing and planned projects and activities worldwide within VTT's EcoCity framework. Although the first projects of the recently started PHASE III are located in Africa, other activities are already under preparation in other parts of the world as it will be shown.

3.1 Ongoing projects and activities

GLOBAL NETWORK FOR SUSTAINABLE HOUSING, GNSH

Officially launched during the 6th session of the World Urban Forum that took place in Naples, Italy from 1st to 7th September 2012, it is oriented to the theme of *"local building cultures (principles, methods, application conditions, potential impacts and limits) with a specific focus on indigenous building materials and traditional building practices in the context of slum upgrading, affordable housing and post-crisis housing".* As a founding member, VTT attended the event and took part in the plenary discussion that followed on the scope and role of the GNSH in promoting sustainable housing practices globally. The GNSH Secretariat, which will coordinate the network, will be based at UN-HABITAT Shelter Branch, Nairobi (Kenya).

NEW BORG EL-ARAB ECOCITY (EGYPT)

The overall objective is to improve the capacity on sustainable city development in Egypt. The purpose of the project is to improve the capacity of the local partner Egypt-Japan University of Science & Technology (E-JUST) in developing them as a top EcoCity expert body in northern Africa and to create a framework for transforming New Borg El Arab City (NBC), close to Alexandria, into an EcoCity.

The approach is based on workshops, training seminars, study tours, awareness raising campaigns, competitions and research exchanges. The cooperation aims at detaching Egypt's sustainable urban development from aid dependency. Increasing attention is paid to support for the use of local resources for development purposes, the reduction of inequality and finding solutions for unsustainable use of natural resources and climate change. The proposed EcoCity approach empowers local people and provides employment together with environmental protection.

Figure 4 New Borg El-Arab City, Egypt. © Pekka Huovila

ECOLUSAKA (ZAMBIA)
Recently started, this project is being carried out in collaboration with Thorn Park Construction Training Centre. The objective of EcoLusaka is to develop and pilot new educational programmes for the construction sector enabling a more environmentally, economic and socially sustainable construction process in Zambia.

The main actions to be implemented are:

- Capacity building of the local partner
- New educational curriculum introducing principles of sustainable construction
- Update of current structure with the aid of ICT technologies
- Improvement of existing facilities and equipment
- Strategic Business Plan
- Links to UN Joint Programme on Enhancing Competitiveness and Sustainable Business among MSMEs in Building and Construction Industry (through ILO Office in Zambia)

Figure 5 Different views of the construction training centre facilities in Lusaka, Zambia. © Carmen Antuña

UN GREEN JOBS PROGRAMME, ILO (ZAMBIA)
VTT has been requested by UN ILO Office in Zambia to provide support to the "Joint Programme on Improved Livelihoods through PSD". VTT's contribution is focusing on the following main components: construction of two demo houses, productivity improvement programmes and training for SMEs, and new efficient technology and innovation to be introduced in the construction sector.

MUF2013 DAR ES SALAAM (TANZANIA)
Along with Aalto University and the Institute of African Leadership for Sustainable Development and other key actors like UNEP, UN-HABITAT, the University of Nairobi and the Asian Institute of Technology, VTT participated in "Managing Urban Futures – Workshop for Supporting Sustainability" that took place in Dar es Salaam in spring 2013.

Figure 6 MUF2013 Workshop in Dar es Salaam, Tanzania. © Pekka Huovila

SUSTAINABLE URBAN DEVELOPMENT WORKAHOP (LIBYA)
National Authority for Scientific Research (NASR), Ministry of Housing and Utilities (MHU) and Libyan Urban Planning Society (LUPS) organized a Workshop in June 2013 at Tripoli where they invited VTT's experts to discuss sustainable urban development issues in Libya. The topics covered sustainable city development and redevelopment, designing of sustainable buildings, innovative programs on water resource use and waste disposal practices, and many other aspects of assessing urban ecological efficiency.

Figure 7 Sustainable Waste Management is one of the challenges in Libya. © Pekka Huovila

3.2 Planned activities

Different activities are being planned at present within the EcoCity framework in Northern Africa and the Middle East (MENA region), East and Southern Africa (Tanzania, Zambia and South Africa) and Latin America (Brazil and Colombia).

Figure 8 Example of housing needs in North Africa. © Pekka Huovila

NORTHERN AFRICA AND THE MIDDLE EAST

Ongoing preparations in the Maghreb region deal with sustainable urban development, affordable housing, water and waste management, sustainable community services and applicable technologies, etc. The challenges vary from reconstruction of destructed areas to regenerating old medinas. In the Middle East, the EcoCity concept still needs formalization and establishment of transparent sustainability assessment schemes together with justification of its added value. Strong emphasis on green cities and technologies can be supported by sustainable building and municipal systems.

LATIN AMERICA

Brazil and Colombia are some of the fastest growing economies in Latin America. In Brazil, a member of the EAGLEs group (Emerging And Growth-Leading Economies, an acronym created by Spanish bank BBVA), around 35 million people have climbed out of poverty in recent years. In turn, Colombia is a member of the EAGLEs Nest group (also according to BBVA). From an urban perspective, both countries are facing enormous challenges with cities extending rapidly, very often in the form of informal settlements.

Figure 9 View of informal settlements in South Brazil. © Pekka Huovila

Figure 10 View of informal settlements in Medellín. © Pekka Huovila

Brazil
Based in São Paulo, VTT Brasil LTDA R&D Center was created in collaboration with Kemira as an answer to an increasing demand for biomass and sustainable development technologies. The center started operations in 2010 and provides high-end technology solutions and innovation services for the South American markets.

Colombia
In collaboration with Alexander von Humboldt Institute for Research on Biological Resources from Colombia and the Environmental Department of the City of Medellín, VTT is planning a project on capacity building of the local partners helping them on assessment, monitoring and management of the dynamics involved in informal settlements from the point of view of urban sustainability. The project is to be inserted in the framework of national policies, including the initiative "Misión Ciudades" led by the Department of National Planning and the Ministry of the Environment and Sustainable Development with the support of the Inter-American Development Bank.

SOUTH EAST ASIA
Rapid urbanization is setting challenges in many fast growing cities in South East Asia in regard with sustainable transport, healthy outdoor and indoor comfort and climate mitigation. VTT is looking for locally adaptable economic solutions that can be applied both to regenerate existing neighborhoods and to develop new sustainable communities. VTT's planned activities focus on the developing countries of South-East Asia, especially on the least-developed countries of the region.

Figure 11 View of a village in Laos. © Antti Ruuska

Philippines

VTT is currently preparing a capacity building project for ecological district development and urban regeneration together with a local government unit in the City of Manila. The project will focus on the most pressing issues, as identified together with the local partners. One of the key components will be the improvement of energy efficiency in buildings, through capacity building, education, public example projects and raising awareness of the public and building professionals. As energy is the basic requisite for economic development, access to clean and affordable energy sources, and energy efficiency are crucial factors to reduce poverty and improve the quality of life.

4 DISCUSSION

- In Phase I VTT's EcoCity concept was still defined based on earlier experiences in Finland as part of European exchange of ideas
- In Phase II the concept was extended from environmental sustainability to better cover social and economic sustainability, and to adjust the content to a pan-European context
- In Phase III the experience and knowledge on ecocities accumulated by VTT's experts (around 100 personyears) supports a further development of the concept towards awareness raising, capacity building and detaching sustainable urban development from aid dependency.

ACKNOWLEDGEMENTS

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APPLICATION OF COMBINED ICE EXTERNAL MELT PARTIAL THERMAL ENERGY STORAGE AND DISTRICT COOLING SYSTEM FOR OPTIMAL ENERGY EFFICIENCY FOR ACADEMIC, REEARCH AND DEVELOPMENT SETTING

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Abstract: This paper primarily discusses the combination of ice-external-melt partial thermal-energy-storage (TES) system and district cooling system (DCS) on the design of air conditioning system for complexes that are used for academic and research and development operations. An institution of such natureand operating in a complex of buildings can take advantage of the TES system and the DCS.Giventhe option for commercial and industrial applications to avail of the time-of-use (TOU) electricity rate, where the electricity rate at night is cheaper than that at day, the cost of operation can be reduced when ice is made at night and melted at the following day for the complex.The efficiency of the chiller system used in making ice can even be improved because the ambient temperature at night is relatively lower than that at day. The efficiency of distribution of cooling medium in a complex, which is normally chilled water, is enhanced when DCS is used.The TES design was based on the computed cooling load of the complex. Cooling loads wereobtained using the Cooling Load Temperature Difference (CLTD) Method on per room or cooling space basis. The designed TES storage tanks are proposed to be installed underground together with the piping network for the DCS distribution. The compressor rack system wherein compressors are placed in racks in the central cooling plant is employed in the design for versatility and economy of operations of the compressors and overall chiller systems. Air handling units (AHU's) were designed based on the area to be conditioned and the cooled air distribution system throughout the buildings is chosen to befabric air ducts which will reduce maintenance costs and noise caused by flow and vibrations.Economic comparison of the proposed system with a conventional one wherein each building will be using separated chillers in the basement was performed. The investment cost is outweighed by the lower operational cost and the resulting payback period is attractively short. The overall coefficient of performance (COP) of the complex using combined TES and DC systems is higher and thus the operational cost and payback period are lower compared to the conventional system. Aside from functioning as the cooling system of the complex, the proposed system can also become a facility for further research and development in ice TES, DCS and cooling systems in general.

***Keywords**: Thermal Energy Storage (TES), District Cooling System (DCS), Time of Use (TOU), Cooling Load Temperature Difference (CLTD) Method, Coefficient of Performance (COP)*

1. INTRODUCTION

The latest update from the Energy Information Administration (EIA) shows that there is a constant increase of 6.7% on carbon emissions for the whole world (from vehicles and buildings) starting 2010.This is due to the fact that there is also an increase on commercial buildings, vehicles and machineries across the world. Increasing carbon emissions contributes largely to the environmental problems the world is facing nowadays, that's why energy efficient systems are needed to help reduce energy consumption without sacrificing the environment.

One of the energy efficient systems emerging today is the Thermal Energy Storage (TES) whereas energy is stored when it is not needed and is used at the most optimized time. This system can be used for air conditioning by making ice on coils at night (using external melt partial system) when air conditioning at schools is not needed, when compressor temperature is low, and when electricity is cheaper.It is melted on day time and chilled water system distribution is enhanced using the district cooling method.

2. METHODOLOGY

2.1 Design Intent

The Engineering Complex is composed of nine 2-floor Engineering buildings (one per department and one graduate studies building) and a 3-floor administrative building. The 8 departments are Mechanical, Civil, Electrical and Electronics, Industrial, Chemical, Geodetic, and Materials and Metallurgical Engineering. The Engineering Complex should provide the needed thermal comfort for students and teachers based on standards using the combination of external-melt partial thermal energy storage system and district cooling system (DCS) distribution.

2.2 Cooling Load Calculation

The Cooling Load Temperature Difference (CLTD) Method was used to approximate heat gains from different heat generating components inside the buildings. These sources of heat include solar transmission and absorption through the roof, walls and windows, heat generated by building occupants, heat generated by lights and appliances, and finally the infiltration air from the ambient.

The CLTD method includes the following formula for computing the cooling load:

Heat Gain from Occupants

$Q_{sensible} = N (Q_S) (CLF)$

$Q_{latent} = N (Q_L)$

Where

- N = number of people in space
- Q_S, Q_L = Sensible and Latent heat gain from occupancy
- CLF = Cooling Load Factor, by hour of occupancy. (This is a constant provided by ASHRAE for the CLTD method)

Heat Gain from Lighting

$Q = 3.41 \times W \times F_{UT} \times F_{SA} \times (CLF)$

Where

- W = Watts input from electrical lighting plan or lighting load data
- F_{UT} = Lighting use factor, as appropriate
- F_{SA} = special ballast allowance factor, as appropriate
- CLF = Cooling Load Factor, by hour of occupancy. (This is a constant provided by ASHRAE for the CLTD method)

Heat Gain from Appliances

$Q_{Sensible} = Q_{in} \times F_u \times F_r \times (CLF)$

$Q_{Latent} = Q_{in} \times F_u$

Where

- Qin = rated energy input from appliances
- F_u = Usage factor
- F_r = Radiation factor
- CLF = Cooling Load Factor, by hour of occupancy

Heat Gain due to Infiltration of Air

$Q_{sensible} = 1.08 \times CFM \times (To – Ti)$

$Q_{latent} = 4840 \times CFM \times (Wo – Wi)$

Primary Heat Gain

$Q_{Roof} = U * A * CLTD_{Roof}$

$Q_{Wall} = U * A * CLTD_{Wall}$

$Q_{Glass\ Conduction} = U * A * CLTD_{Glass}$

$Q_{Glass\ Solar\ Radiation} = A * SC * SCL$

Note: CLTD, CFM, SC, CLF are constants provided by ASHRAE for simpler computation.

Table 1: Cooling Load Calculations Summary

Solar Time	Total Cooling Load Per Engineering Building	Total Cooling Load for All Engineering Buildings	Total Cooling Load for Admin Building	Total Cooling Load for Engineering Complex (Btu/hr)	Total Cooling Load for Engineering Complex (TR-hr)
7am	310850.582	2486804.656	358568.984	2845373.64	237.11447
8am	376362.9852	3010903.882	431312.8512	3442216.733	286.8513944
9am	384791.03	3078328.24	440379.392	3518707.632	293.225636
10am	396061.9844	3168495.875	452597.1264	3621093.002	301.7577501
11am	409887.5082	3279100.066	468495.8312	3747595.897	312.2996581
12nn	423191.2138	3385529.71	483661.1288	3869190.839	322.4325699
1pm	436567.4224	3492539.379	499156.7944	3991696.174	332.6413478
2pm	448522.591	3588180.728	513309.596	4101490.324	341.7908603
3pm	459864.6696	3678917.357	527022.0336	4205939.39	350.4949492
4pm	467100.8992	3736807.194	536118.7032	4272925.897	356.0771581
5pm	474202.3358	3793618.686	545063.8408	4338682.527	361.5568773
6pm	475255.8414	3802046.731	546197.1584	4348243.89	362.3536575
7pm	476309.347	3810474.776	547330.476	4357805.252	363.1504377

The cooling loads for the nine engineering buildings are assumed to be the same since they are all composed of the same number of classrooms, laboratories, etc. There is a separate computation for the administrative building's second and third floor cooling loads. The first floor of the admin building (the cafeteria) will not be included in the centralized air conditioning system. Table 1 shows the summary of the total hourly cooling load calculations that will be the basis for designing the size and capacity to be used for the engineering complex.

2.3 Thermal Energy Storage System Design

Thermal Energy Storage (TES) systems, in general, refer to a system that stores energy for later use. This scheme can be applied for district cooling of the engineering complex. Figure 1 and 2 shows the schematic of a conventional water chiller system and an external melt ice on coil TES system respectively. Utilizing TES can lower operating costs and reduce maintenance expenses of the university. The external melt ice on coil system builds and stores ice on the external surface of a heat exchanger coils submerged in a non-pressurized water tank. This system operates at night when electricity costs are lower and it will then melt the stored ice to meet the cooling demand the next day when the power costs are higher. Capitalizing on this price difference between on-peak and off-peak electricity cost makes TES an attractive alternative to conventional water chiller systems.

The external melt ice on coil system requires less electricity than conventional water chiller systems since the ambient dry-bulb conditions are lower at night than day time. These result in lower system discharge pressure, higher coefficient of performance and lower compressor drawn current. Wet-bulb temperature during night is also lower than it is at day time thus; cooling tower operation is more efficient, requiring less water flow rate and lower pumping power requirement. Lastly, TES has a lower chilled water discharge temperature which results in higher available water temperature difference. This lowers chilled water flow rate requirement of building cooling systems requiring smaller pumping power.

Partial ice storage was selected over the full ice storage for the air conditioning system of the engineering complex. In a partial ice storage system, the compressors still operate at part-load and aid the ice thermal energy storage during the day while in a full TES the compressors are totally shut down during the day. Partial ice storage is practical for comfort cooling applications compared to full ice storage which is best suited for process cooling applications. Full ice storage has advantages such as a higher COP and lower operations cost but partial ice storage has a significantly lower capital installation. Full ice storage system requires more compressors, pumps and cooling towers since the amount of ice made should be greater to meet the building cooling load. Partial ice storage also has a simpler control system due to fewer components. The operating cost savings of full ice storage are not sufficient to justify its high installation cost,while advantages of the partial ice storage system justify its high operating cost in the setting of this research.

One constraint in the use of TES for building air conditioning is the usual space constraint but in the case of our engineering complex, the ice storage tanks would be placed underground so that the space above it can be utilized for other facilities such as a sports complex or a park. This scheme also lessens the solar heat absorbed by the ice storage tanks which would otherwise hasten the melting of the ice and have a negative impact on the system.

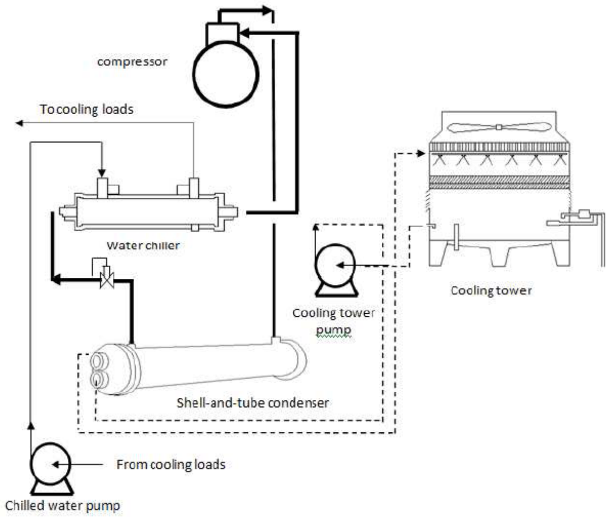

Figure 1 Schematic Diagram of water chiller with shell and tube condenser, cooling tower, semi-hermetic compressor and centrifugal pumps

Our engineering complex will utilize an external melt ice-on-coil system which uses submerged evaporator coils where refrigerant or secondary coolant is circulated, resulting in ice accumulating on the external surface of the evaporator coils during the night. Storage is discharged by circulating warm return over the evaporator coils during the day, melting ice from the outside.

Figure 2 shows the schematic diagram of an external melt ice-on-coil TES system which includes a heat exchanger (aimed to isolate the open storage tank from the building distribution system) and a chiller barrel to supplement stored cooling during discharging periods. Pre-cooling of return chilled water was done on the water chiller, reducing its temperature from 16^0C to 8^0C. Melting the ice from the TES storage tank further reduces its temperature to 2^0C before supplying to the engineering complex buildings. Outlet and inlet temperatures at TES storage tank are 1^0C and 6^0, respectively.

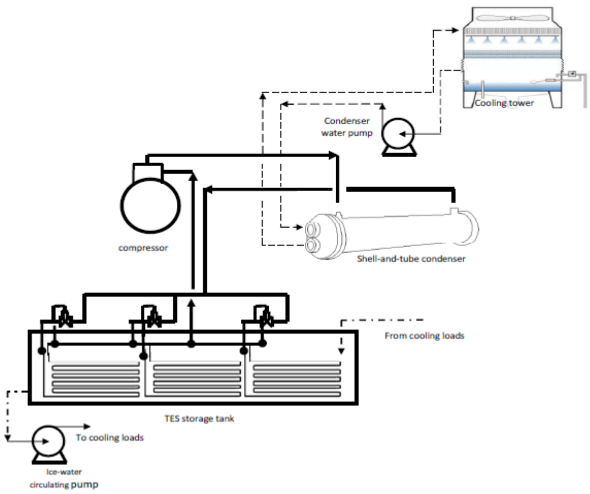

Figure 2: Schematic diagram of external melt ice on coil system

Table 2 shows the results for the ice thickness computations for three types of compressors. The calculation procedure used is based on mathematical modeling made by Bongat, 2012 [1]. The results are also presented graphically on Figure 3. The ice build-up time is from 8 pm to 7 am and during this time, the engineering complex is no longer under operation while the system is in full blast. From 8 am to 3 pm the compressors will just aid in the cooling done primarily by melting the ice made overnight. From 4 pm to 8 pm, the compressors will be totally shut down emptying the ice formed on the evaporator coils for another cycle of the ice thermal energy storage system to initialize again.

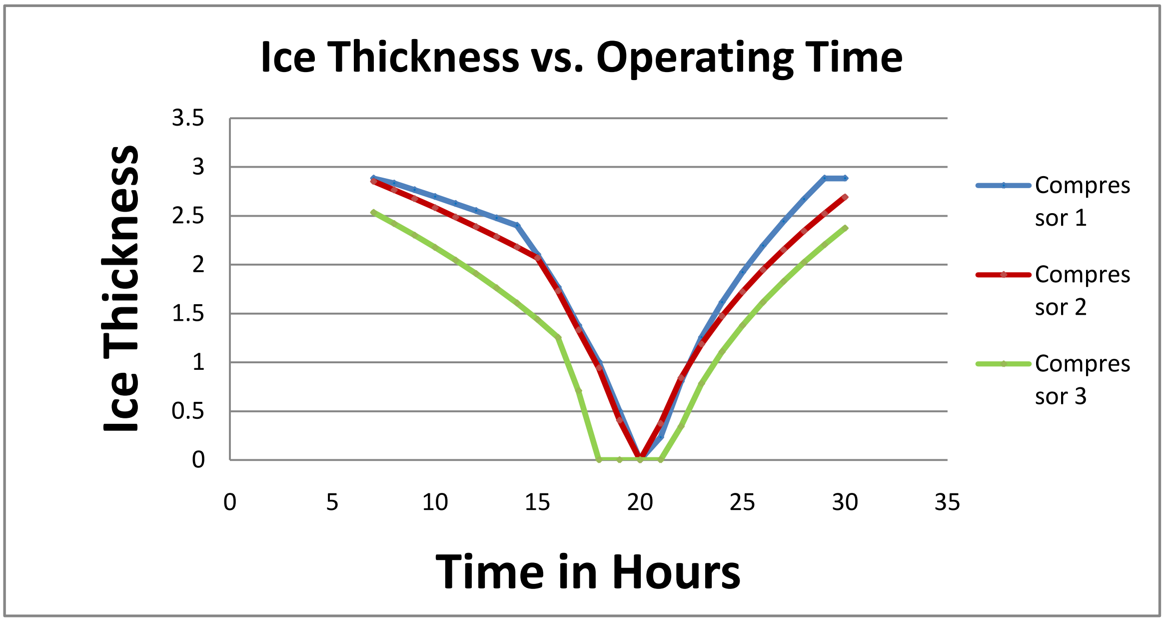

Figure 3 The corresponding plot of ice thickness on coils versus time of day for the 3 compressor models

Four (4) Compressors each with a capacity of 182 tons of refrigeration will be used for the ice build-up of the thermal energy storage system of the engineering complex. The system will have an evaporator temperature of 20.13°F (-6.54°C). Computations for the compressor capacity and evaporator temperature can be found in Appendix B.

Table 3 shows the comparison of power consumption for two centralized air conditioning systems with the same total compressor capacity (tons of refrigeration). One system utilizes ice TES partial storage and the other system uses conventional water chillers only. The values for the annual projected energy consumption are from the electric motors of the two systems that could be found in the compressors, cooling tower fans, chilled water pumps and cooling tower pumps.

Table 2 Hourly ice build-up on coil

Time	Accumulated ice thickness in			Remarks
	W50 168Y	W40 168Y	Z50 154Y	
01:00	1.92	1.72	1.38	ice build-up
02:00	2.19	1.95	1.61	ice build-up
03:00	2.44	2.15	1.83	ice build-up
04:00	2.67	2.34	2.02	ice build-up
05:00	2.88	2.52	2.20	ice build-up
06:00	2.88	2.69	2.37	ice build-up
07:00	2.88	2.85	2.53	ice build-up
08:00	2.83	2.76	2.42	melting while comp in operation

09:00	2.76	2.67	2.30	melting while comp in operation
10:00	2.69	2.58	2.18	melting while comp in operation
11:00	2.62	2.49	2.04	melting while comp in operation
12:00	2.55	2.39	1.91	melting while comp in operation
13:00	2.48	2.28	1.76	melting while comp in operation
14:00	2.40	2.18	1.61	melting while comp in operation
15:00	2.10	2.07	1.44	melting while comp in operation
16:00	1.77	1.73	1.25	forced compressor shut-down
17:00	1.38	1.33	0.71	forced compressor shut-down
18:00	1.00	0.94	0.00	forced compressor shut-down
19:00	0.50	0.41	0.00	forced compressor shut-down
20:00	0.00	0.00	0.00	pre-cooling and ice build-up
21:00	0.23	0.37	0.00	ice build-up
22:00	0.80	0.84	0.34	ice build-up
23:00	1.26	1.18	0.78	ice build-up
24:00	1.61	1.47	1.11	ice build-up

Annual electricity consumption for the water chiller option was computed at 1,419,632 kW-hrs, valued at PhP 7,898,321 while for the TES option: 1,661,587 kW-hrs/year at PhP 6,986,787.68. Note that the annual projected power cost of TES system is 11.54% lower than that of conventional water chiller with cost difference amounting to PhP 911,533. Operating the system at night when the temperature is lower will result in an increase of COP contributing 13.76% to the total electricity cost reduction.

The bulk of the electricity cost savings (86.24%) are due to the time of use (TOU) ratesimplemented in the country wherein electricity rates for utilities using more than 500 kWh per month are lower during off-peak hours. As can be seen from Table 4, electricity costs are significantly lower from 10 pm to 8 am compared to the normal electricity rates shown on Table 5. The ice thermal energy storage system utilized by our engineering complex predominantly runs at full capacity during these off-peak hours to build ice thus, greatly reducing the monthly electricity bills of the university.

Table 3 Comparison of operating parameters (conventional chiller and TES partial storage)

Particulars	Conventional Water Chiller (1)	TES partial storage (2)
Annual operating time, hours	3,696	5,016
Total annual power consumption, kW-hrs	1,419,632	1,661,587
Average hourly power consumption, kW	384	331
Total compressor capacity, TR	497	497
Average annual kW/TR	0.773	0.667
kW/TR reduction	Basis of comparison	13.76%
Computation of total savings due to COP improvement and TOU power rate		
Particulars	Conventional Water Chiller (1)	TES partial storage (2)
Power cost, PhP/yr	7,898,321	6,986,788
Annual power savings, PhP	Basis of comparison	911,533
Annual power cost reduction, %	Basis of comparison	11.54%
Percentage of reduction due to COP improvement	Basis of comparison	13.76%
Percentage of reduction due to TOU power rate		86.24%

The cooling towers that will cool the chiller condensers will also have a better operation during the night since the wet bulb temperature of the ambient air that the water being cooled should approach is lower as compared to its wet bulb temperature during the day.

Table 5 Time of Use (TOU) Rates in Luzon

PERIOD	(JANUARY - JUNE)		(JULY - DECEMBER)	
	Monday - Saturday	Sunday/Holiday	Monday - Saturday	Sunday/Holiday
1:00 AM	2.3426	2.5022	2.3426	2.3426
2:00 AM	2.3426	2.3426	2.3426	2.3426
3:00 AM	2.3426	2.3426	2.3426	2.3426
4:00 AM	2.3426	2.3426	2.3426	1.8649
5:00 AM	2.3426	2.3426	2.3426	1.8649
6:00 AM	2.3426	2.3426	2.3426	1.8649
7:00 AM	2.3426	2.3426	2.3426	1.8649
8:00 AM	2.6256	2.3426	2.5022	2.3426
9:00 AM	5.7790	2.3426	2.6256	2.3426
10:00 AM	6.5283	2.5022	5.9872	2.5022
11:00 AM	6.5283	2.5022	6.5283	2.5022
12:00 PM	6.5283	2.5022	5.9872	2.5022
1:00 PM	6.5283	2.5022	5.9872	2.5022
2:00 PM	6.5283	2.5022	6.5283	2.5022
3:00 PM	6.5283	2.5022	5.9872	2.5022
4:00 PM	6.5283	2.5022	5.7790	2.5022
5:00 PM	5.9872	2.5022	5.5481	2.5022
6:00 PM	5.9872	2.5022	5.9872	2.6256
7:00 PM	6.5283	5.7790	6.5283	5.5481
8:00 PM	6.5283	5.7790	5.9872	5.5481
9:00 PM	5.9872	3.2594	5.7790	2.6256
10:00 PM	3.2594	2.6256	2.6256	2.5022
11:00 PM	2.6256	2.5022	2.5022	2.3426
12:00 AM	2.5022	2.3426	2.3426	2.3426

Table 6: Normal Electricity Rates in Luzon

UNBUNDLED RATES FOR LUZON GRID, P/kWh

January 2012 - July 2012

Month	Average Generation Rate	Franchise & Benefits to Host Communities*	Deferred Accounting Adjustment (DAA)*				Automatic Cost Adjustment				NPC Effective Rate
			GRAM		ICERA		FPPCA		FxA		
2012											
JAN	4.3648	0.0245	0.0000		0.0000		0.4325		0.1950		5.0168
FEB	4.3648	0.0245	0.0000		0.0000		0.4344		0.1923		5.0160
MAR	4.3648	0.0245	0.0000		0.0000		0.4374		0.1947		5.0214
APR	4.3648	0.0245	0.3267	/42	0.3637	/43	0.4340		0.1940		5.7077
MAY	4.3648	0.0245	0.3267		0.3637		0.4268		0.1975		5.7040
JUN	4.3648	0.0245	0.3267		0.3637		0.4092		0.1924		5.6813
JUL	4.3648	0.0245	0.3267		0.3637		0.4089		0.1827		5.6713

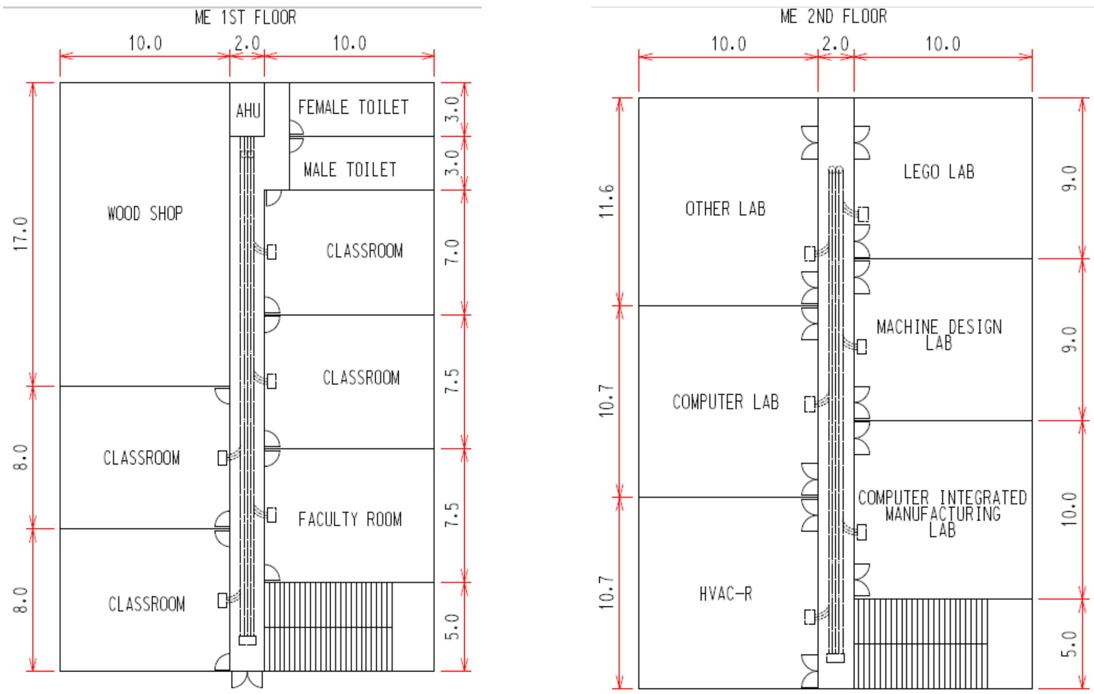

Figure 4 The air conditioning ducting and floor plans for the mechanical engineering building.

Note: Other engineering buildings just follow the same layout as the ME building.

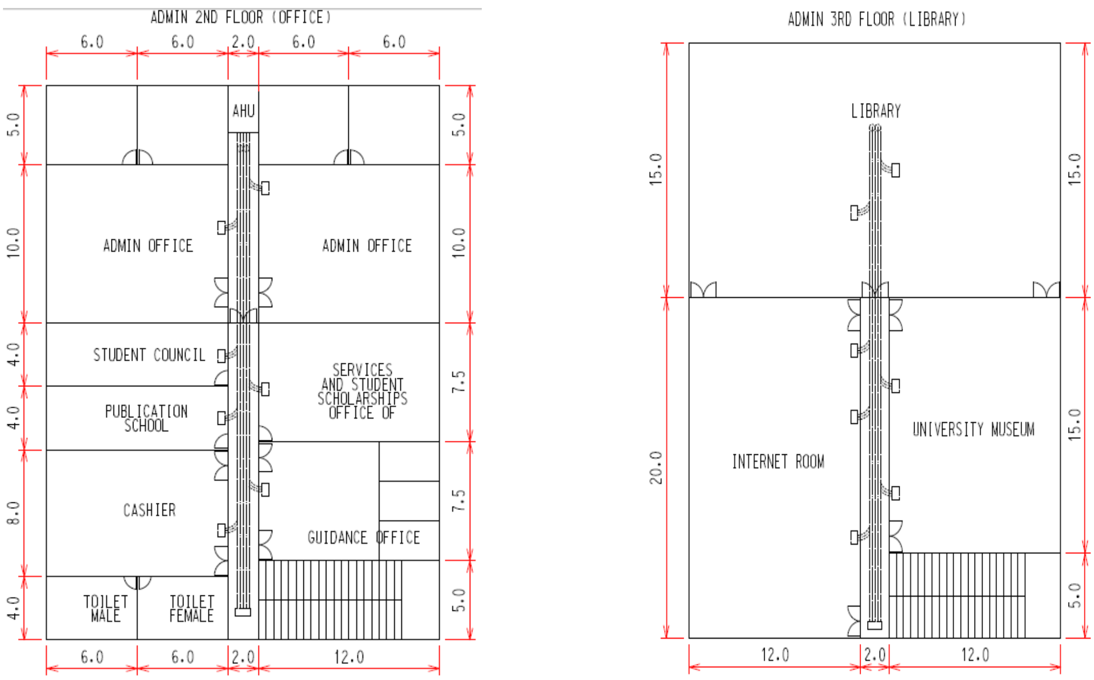

Figure 5 The air conditioning ducting and floor plans for the administrative building

There will be one air handling unit (AHU) per building that will blow air (a mix of warm return air and fresh air from the outside) towards the coils containing the supply chilled water from the ice thermal energy storage system. The ducting used will be rectangular galvanized iron sheet covered with polyurethane insulation. Vibration isolators are present at the entrance and exit of the AHU to dampen noise and vibration. Volume control dampers are also present inside the ducts to control the volume of air flow to various parts of the system. Each duct is subdivided into a supply air duct which supplies cold air to the building load and a return air duct which delivers warm air back to the AHU for cooling. A fresh air duct is connected to the AHU to replenish the oxygen content of air inside the building which is used up by the building occupants.

3 CONCLUSIONS

The layout of the proposed engineering institution is shown in Figure 8.

The engineering complex would utilize external melt partial energy storage with district cooling system distribution. There would be four chillers as computed connected to the ice storage tanks. The ice storage tanks will be located underground and so with the pipes connecting it to the distribution system for the solar heat effect on the tanks to be minimized and to provide more space for the complex. Four cooling towers are located beside the mechanical engineering department to serve cooling water for the condensers.

Power cost savings of the proposed engineering complex for utilizing thermal energy storage over the conventional water chiller district air conditioning system amounts to Php 911,533.00. This is due to the utilization of Time of Use (TOU) and the ambient temperature at night time in the ice thermal system.

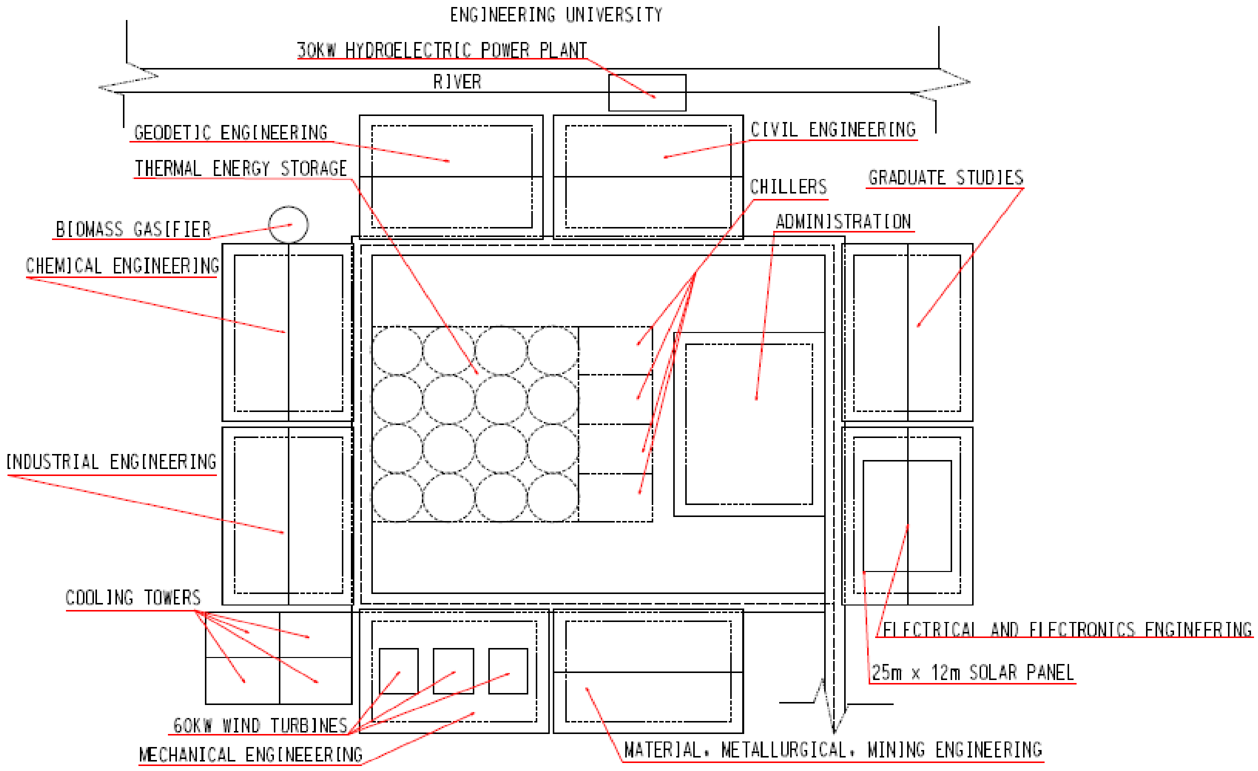

Figure 8: Proposed Engineering University Complex Layout

4 RECOMMENDATIONS

Partial external melt ice thermal energy storage, a compressor aided system, was used in the design and computation in this paper. In this scheme, the compressors still run during some of the system cooling time. Full storage system, another type of thermal energy storage wherein compressors are fully shut down during cooling time of the system, can be modeled in replacement for the partial energy storage. This system will benefit on low cost operation but the initial capital cost will be very high compared to the compressor aided system.

APPENDICES

Appendix A. Hourly cooling load profile

Scheme 1

1. Chilled water load profile (scheme 1)

	Time of day	TR-Hrs	Ice Build-up Time	Cooling Time	Comp. cap, TR	Excess Cap, TR
	1	0.0	1.00	0.00	182	911
	2	0.0	1.00	0.00	182	1,093
	3	0.0	1.00	0.00	182	1,275
	4	0.0	1.00	0.00	182	1,457
	5	0.0	1.00	0.00	182	1,639
	6	0.0	1.00	0.00	182	1,821
	7	237.1	0.00	1.00	182	1,766
	8	286.9	0.00	1.00	182	1,662
	9	293.2	0.00	1.00	182	1,550
	10	301.8	0.00	1.00	182	1,431
	11	312.3	0.00	1.00	182	1,301
	12	322.4	0.00	1.00	182	1,160
	13	332.6	0.00	1.00	182	1,010
	14	341.8	0.00	1.00	182	850
	15	350.5	0.00	1.00	182	682
	16	356.1	0.00	1.00	182	508
1	17	361.6	0.00	1.00	0	146
1	18	362.4	0.00	1.00	0	-216
1	19	363.2	1.00	0.00	0	-579
1	20	0.0	1.00	0.00	0	0
	21	0.0	1.00	0.00	182	182
	22	0.0	1.00	0.00	182	364
	23	0.0	1.00	0.00	182	546
	24	0.0	1.00	0.00	182	729
4		**4,222**	**12.0**	**12.0**	**3,643**	

2. Determine the total system operating time

ice build time, hr	12
cooling load time, hr	12
rest period, hr	4
sys. operating time, hr	20

3. Compute adjusted TR-hrs

adjusted TR-hrs 2,533.05

4. Determine number of thermal storage systems

TSU model no.	720		
Ice capacity, lbs	60,000		
Computed quantity	3.52	use:	4
desired qty = 3	70,362		

3. Calculate storage factor

storage factor	1.1370

4. Compute evaporator temperature (from table 1)

storage factor	1.1370	
ice build time, hr	12.0	
evap temp, °F	20.1303	-6.59 °C

5. Compute compressor capacity

computed cap, TR	211	
use comp cap,TR	182	-13.72%
safety factor	0%	

equiv. kW = 742

Scheme 2

1. Chilled water load profile (scheme 2)

	Time of day	TR-Hrs	Ice Build-up Time	Cooling Time	Comp. cap, TR	Excess Cap, TR
	1	0.0	1.00	0.00	178	892
	2	0.0	1.00	0.00	178	1,071
	3	0.0	1.00	0.00	178	1,249
	4	0.0	1.00	0.00	178	1,428
	5	0.0	1.00	0.00	178	1,606
	6	0.0	1.00	0.00	178	1,785
	7	237.1	0.00	1.00	178	1,726
	8	286.9	0.00	1.00	178	1,618
	9	293.2	0.00	1.00	178	1,503
	10	301.8	0.00	1.00	178	1,380
	11	312.3	0.00	1.00	178	1,246
	12	322.4	0.00	1.00	178	1,102
	13	332.6	0.00	1.00	178	948
	14	341.8	0.00	1.00	178	784
	15	350.5	0.00	1.00	178	612
	16	356.1	0.00	1.00	178	435
1	17	361.6	0.00	1.00	0	73
1	18	362.4	0.00	1.00	0	-289
1	19	363.2	1.00	0.00	0	-652
1	20	0.0	1.00	0.00	0	0
	21	0.0	1.00	0.00	178	178
	22	0.0	1.00	0.00	178	357
	23	0.0	1.00	0.00	178	535
	24	0.0	1.00	0.00	178	714
4		**4,222**	**12.0**	**12.0**	**3,569**	

2. Determine the total system operating time

ice build time, hr	12
cooling load time, hr	12
rest period, hr	4
sys. operating time, hr	20

3. Compute adjusted TR-hrs

adjusted TR-hrs 2,533.05

4. Determine number of thermal storage systems

TSU model no.	720		
Ice capacity, lbs	60,000		
Qty. required	3.52	use:	4

3. Calculate storage factor

storage factor	1.1370

4. Compute evaporator temperature (from table 1)

storage factor	1.1370	
ice build time, hr	12.0	
evap temp, °F	20.1	-6.59 °C

5. Compute compressor capacity

computed cap, TR	211	
use comp cap,TR	178	-15.46%
safety factor	0%	

95%

Scheme 3

1. Chilled water load profile (scheme 3)

	Time of day	TR-Hrs	Ice Build-up Time	Cooling Time	Comp. cap, TR	Excess Cap, TR
	1	0.0	1.00	0.00	161	805
	2	0.0	1.00	0.00	161	966
	3	0.0	1.00	0.00	161	1,127
	4	0.0	1.00	0.00	161	1,288
	5	0.0	1.00	0.00	161	1,449
	6	0.0	1.00	0.00	161	1,610
	7	237.1	0.00	1.00	161	1,534
	8	286.9	0.00	1.00	161	1,408
	9	293.2	0.00	1.00	161	1,276
	10	301.8	0.00	1.00	161	1,135
	11	312.3	0.00	1.00	161	984
	12	322.4	0.00	1.00	161	822
	13	332.6	0.00	1.00	161	651
	14	341.8	0.00	1.00	161	470
	15	350.5	0.00	1.00	161	280
	16	356.1	0.00	1.00	161	85
1	17	361.6	0.00	1.00	0	-276
1	18	362.4	0.00	1.00	0	-639
1	19	363.2	1.00	0.00	0	-1,002
1	20	0.0	1.00	0.00	0	0
	21	0.0	1.00	0.00	161	161
	22	0.0	1.00	0.00	161	322
	23	0.0	1.00	0.00	161	483
	24	0.0	1.00	0.00	161	644
4		**4,222**	**12.0**	**12.0**	**3,220**	

2. Determine the total system operating time

ice build time, hr	12
cooling load time, hr	12
rest period, hr	4
sys. operating time, hr	20

3. Compute adjusted TR-hrs

adjusted TR-hrs 2,533.05

4. Determine number of thermal storage systems

TSU model no.	720		
Ice capacity, lbs	60,000		
Qty. required	3.52	use:	4

3. Calculate storage factor

storage factor	1.1370

4. Compute evaporator temperature (from table 1)

storage factor	1.1370	
ice build time, hr	12.0	
evap temp, °F	20.1	-6.59 °C

5. Compute compressor capacity

computed cap, TR	211	
use comp cap,TR	161	-23.73%
safety factor	0%	

90%

Appendix B. Design Evaporator Temperature in °F

Storage Factor	Ice Build-up Time (hrs)					
	8	9	10	11	12	13
1.00	12.0	14.0	16.0	17.5	18.5	19.5
1.05	13.5	15.0	17.0	18.5	19.5	20.5
1.10	14.5	16.5	18.0	19.0	20.0	21.0
1.15	15.5	17.5	19.0	20.0	20.5	21.5
1.20	16.5	18.0	19.5	20.5	21.5	22.0
1.25	17.5	19.0	20.0	21.0	22.0	22.5
1.30	18.0	19.5	20.5	21.5	22.5	23.0
1.35	19.0	20.0	21.0	22.0	23.0	23.0
1.40	19.5	21.0	21.5	22.5	23.0	23.5

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EMPIRICAL THRESHOLD VALUES OF ROOF CONNECTIONS USING PULL-OUT TEST ON NAILS AND SCREWS

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Abstract: Philippines is a pathway of typhoons. Strong typhoons inflict damages in residential house especially on its building envelope. Due to negative pressures produced by the strong winds, the roofing materials are being pulled away and the only type of connection that holds the roofing is its fasteners. The study deals with the determination of threshold values of these connections in Philippine context. These threshold values are important on simulations involving wind loads. In addition, disaster risk management relies on experimental data to predict how large the damage would be on single or group structures. The determination of fastener pullout resistance (FPR) in static loading and cyclic loading tests were done. Combination of roofing, fasteners and purlins were made to determine the governing modes of failure for the roof connections. For single fastener test – static loading, wood nail, metal screw and wood screw had FPR of 0.89 kN, 0.87 kN and 5.6 kN respectively. The decrease in FPR from the static loads to cyclic loads in the 1500-2000 cycles test for wood nail, metal screw and wood screw was 2.8%, 9.4% and 23% respectively. When the type of connection is nail, the nail is pulled out without experiencing tearing of GI sheet. For metal screw, mostly tearing occurs rather than pullout. If the fastener in the connection is wood screw, tearing will always be the mode of failure for the connection. The maximum loads are 1.43 kN, 1.26, kN and 1.37 kN for wood nail, metal screw and wood screw respectively.

Key words : Pullout, Static Loading, Cyclic Loading, Roof Connections

1 INTRODUCTION

1.1 Background

Structural roof systems are an important part of a building. It protects the interior parts of the building from heat, rain, wind, humidity and others. One of the elements on the environment that is enough to damage the structural roof system is the wind loads. Wind loads during typhoons apply suction in the roof such that the negative pressure is enough to pull out one or more parts of the system.

The Philippines is a typical pathway for typhoons. It experiences 20 or more typhoons annually with varying winds speeds. Residential buildings are the most commonly constructed structures here in the Philippines. It is frequently observed that low rise residential buildings suffer largely during tropical cyclones Li (2005).

The most vulnerable part of a residential building is its envelope. It includes the roof, walls, doors and windows. Failure of one these components may lead to the decrease of the structural integrity of the building (Veron, 2012). The common failures that roofing experience are pullout of the connections on roof-to-wall, tearing of the roofing material, and pullout of the fasteners connecting the roof to the purlin.

Researches were conducted for roof-to-wall connections (Shanmugama, et al. 2009), tearing of the roof (Henderson, 2011) and pullout of fasteners in a roofing field (Baskaran, et al. 2008). The results may be different for the structures in the Philippines since researches were made in other countries. Currently, the threshold values used for the uplift resistances were based on foreign researches and not based on the conditions here in the Philippines. Thus, it is important to determine these values in the Philippine context.

1.2 Statement of the Problem

Roofing materials are always subjected to negative pressure during typhoons which cause uplift to the fasteners. Therefore, this research will focus on developing uplift threshold values in the Philippines that will be used in developing fragility curves of structures subjected to wind loading. The study specifically involved materials commonly used in roofs in the Philippines. The research also focused on the difference on static and cyclic loading and behavior of multiple fasteners during uplift.

1.3 Objectives

The objective of the study is to conduct pullout test on the commonly used fasteners in the roof-to-purlin connections to observe the behavior of the components of the roof systems under pullout and to determine uplift threshold values for the resistance of the fasteners. Another objective is to conduct two types of tests: static and cyclic loading to determine the decrease in resistance of the fastener to pullout..

1.4 Significance of the Study

Threshold values are important since they are used in preliminary design or simulations of structures. Simulations use threshold values in order to predict possible failures in the building envelope, which are then used to develop fragility curves. Uplift threshold values vary depending on the type of materials and their properties. The developed threshold values from this study are suitable based to the Philippine setting.

Another importance of the research is to compare the decrease on fastener pullout resistance (FPR). Lastly, the design for the fastener spacing in the National Structural Code of the Philippines 2010 (NSCP) did not state what kind of fastener to be used. Different fasteners have different FPR therefore fastener spacing should vary depending on the type of fastener. After obtaining values of FPR, the research would be able to recommend design fastener spacing for roofing systems based on empirical data.

1.5 Scope and Limitations

The study only focuses on the nail and screw resistances during pullout. Tearing of the roof cladding during pullout was not considered. Wood panel sheathing and metal cladding were not used during pullout. Other factors that were not considered include angle of penetration, depth of penetration, moisture in the system, and variation of material to be used. The factors not considered may be included in succeeding researches. The common types of fasteners such as wood nail, wood screw and metal screw were used.

1.6 Conceptual Framework

Quantitative risk assessment methodology involves computations based on the magnitude and probability that loss will occur. One of the factors that is used in risk assessment is vulnerability which is quantified by fragility or vulnerability curves.

Fragility curves, in view of severe wind loadings, show the relationship of the probability of occurrence of each damage state as a function of wind speed. Damage states vary with different building types (e.g. residential buildings, industrial buildings, etc.) and different hazards (e.g. wind speed for tropical cyclones, spectral acceleration for earthquakes) (Veron, 2012). For the development of fragility curves, simulations were done in computer applications such as ANSYS. Before running simulations, parameters should be specified such as the threshold values for uplift resistance of nails. The values of these parameters are critical since they will change the resulting fragility/vulnerability depending on the assumptions.

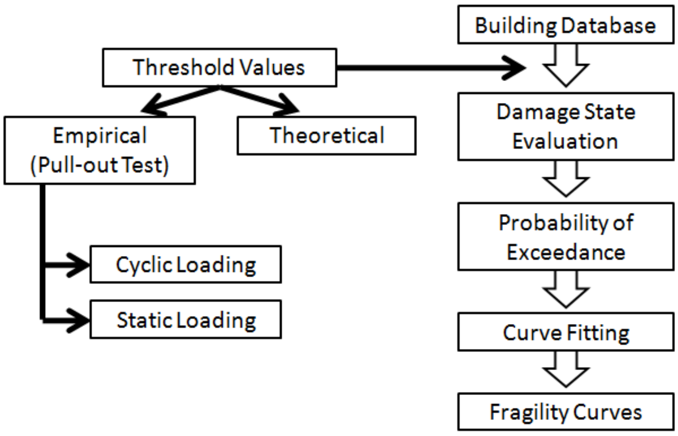

Figure 1 Conceptual Framework

2. METHODOLOGY

2.1 Test Types
For the study, there were 5 types of tests conducted. The first two were static and cyclic loading of single fasteners (Single Fastener Test). The purpose of these two types of tests is to determine whether there is significant decrease in fastener pullout resistance (FPR) of the fasteners if subjected to series of progressive cycles.

The third type of test, Static loading for GI Roof (Roofing Test), was done to determine the strengths of GI roofing when upward pressure is applied on it. After the third test, it was compared to the results of the static loading of single fasteners in order to determine what kind of failure will govern depending on the maximum pull out resistances.

The fourth test, which was a combination of first and third, was performed to determine whether increase in performance exists when the strengths of roofing and purlin were combined.

Lastly, the fifth test, the multiple fastener test was performed to observe the behavior of group of fasteners during pullout. Of particular importance in this test is the sequence of pullout and the maximum resistance the group can hold.

Table 1. Loading types and corresponding test types for pullout

Loading Type	Test Types
Static Loading	Fastener pullout resistance (FPR)
	Roofing Test
	Combination Test
	Multiple Fastener Test
Cyclic Loading	Fastener pullout resistance (FPR)

2.2 Test Specimen

2.2.1 Fasteners Properties
Three types of fastener were used in the experiment. The fasteners used were wood nail, metal screw and wood screw. Below are the dimensions of the fasteners that were used.

Table 2. Specifications of fasteners used

	Inner Diameter	Outer Diameter	Head Diameter	Threaded Length	Total Length
Wood Nail	N/A	N/A	20 mm	N/A	75 mm
Metal Screw	2.5 mm	4 mm	12 mm	35 mm	80 mm
Wood Screw	3 mm	5 mm	13 mm	60 mm	85 mm

2.2.2 Purlin Properties
The purlin sample dimensions are 2 x 3 x 6 in per sample. Wood S4S and galvanized iron c channel were the types of material used. The thickness of the C Channel is 1 mm.

2.2.3 Roof Properties
The roofing used in the experiment was gauge 24 galvanized iron with a size of 200 x 200 mm. The thickness of the roof is 0.76 mm. The fastener is placed on the crest of the wave of the roof

2.3 Design and Test Set Up
Since the Universal Testing Machine's wedge grips are not capable of holding the specimen, attachments were designed such that they are capable and flexible enough to conduct different types of test. Figures 11 – 17 shows the experimental setups for the different tests performed.

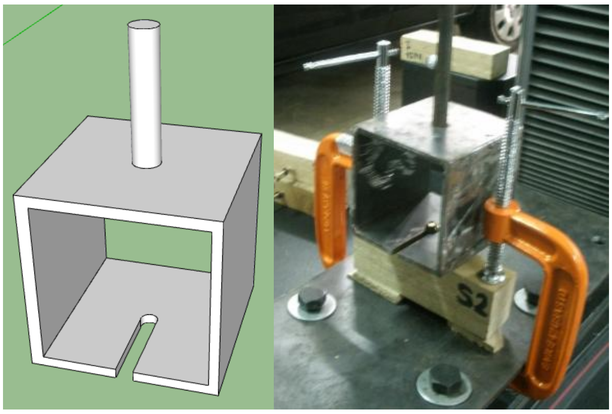

Figure 2 Design and setup of single fastener test (Static loading)

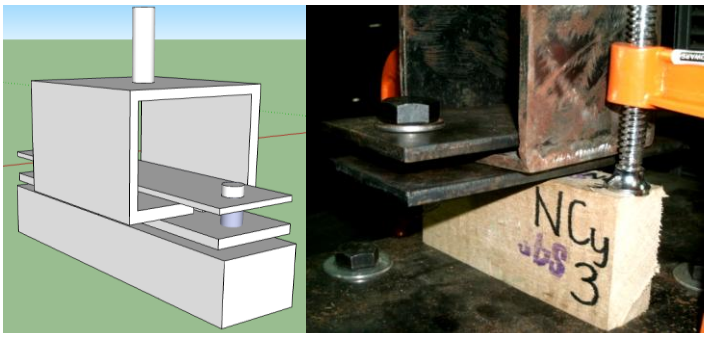

Figure 3 Design and setup for single fastener test (Cyclic loading)

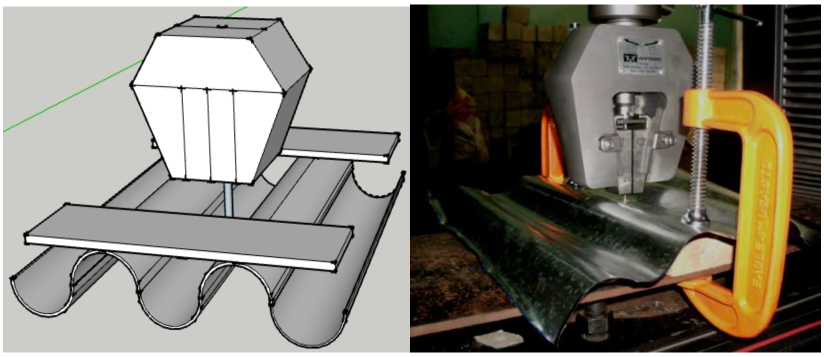

Figure 4 Design and setup for roofing test

Figure 5 Combination of roofing, fastener, purlin test set-up

2.4 Testing Process and Parameters

Since there are five types of tests, each of the tests needs specifications for loading that will be set in the Bluehill software. Therefore the researcher made some protocols for testing based on ASTM D1761 – 06, ASTM D7332/D7332M – 09 and modified CSA Loading Cycles from (Baskaran et al, 2012).

2.4.1 Static Loading Parameters

For static loading, the loading rate is 2 mm/min. The movement of the crossbeam is constant until the fastener reached total pull-out.

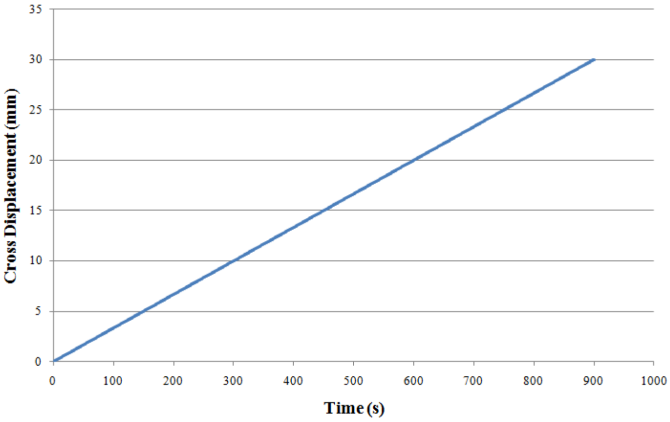

Figure 6 Static loading rate

2.4.2 Cyclic Loading Sequence

For cyclic loading, the crossbeam is displaced up and down with increasing amplitude. The loading rate for the crossbeam is 75 mm/min. For certain amplitude, there are 200 cycles applied on the specimen. The sequence is similar to Baskaran but the amplitude increases by 0.5 mm after every 200 cycles to determine the behavior of the load displacement curve at a certain loading sequence..

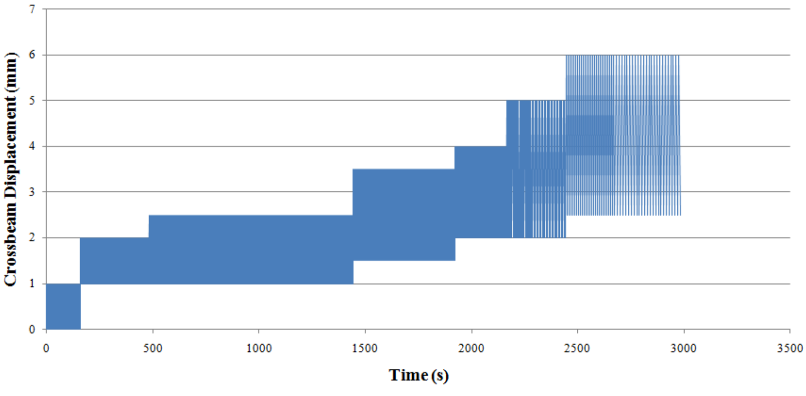

Figure 7 Sample cyclic loading sequence for metal screw

3. RESULTS AND DISCUSSION

3.1 Static Loading for Fasteners

Three types of fasteners were used and tested until pullout. During the test, the load displacement curve of the crossbeam was automatically generated by Bluehill 3. It was observed that the wood nail after pull out test did not tear the fibers the purlin. The fibers of the wood remained intact since the texture of the nail is smooth.

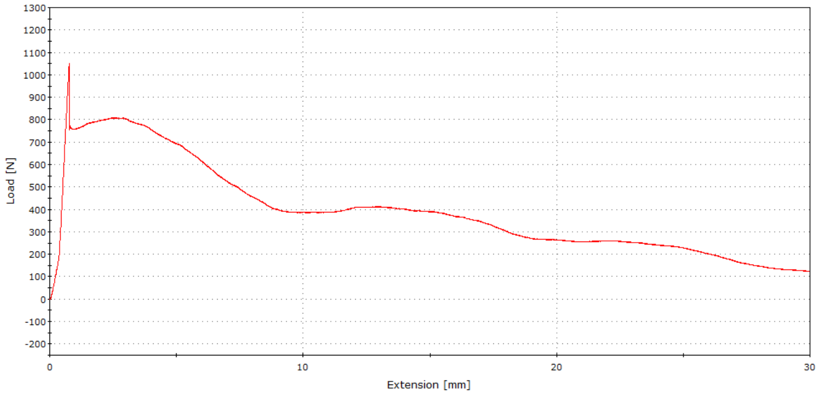

Figure 8 Force vs. displacement of wood nail sample (Static loading)

The force vs. displacement graph of wood nail (Figure 8) has a spike where the maximum load is located. These spike, which is due to the slipping of the nail, are similar to the results discussed by (Rammer, 2010) for smooth surfaced fasteners.

Table 3 Maximum Loads per Fastener during Static Loading

Sample number	FPR (Newtons)		
	Nail	Screw	Metal
1	725	6100	880
2	890	4950	700
3	915	5000	675
4	900	4950	1000
5	890	5010	760
6	800	5000	840
7	910	6200	1030
8	910	4485	680
9	1055	7000	1150
10	950	6500	950
Average	894.5	5519.5	866.5
SD	86.5849	847.9729	164.419

Based on the table, the FPR of wood nail and metal screw are identical with values of 0.89 kN and 0.87 kN respectively. On the other hand, wood screw is 5 times stronger than wood nail and metal screw. It should be noted, however, that the presence of moisture and corrosion were not considered and may affect the FPR in actual conditions.

3.2 Cyclic Loading for Fasteners

In cyclic loading tests, the fastener was displaced up and down due to the movement of the crossbeam. As the crossbeam moves, it makes a cycle which is repeated for many times. Cycle is the completed up and down movement of the crossbeam from two lowest points. Since the loading cycle used has increasing amplitude, every sequence produce cycles which are changing in sizes. Every sample takes about 2 hours since 1000-2000 cycles were made. To save time, static loading was then applied when the fastener displacement is more than 10 mm. This is because most of the peak loads occur from 4-6 mm extension. Figure 9,10 and 11 shows the load displacement of the wood nail, metal screw and wood screw specimen under cyclic loading respectively.

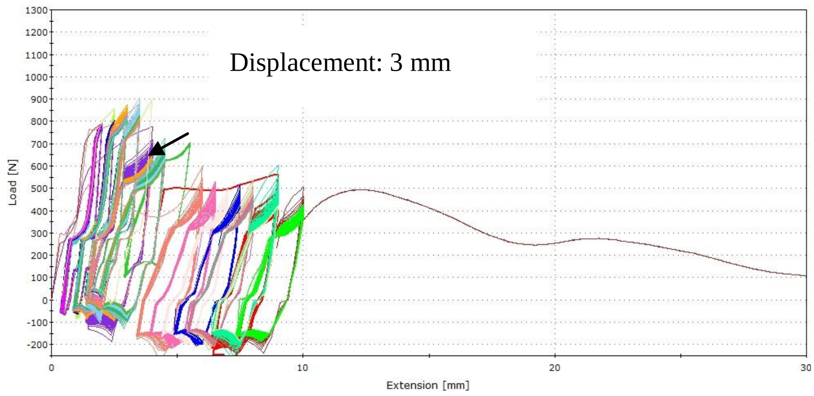

Figure 9 Force vs. displacement of Wood nail specimen (cyclic loading)

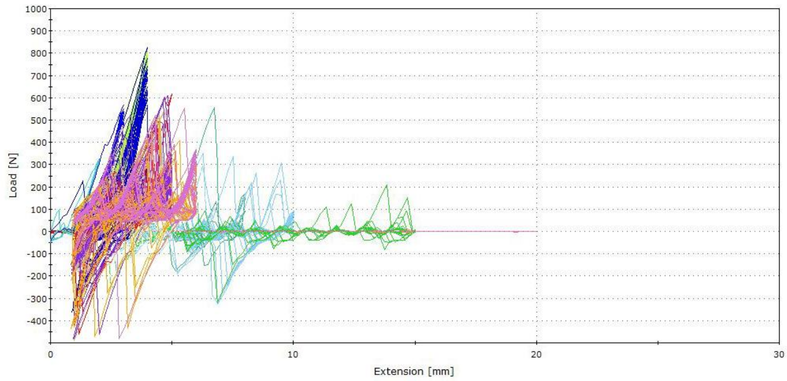

Figure 10 Force vs. displacement of metal screw (Cyclic loading)

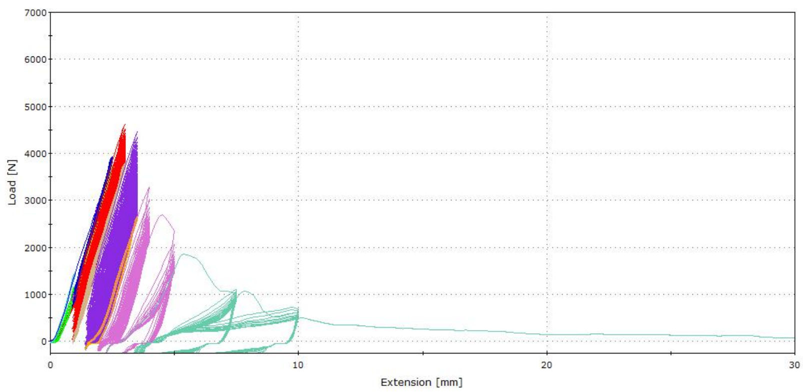

Figure 11 Wood screw specimen after cyclic loading test

Table 4 summarizes all the maximum loads obtained in 17 samples. The average FPR of wood nail and metal screw are 0.86 kN and 0.76 kN, respectively. On the other hand, the FPR of the wood screw is about 4 times stronger than the two. Comparing it with the FPR from static loading, Table 4 shows that there is a decrease in fastener resistances: 2.9%, 9.4%, and 23% for wood nail, metal screw and wood screw, respectively.

Table 4 Maximum loads per fastener during cyclic loading

Sample Number	FPR (Newtons)		
	Nail	Metal	Screw
1	900	820	3900
2	900	740	4250
3	840	720	4200
4	850	950	4300
5	820	800	4700
6		680	4600
Average	862	785	4325
SD	36.3318	95.86449	289.3959

Table 5 Comparison of average FPR (Static and cyclic Loading) per fastener type

	Static (N)	Cyclic (N)		Decrease (%)
Wood Nail	887.5	862		2.873
Metal Screw	866.5	785		9.406
Wood Screw	5619.5	4325		23.036

3.3 Roofing Test

The roofing test was performed to determine the maximum load a roofing field can hold before tearing occurs. From the load displacement curve (Figure 12), the graph has reached a maximum load of approximately 2.4 kN. Based on the graph, the formed curve has some bulges which are possibly due to the creasing of the GI sheet.

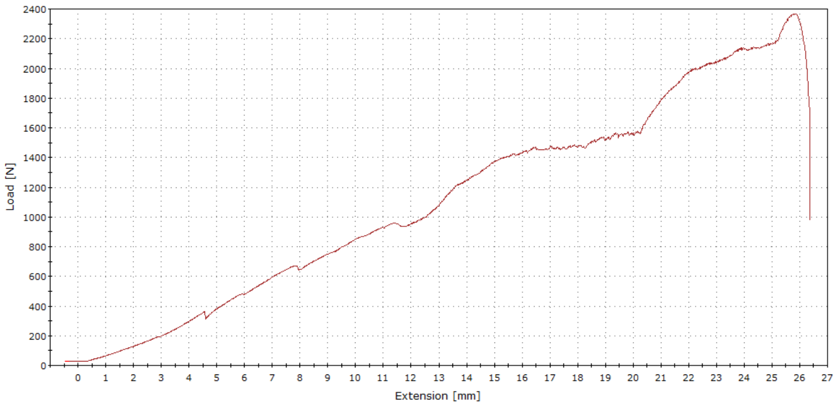

Figure 12 Wood nail + GI sheet specimen after roofing test

In summary, wood nail with GI sheet has the largest maximum load while metal screw and wood screw are identical. With a difference of 60 N in average maximum loads, the metal screw and wood screw can be considered close while wood nail has larger maximum load with an average 1.96 kN. Wood nail has a larger maximum load because the head has a larger area. This area allowed more capacity for the roof to resist force compared with the screw with small heads.

Table 6 Maximum loads per fastener during roofing test

Sample Number	Fastener Types in Roofing Test (Newtons)		
	Wood Nail	Metal Screw	Wood Screw
1	1570	1420	1720
2	2370	1330	1110
3	1950		1110
Average	1963.333333	1375	1313.333333

3.4 Combination Test

After the roofing test, combination of roofing, fastener and purlin test was done. This is to check whether the there is increase in strength when the materials were combined.

Table 7 Expected governing mode of failure for combination tests

Fastener type used in combination test	Expected governing mode of failure
Wood Nail	Pullout
Metal Screw	Pullout
Wood Screw	Tearing

Table 8 Maximum loads per combination type

	Combination Types		
Sample Number	Roofing + Wood Nail + Purlin	Roofing + Wood Nail + Purlin	Roofing + Wood Nail + Purlin
1	1.435 kN (P)	1.400 kN (P)	1.260 kN (T)
2	1.380 kN (P)	1.250 kN (T)	1.345 kN (T)
3	1.475 kN (P)	1.300 kN (T)	1.503 kN (T)
4		1.070 kN (T)	
Average (kN)	1.43	1.255	1.369333333
SD (kN)	0.04769696	0.076376262	0.123313962

P: Pull-out T: Tearing

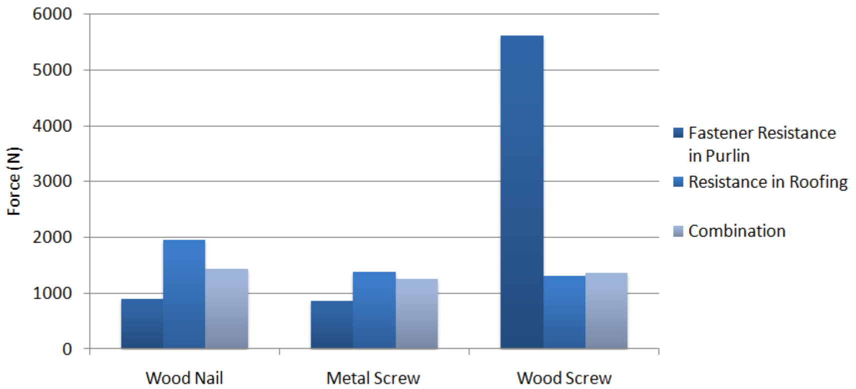

Figure 13 Comparison of average maximum loads on fastener, roofing and combination test

From Fig. 13, the results in combination test showed that there is an increase in fastener resistance. This pattern will lead us to conclusion that there is an increase in fastener resistance when all materials are combined in one system. In contrary, one of the results differed from the hypothesis made. In the combination test, failure in wood nail (pullout) and wood screw (tearing) tallied with the hypothesis while metal screw experienced 1 pullout and 3 tearing failures. The possible explanation for this is that the tearing and the pullout have no substantial difference in values. If there is an increase in strength due to the combination of roofing strength and fastener resistance, then the maximum loads for the both pullout and tearing will be almost the same. If they are almost the same, then there is uncertainty in the mode of failure. Only 4 samples were made, therefore, it is recommended for future studies to conduct more samples.

4 CONCLUSIONS

After the series of tests conducted in different set up of roof connections, threshold values were obtained.

For single fastener test – static loading, wood nail, metal screw and wood screw had FPR of 0.89 kN, 0.87 kN and 5.6 kN respectively. The percentages of the standard deviation for the static loading range from 10-20%. The decrease in FPR from the static loads to cyclic loads in the 1500-2000 cycles test for wood nail, metal screw and wood screw was 2.8%, 9.4% and 23% respectively. The percentage of standard deviation of FPR in cyclic loading ranges from 4-13%. Therefore, based on the changes in FPR, it could be concluded that cyclic loading gives significant decrease in FPR. This study points out that the decrease in FPR was based on testing under controlled condition and do not consider factors such as corrosion, water immersion, and realistic wind pressures.

When the type of connection is wood nail, the nail is pulled out without experiencing tearing of GI sheet. The explanation for this is because the FPR is lower than the capacity of the roof before tearing. Before the load reached the maximum load for tearing, the nail will be the first to be pulled out. For metal screw, mostly tearing occurs rather than pull-out. The reason for this is due to the fact that the FPR for metal screw is close to the capacity of roofing against tearing. If the fastener in the connection is wood screw, tearing will always be the mode of failure for the connection because the FPR of the wood screw is stronger than the capacity of roofing against tearing. The maximum loads are 1.43 kN, 1.26, kN and 1.37 kN for wood nail, metal screw and wood screw respectively.

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ENGINEERING ANALYSIS FOR A MANGROVE PLANTING SITE – TOWARDS A SUSTAINABLE COMMUNITY-ENGAGED COASTAL PROTECTION PROGRAM IN THE PHILIPPINES

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Abstract : Engineering methodologies are incorporated into community-based programs of mangrove rehabilitation in Panay Island that aim to provide viable protection to eroding typhoon-frequented Philippine coastlines. These involve analyses of storm waves and formulation of an engineering solution to promote calmer wave conditions around a pilot planting site. The study mainly involves the use of wave simulations to determine the wave loadings on the planting areas with site-specific data on winds, tides and seabed topography. Suitable design criteria based on the project's economic constraints and logistics are used to adapt the solution to the site. The incorporation of engineering approach into the project helps ensure a higher success rate in terms of mangrove survival rate and recovery of eroded backshore, as indicated by an initial post-construction monitoring of waves in the planting site and backshore sediment accretion.

Key words : mangroves, engineering analysis, rehabilitation, waves, typhoons

1 INTRODUCTION

Mangroves are semi-terrestrial habitats that afford natural protection to coastal areas by acting as buffer zones during typhoons and storm surges, mitigating the erosion of shorelines and riverbanks. Due to their unique root system, mangroves are known to be sediment interceptors (Hamilton and Snedaker, 1984) making them effective in the long-term stabilization of coastlines. Mangroves are also sources of various food products, such as fish, crustaceans and mollusks. Other mangrove-derived products include fuel (firewood, charcoal), leather products (dyes, tannins), construction materials (timber, poles), paper production raw materials, beverages (vinegar), drugs (alcohol, medicines), and forage for livestock (Primavera, 2000). Kapetsky (1987) estimated the annual production of mollusks, fish, shrimps and crabs from the total mangrove area of 171,000 km^2 in 1985, and reported that about 462,200 fisher folk derived livelihood from these mangroves.

Despite the many uses of mangroves and the shore protection they provide, mangrove areas along coastlines have dwindled through the years. In the Philippines, mangrove coverage has declined from an estimated 500,000 ha in the early 20th century (Brown and Fisher, 1918) to 132,500 ha in 1990 (Auburn University, 1993), which is equivalent to an average yearly loss rate of 4.7 ha. This decline has been accompanied by an increase in aquaculture production, which converted an estimated 141,000 ha of mangrove areas into brackish water ponds in the period 1988-1990 for fish and shrimp production (Primavera, 1995).

In more recent years, efforts have been exerted to attempt to reverse this anthropogenic process by implementing rehabilitation programs, including setting up inland nurseries and transplanting of mangrove seedlings into the natural environment. However, these traditional efforts have resulted in low success rate, mainly because the transplants are destroyed before reaching their minimum resiliency stage to withstand the natural environmental forces.

This study aims to present an approach to incorporate engineering methodologies into the mangrove rehabilitation efforts. The approach has been applied to one of several mangrove rehabilitation sites in the Visayas, where erosion is particularly severe and waves negatively affect the survival of newly planted mangroves. A scientific approach is adopted by examining the wave climate of the proposed planting area. Numerical analyses of the wave and tide loadings are carried out and synthesized, with the aim of locating wave energy concentration zones that may need suitable wave breakers to protect the mangrove saplings over a short-term period. In this manner, the coastal protectors are protected while growing to their minimum resiliency stage.

Section 2 of this paper presents a discussion of mangrove functions in coastal protection. A brief discussion of mangrove rehabilitation activities then follows. The project site and available data are discussed in Section 3. Section 4 presents typhoon data and Section 5 focuses on the hydraulic analyses of their induced waves. Section 7 discusses the engineering design of the protective structures. Section 6 briefly discusses the design implementation and post-construction monitoring.

2 MANGROVES IN COASTAL EROSION PROTECTION

Fully-grown mangroves (see Figure 2) provide natural protection to the coasts by acting as energy dissipation zones of waves that would otherwise approach the coast with full force. Due to their intricate semi-terrestrial root system, they are also able to trap littoral sediments and thereby stabilize the coastline. Considering the significant decline of mangrove coverage in the country and recent alarming natural disasters, a community-based project has embarked on a program to rehabilitate mangroves in presently unsuccessful planting zones and to plant mangrove saplings in new pilot areas. Due to the low success rate of earlier rehabilitation programs where the saplings were immediately exposed to the wave environment, it was recognized that protection works must be in place prior to transplanting from inland nurseries.

Full-grown mangroves are able to protect vulnerable shores against high waves by causing them to break. Such breaking allows only the smaller waves to reach the shore. Since waves usually approach from various directions on most open-sea shores, some waves may impinge on mangroves without breaking. Fortunately, energy dissipation of these waves normally occurs through fluid friction around the plants' trunk and other surfaces, the intensity of which increases with the size of the plants and the height of the impinging waves. Energy dissipation is also afforded by the fluid turbulence generated in the interstitial spaces of these plants by the entrainment of air when waves and currents impinge on them.

It is known that mangroves are affected more directly by the physical, rather than the biological, environment. The frequency of tidal inundation appears to exert primary influence on their growth and propagation, with about 30 percent annual submergence in the tides as a maximum threshold for their survival. The depth of sediment cover also influences their survival and propagation, as this directly affects the metabolic respiration through the pneumatophores, or the root system. Some species of mangroves are capable of innately propagating along the coasts under ambient conditions of tides, waves and sediments, i.e. non-typhoon conditions On the other hand, growth of young mangrove saplings can be stunted even by ambient waves; in some cases, they are destroyed before reaching the minimum resiliency level when exposed to a harsh physical environment, e.g. nearshore areas frequented by typhoons and tropical storms. In order for these young mangroves to survive, it is necessary to choose a planting area where high waves are dissipated by natural wave breaking or shallow-water transformations. In case such ideal location is impossible to find, mangrove planting sites must be located in a wave shelter, that is, where energy dissipation of both ambient and extreme waves is deliberately induced through an impinging structure, such as a breakwater, submerged breakwater or artificial reef, by forcing these waves to break on the structure.

3 COMMUNITY-ENGAGED MANGROVE REHABILITATION PROGRAM

A number of organizations have initiated rehabilitation programs to reverse the depletion of mangrove areas in a number of countries in Southeast Asia. In the Philippines, these efforts are undertaken in cooperation with various stakeholders, including the local government unit, the coastal community residents, fisher folks and their organization, environment and natural resources agency, public works agency, industry organizations representing farmers and other workers with stake in agricultural and aquaculture productions, and local community organizers. These community-based efforts to rehabilitate mangroves typically involve inland nursing of seedlings or "wildings" around mother mangrove trees, subsequent coastal transplanting or "out-planting" of young mangrove saplings, and fencing off the area with bamboo or similar inexpensive indigenous materials (Primavera, 2004). However, they sometimes fail to ensure mangrove survival, resulting in low success rate of rehabilitation activities. To increase the success rate of these programs, an engineering component is incorporated into the rehabilitation efforts by undertaking a quantitative analysis of the wave climate to identify suitable planting areas for coastal mangroves. In cases where it is found that existing planting sites are in harsh wave environment, the results of the analysis will be used to determine the appropriate intervention and carry out its design and implementation.

A pilot site to implement an engineering component to the rehabilitation program was selected based on comparison of existing mangrove sites mostly in the Visayan Islands and a few in southern Luzon. This site was chosen because it is known to be exposed to tropical storms and typhoons, resulting in severe erosion rates. This mangrove rehabilitation project will benefit initially the coastal communities of Panay and Guimaras Islands (Figure 1) by providing coastal protection against the high waves, providing agricultural workers additional raw materials for food and other uses, and provide increased livelihood to farmers and fishermen. Due to the active participation of all stakeholders, the project is deemed to be sustainable in the long term.

4 PROJECT DESCRIPTION AND DATA

The pilot site for the deployment of mangrove protective structures is along the coastline of Panay Island (Figure 1). Existing planting areas are located inside Pedada Bay (Figure 1) which partially provides protection against waves during non-storm season. However, the same bay faces Sibuyan Sea which is frequented by typhoons. Such location allows high waves during typhoons to penetrate the bay and erode the interior coastline, a condition to which the low success rate of the mangrove transplanting activities is attributed. Fully-grown trees of a local mangrove species called "pagatpat" (Figure 2), which are generally found as front-liners in other thriving coastal mangrove sites, are found in significant numbers along either side of the proposed planting areas, but are nonexistent in the central zone. Previously built crib-like concrete structures called "modules" (Figure 3), intended to protect young saplings while promoting fish breeding, proved ineffective in promoting a calm zone for mangrove saplings to thrive. Either as a result or cause of the death of transplanted mangroves in this area, fishermen now find use for this foreshore zone as a boat dock (see Figure 2, right).

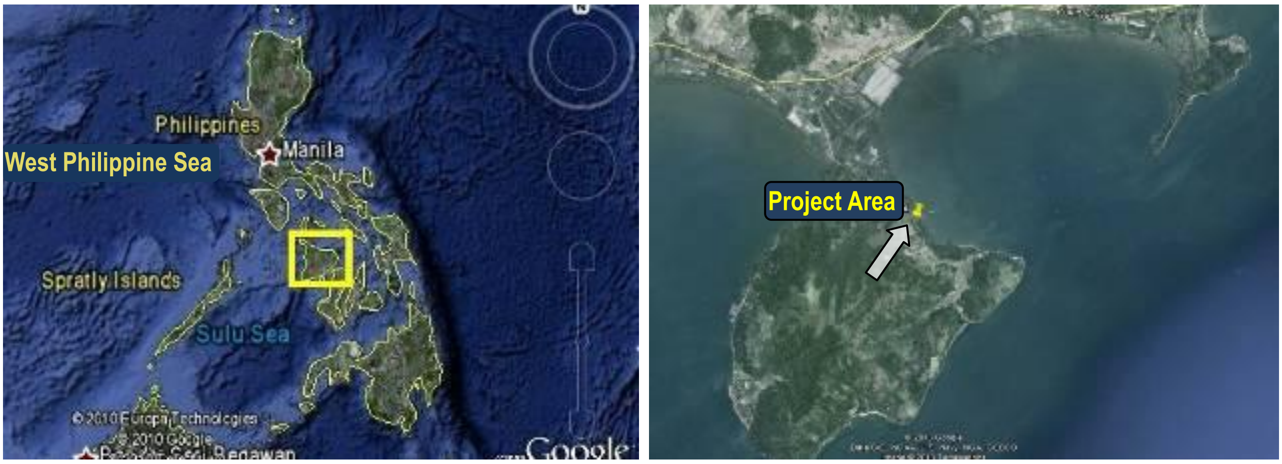

Figure 1 Project national location (left), Pedada Bay (right) (source: Google Earth)

Figure 2 View from inland of project bay (left), and of fully-grown mangroves to the north (middle) and south (right) coasts at low tide

Figure 3 (left) Damaged "modules"; (middle) closer view of a module; (right) mangrove seedlings in inland nursery

4.1 Tide Data

Astronomic tides primarily determine the prevailing water levels in the foreshore zone where the planting areas are located. Based on a 30-year record at the nearest tide station (NAMRIA, 2009), these water levels have a mean tidal range of 2.1 m, with the mean high tide and mean low tide almost equally displaced from mean tide level; the other tide statistics are shown in Table 1. These data are used, among others, in determining the most inland extent of the shoreline for input in the nearshore wave simulations, and in determining the seaward limit of the wave breaking zones.

Prevailing winds are characterized through the wind rose diagram shown in Figure 4 (left), showing the annual frequency and directional distribution of surface winds at the closest inland wind station. The diagram indicates that surface winds are dominantly southwesterly-northeasterly, which is consistent with the seasonal "Amihan-Habagat" wind patterns of the archipelago. Prevailing surface wind speeds can be moderate (up to 8 m/s) and very infrequently strong (up to 12 m/s).

Table 1 Tide characteristics

Mean Higher High Water MHHW	Mean High Water MHW	Mean Tide Level MLW	Mean Low Water MLW	Mean Lower Low Water MLLW
+1.07	+0.77	0.0	-0.80	-1.04

4.2 Prevailing Winds and Tropical Storms

The eastern sea fronting the project bay is frequented by tropical storms and typhoons. Table 2 summarizes the strongest historical typhoons that tracked this sea. The tracks of two of these typhoons, which are found below to be the critical cases for the site, are shown in Figure 5 (bottom); as shown, typhoons in the east-bounding sea are generally produced in the Pacific Ocean. Together with the computed wave fetches and information on the wind station, these data are used to predict the growth of storm-induced waves in deep water and to hindcast the extreme historical waves that most likely approached the project coastline.

Table 2 Strongest tropical cyclones

Date	Tropical Cyclone	Highest wind (mps)	Direction
Oct-28-1995	Super Typhoon Rosing	36	SW
Dec-10-1951	Typhoon Amy	34	NE
Apr-25-1971	Typhoon Diding	25	SE
Jul-28-1982	Typhoon Iliang	25	SSW

Figure 4 (left) Annual prevailing winds; tracks of Typhoons Amy (middle) and Diding (right)

5 HYDRAULIC ANALYSIS OF WAVE LOADINGS ON MANGROVE PLANTING SITE

Wave conditions in the offshore deepwater can be estimated from surface wind data at the wind station, wave fetch and the duration of the wind. For prevailing waves, wind duration does not limit the height and period of offshore waves. To determine the storm-induced wave fields in the shallower nearshore zone where the mangrove planting site is typically located, a wave transformation model is numerically implemented. A special case of a nonlinear wave model developed for a porous seabed on arbitrary bathymetry (Cruz et al., 1997) is used for this purpose. This special Boussinesq-type wave model considers the seabed to be impermeable, and can be written as:

$$\frac{\partial \eta}{\partial t} + \nabla \cdot [\mathbf{u}(h+\eta)] = 0 \qquad (1)$$

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u}\cdot\nabla)\mathbf{u} + g\nabla\eta + \frac{h^2}{6}\left(\nabla\cdot\frac{\partial \mathbf{u}}{\partial t}\right) - (\tfrac{1}{2}+\gamma)h\nabla\left(h\nabla\cdot\frac{\partial \mathbf{u}}{\partial t}\right) - \gamma g h\nabla[\nabla\cdot(h\nabla\eta)] + \mathbf{F}_b + \mathbf{F}_s + \mathbf{F}_w = 0 \qquad (2)$$

where $\eta(x,y,t)$ is the water surface displacement from still water level, $\mathbf{u} = (u,v)$ the depth-averaged fluid particle horizontal velocity vector, (x, y) the horizontal coordinates, t time, $\nabla = (\partial/\partial x, \partial/\partial y)$ the horizontal gradient operator, γ the frequency dispersivity extension factor, g the gravity acceleration, $\mathbf{F_b}$ the wave-breaking energy-dissipation term, $\mathbf{F_s}$ the structure-induced damping term, and $\mathbf{F_w}$ the bottom friction term. Eqs. (1) and (2) are respectively the continuity and momentum equations formulated for nonlinear and dispersive water waves. With $\gamma = 1/15$, the model has an extended frequency dispersion range and can therefore be used for relative depths (h/L_O) ranging from the lower limit of deep water ($h/L_O = 0.5$) to the shallow waters fronting the project area. This special wave model has been applied to study the wave climate in coastal harbors (Cruz, 2007).

A primary data needed in the wave loading analyses is the distribution of water depths, or bathymetry, around the planting areas. For this purpose, a bathymetric geodetic survey was commissioned. Raw data of existing water depths at various locations on an irregular grid (shown as the number marks in Figure 7), are used to obtain contours of still-water depths, which are plotted in simulation output graphics below. These data are consolidated with available spot depths from 1:50,000 scale offshore topographic map (NAMRIA Topographic Map Central Philippines), which are then jointly digitized as raster depth data to be inputted into the wave simulations.

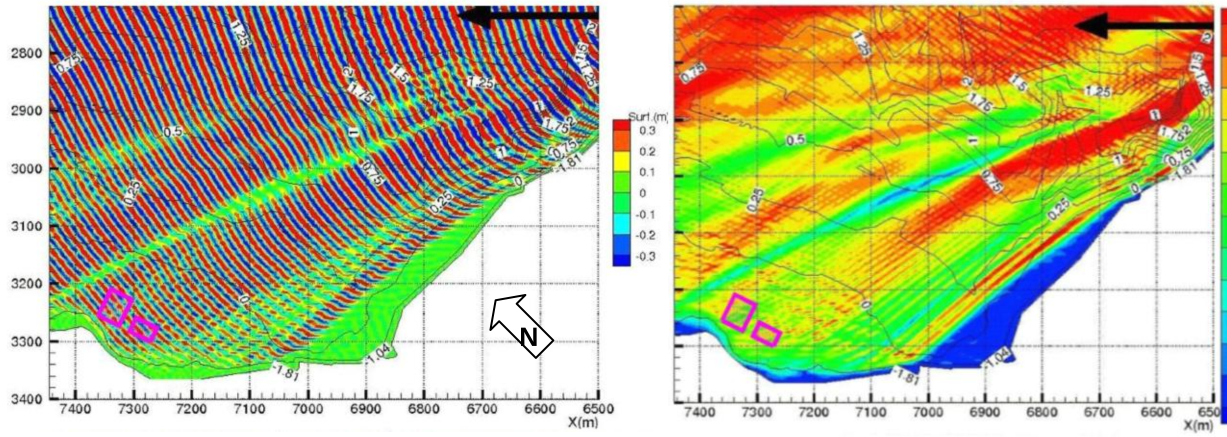

Figure 5 Waves generated by Typhoon Diding approaching from southeast at high tide: (left) water surface snapshot, (right) resulting wave height distribution

The nearshore wave fields generated by the 4 historical typhoons shown in Table 2 have been simulated using the above model, digitized bathymetry, and hindcast offshore wave conditions. It is found that Typhoons Amy and Diding are most critical to the project coast. Figure 5 shows the simulated wave fields, i.e., water surface snapshot and resulting wave heights, for Typhoon Diding which generated offshore waves that approached from the southeast. The water level in the simulations is set to MHHW to account indirectly for the storm surge (note that the rectangles indicate the proposed planting areas). Patterns of wave energy concentrations and divergence are revealed by these plots.

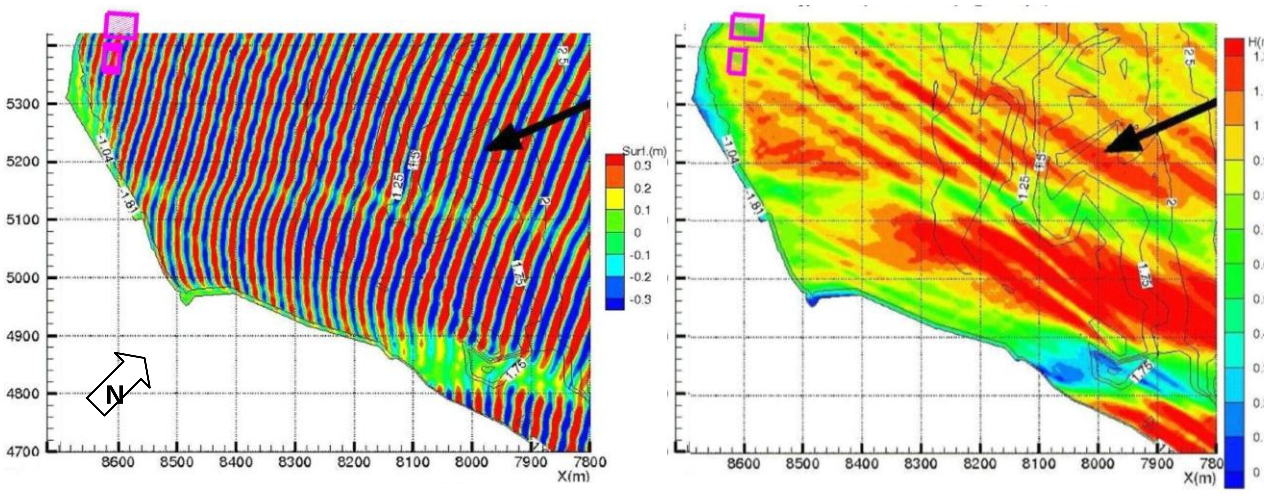

Figure 6 Waves generated by Typhoon Amy approaching from northeast at high tide: (left) water surface snapshot, (right) resulting wave heights

Figure 6 shows the wave fields due to Typhoon Amy which induced offshore waves approaching from the northeast. Due to the two smaller islands to the northeast of the bay entrance, the local waves are strongly diffracted, resulting in strong penetration of wave energy into the bay, including the site's nearshore zone.

6 ENGINEERING DESIGN OF PROTECTIVE STRUCTURES

Coastal structures are normally designed to withstand extreme waves, i.e. due to typhoons. A synthesis of all simulated cases of typhoon-induced waves indicates that a detached breakwater fronting the planting areas will provide protection to the mangrove saplings. Considering the requirement of an entranceway for fishing boats and the effects of the structures on wave-and tide-induced circulations, two nearshore breakwaters with a gap are laid out as shown in Figure 7. Their orientation and length are based on the wave approach directions and distribution of local wave heights.

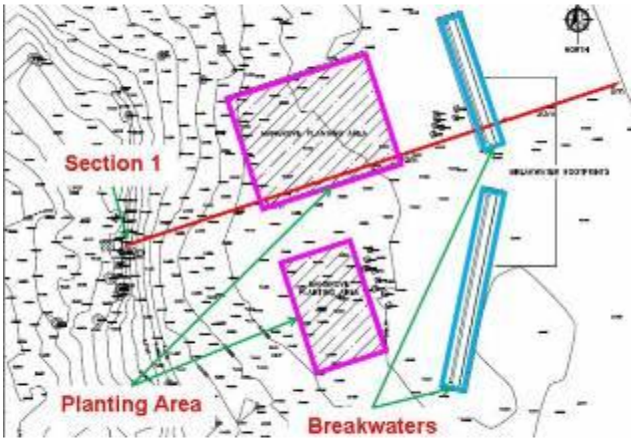

Figure 7 Location of planting zones and breakwaters

The required median size (kg) of armor stones is determined from the semi-empirical formula (USACE, 2004) as follows:

$$M_{50} = \frac{\rho_r H^3}{\left(\frac{\rho_r}{\rho} - 1\right)^3 K_D \cot\alpha} \tag{3}$$

where ρ_r is the mass density of the armor stones, ρ the density of water, H the design wave height, α the angle of the armor slope, and K_D the stability coefficient of the armor stones.

Based on data of climatological extremes, the apparent recurrence intervals of the critical typhoons are about 54 and 34 years. When the results shown in Figures 5 and 6 are used to layout and design the protective breakwaters, the required median mass of the armor layer (see Figure 8) comes out to be about 500 kg. Unfortunately, such large stones cannot be sourced close to the site. Furthermore, this community-based project prefers to utilize manpower that is already available from the workers in the project's organizations. Also considering the useful life of the protection of 5 years, which is just sufficient for the saplings to grow big enough to withstand the waves, the initial structure size is deemed unsuitable to the project objectives.

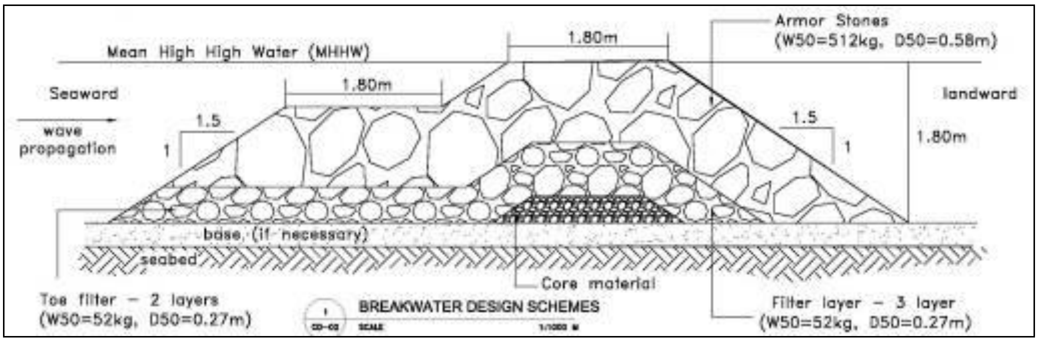

Figure 8 Full wave-loading breakwater cross-section

To obtain an engineering design of the mangrove protection that is best suited to the characteristics of the pilot site and to the project objectives, the following design conditions were adopted: (a) a useful life of 5 years, which is deemed sufficient to provide protection over the minimum resiliency period of 2 to 3 years from transplanting; (b) a reduced design water level based on the mean tide; (c) allowable local wave height of 20 cm at the planting areas; and (d) width of passageway for fishing boats of about 18 meters. With these design conditions, wave field simulations were again carried out. Figure 9 shows the resulting wave heights for the critical cases of typhoon-induced waves approaching from the southeast and northeast. It is clear that the local waves around the contemplated planting areas are significantly reduced from those in Figures 5 and 6.

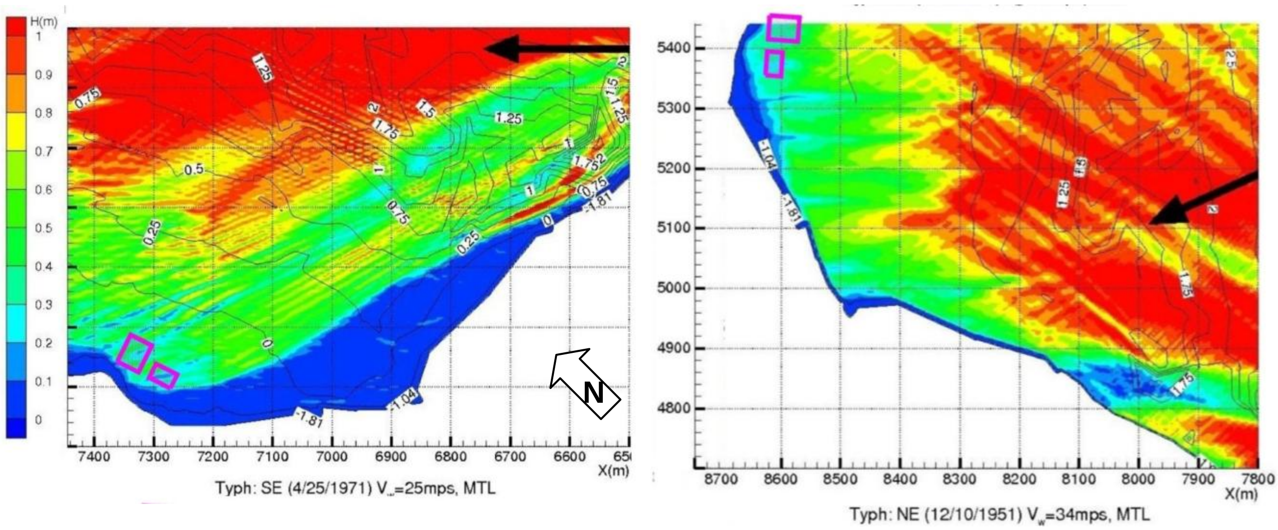

Figure 9 Wave heights due to (left) Typhoon Diding and (right) Typhoon Amy, at mean tide level

The results in Figure 9 have been adopted in the design of the breakwaters. A preliminary layout was designed and subjected to post-implementation wave simulations, some results of which are shown in Figure 10. It is seen that some wave energy will penetrate the gap into the planting areas when exposed to Typhoon Amy, i.e. extreme waves from northeast. However, the local waves will not be higher than 20 cm.

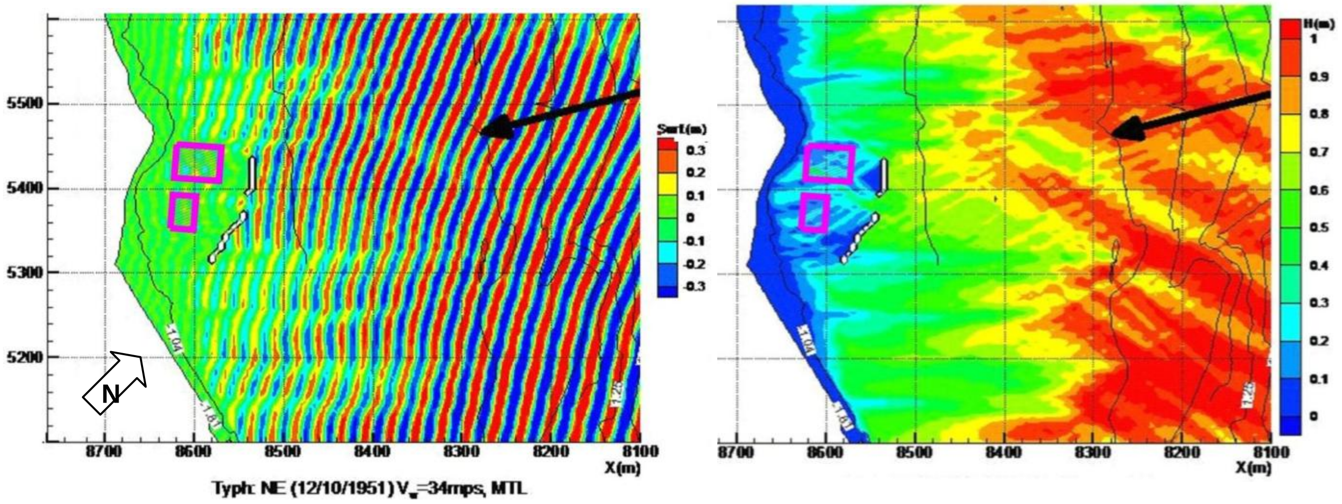

Figure 10 Waves due to Typhoon Amy at mean tide: (left) water surface snapshot, (right) resulting wave heights

The recommended plan-form layout of the mangrove protection, shown in Figure 7, consists of two detached breakwaters of the rock-mound type, consisting of an armor layer, filter layer, toe protection and core materials. A base layer is optional depending on the existence of suitable seabed material. Two alternative breakwater cross-sections are shown in Figure 11. The first is a traditional rubble-mound breakwater with 120-kg armor stones, which are available near the site and can be carried by men without hauling equipment. The other is a modified mound breakwater with armor stones of the same size, but with gabions at the lee side; this section reduces the quantity of the larger armor stones, in exchange for requiring the smaller core stones to be enclosed by a wire mesh. The cost of this second design depends on the durability requirement of the wire mesh; regular non-galvanized mesh will probably withstand 3 years of marine water-induced corrosion without replacement or expensive coating treatment. Mainly on account of maintenance requirements and material cost, the first alternative was selected by the project organizers.

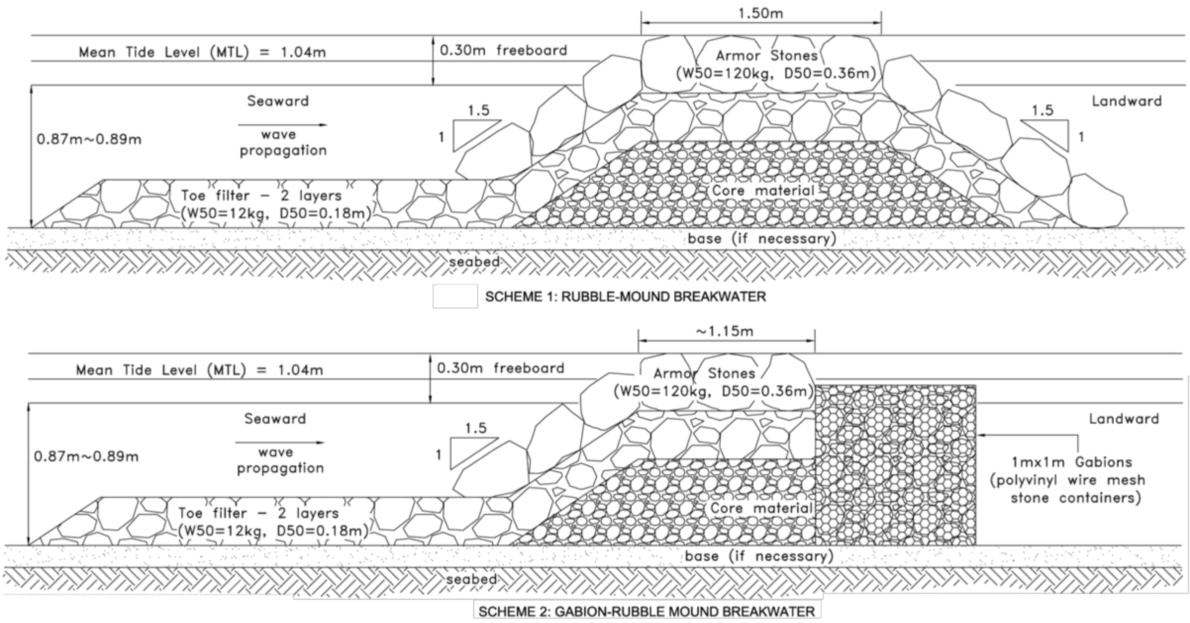

Figure 11 Reduced-loading breakwater alternatives: (top) rock-mound type, (bottom) mound-gabion breakwater

7 PROJECT IMPLEMENTATION AND MONITORING

7.1 Construction of Breakwaters

Construction of the breakwaters was facilitated by the non-governmental organization in cooperation with engineers from the provincial office of the public works department DPWH. The community stakeholders also helped by providing manpower, hauling tools, logistics, and work coordination. Actual construction was started immediately after approval of the final design scheme prior to the onset of the northeast monsoon. Portions of the old and damaged “modules” were removed to avoid undesirable wave effects outside the breakwater-protected foreshore. Figure 12 (left) shows the manual placement of rocks on the armor layer of one of the almost-complete mound breakwaters. The entranceway for fishing boats can be seen.

7.2 Monitoring of mangrove saplings’ growth and sediment accretion

After 26 months and 4 seasonal changes, the breakwaters have caused visible changes in the nearshore landscape of the planting zone (Figure 12, right). In particular, coastal sediments have accreted in the shadow zones of the structures as a result of calmer wave conditions. The aggraded zones have been used as mangrove transplanting areas. The transplanted mangroves appear healthy and the eroded coasts further inland have shown significant recovery from erosion. If the transplanted mangrove saplings are able to withstand the harsher wave and wind environments of typhoons within at least 5 years, the protective breakwaters can be dismantled as the saplings are assumed to be robust enough for such environment. It should be noted that the breakwaters are temporary, as the rocks are merely piled on top of each other and not cemented.

Figure 12 (left) Breakwaters completed in 2010; (right) accreted sediments after 26 months, mangrove saplings transplanted, and fully grown mangroves seen in the background (ZSL-CMRP photos by J.H. Primavera (left) and A.M. Torrechilla)

Figure 13 compares the backshore elevations before and after the breakwater construction (2010 versus 2012). A concrete road used to exist along the alignment indicated by the arrows, but was eventually eroded by ambient and storm waves. At this location, visible accretion of silt has been observed after construction. A geodetic survey was conducted to quantify the ground elevation. The results of this survey have been plotted in Figure 14 (right) with the pre-construction data along a transect through the southern breakwater (Figure 14, left). In general, an average accretion of about 20 cm is experienced over a cross-shore distance of about 100 m nearest the breakwaters. Further into the backshore near the eroded road location, accretion is about 5 to 10 cm.

Figure 13 Backshore elevation before and after breakwater construction (ZSL-CMRP photos by J.H. Primavera)

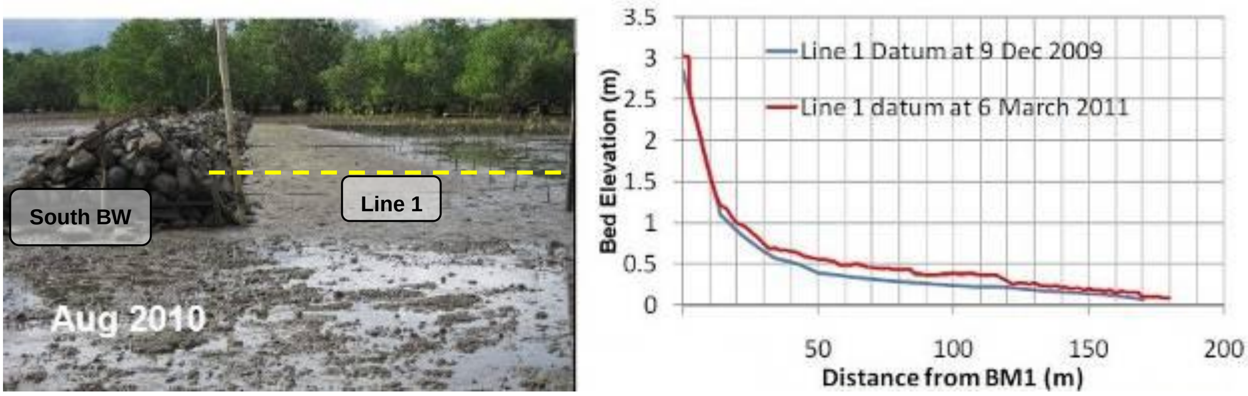

Figure 14 Measured post-construction accretion behind the breakwaters (ZSL-CMRP photo by R.V. Joven; Mar 2011 data from UP-MSI).

8 CONCLUSIONS

It is found from this study that engineering methodologies are needed to increase the likelihood of success of mangrove rehabilitation activities. These include gathering data of tides, prevailing winds and typhoons, and conducting bathymetric survey around the contemplated planting areas. In order to quantify the extreme wave loadings due to typhoons and possibly explain causative mechanisms for unsuccessful transplanting sites, it is necessary to carry out numerical modeling and wave loading analyses of the site's nearshore area. A synthesis of these simulative analyses will help identify unsuitable planting areas and lead to the formulation of high-wave hazard mitigating schemes or engineering solutions. In existing mangrove areas exposed to a harsh wave environment, an engineering approach is imperative in studying the proper course of intervention, and in designing a suitable protective structure when found necessary.

The above engineering methodologies have been applied to the pilot site of a typhoon-tracked mangrove planting area in Panay Island. The above methodologies were further used to eliminate unfeasible or uneconomic options, adapt the identified mitigating solution to the project objectives in terms of economic cost and project logistics, and validate the effects of the selected solution prior to construction implementation. In totality, these methodologies will help ensure the success of the mangrove rehabilitation program for this pilot site.

A post-construction evaluation over a 2-year period indicates that the solution is initially effective on the basis of the project's objectives. A longer-term monitoring will help in evaluating the overall soundness of the solution implementation.

ACKNOWLEDGMENT

This paper resulted from a study commissioned by the Zoological Society of London for its Community-based Mangrove Rehabilitation Project. The methodology discussed in this paper was applied to a pilot coastal mangrove planting site and the recommended protective structures were implemented in February 2010 in Pedada, Ajuy, Iloilo Province in central Philippines. Accretion data for March 2011 are courtesy of F. Siringan of UP-MSI.

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INTEGRATING STORAGE SIZING AND WATER TREATMENT FOR RAINWATER HARVESTING IN THE PHILIPPINES

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Abstract :Rainwater harvesting technologies refer to methods of collecting and storing rainwater to supplement the demand of the population. The design of its components, specifically the storage component, is highly dependent on the rainfall pattern for a given locality. The main objective of the study is to develop guidelines that would generate water for potable and non-potable applications through rainwater harvesting. In this study we analyzed the rainfall patterns of each climatic region by considering representative areas such as Sangley (Cavite), Daet (Camarines Norte), Tanay (Rizal), and Davao City (Davao del Sur) to determine the recommended tank size for each region. Using the Yield-After-Spill Algorithm, we found out that rainwater harvesting systems are more reliable in Daet (Type II Climate) and least for Sangley (Type I Climate). Reliability curves are made to aid in decision making. For potable applications of harvested rainwater, the study proposed to incorporate the following treatment technologies: first flush diverters, neutralization and filtration, and disinfection. To be able to define the "shifting point" – when is it economical for a user to use whole of his roof area than just half of it, we studied the harvesting system of UP BRS Model House. We found out that whatever demand we satisfy and whatever study area we consider, it will be economically advantageous to use the whole roof area if the recommended tank size is 600 L or larger. Finally, we can promote RWH technology through education and awareness programs, demonstration projects, and networking between government and non-government institutions.

Key words :Rainwater harvesting; reliability; yield-after-spill algorithm

1 INTRODUCTION

1.1 Background

Food supply problem is one of the five major environmental problems that the world is facing today. Water shortages and groundwater depletion are identified as two important issues associated with this problem. Inefficient use of water resource and ineffective water allocation yields to water shortages which require research on possible alternative resource that could help satisfy the requirement of the population for adequate water supply.

Rainwater harvesting (RWH), in general, refers to methods (e.g. simple and engineered) employed to collect rainwater through catchment systems, divert them through gutters to a storage tank to provide water for specific applications such as toilet flushing, gardening, bathing, dishwashing, cooking, and drinking. Rainwater harvesting system usually consists of three major components: catchment system, conveyance system, and storage tank. Designing storage tank is a vital part since it is considered as the most expensive part of a rainwater harvesting system. Thus, much concern is required to determine the storage tank size applicable for a given set of conditions usually demand, supply, and roof area (Ward, 2010).

To be able to promote the technology, we need to identify and supply the users with the advantages of the system over the current "lined system" of water distribution. Its advantages include ease in terms of installation, operation, and maintenance with readily available construction materials. In comparison with the current system, through rainwater harvesting, water can be supplied at the point of consumption thus, owners are in full control of the technology. In terms of water quality, harvested rainwater can directly be used in non-potable applications such as gardening and toilet flushing. In terms of environmental impacts, as compared to other sources, rainwater harvesting technology pose lesser or no damage at all for the environment since existing structures such as domestic houses will only be retrofitted. Its disadvantage relies mainly on the randomness of the rainfall pattern thus the demand of the user will not always be met.

In terms of its economic value, rainwater harvesting can be costly and often, systems that could meet a household water demand are unaffordable. Since costs are mainly concentrated on the storage tank, there is a need to ensure that tanks and effective roof area are matched properly to meet the water demand at the least cost (Figure 1). But if sized properly, it will yield acceptable and economically justified technology.

Of all the sources of water, rainwater is among the cleanest. Its quality diminishes depending on the quality of the atmosphere, the catchment and conveyance systems, and storage tank. At present, harvested rainwater is used mainly to supply the demand of the population for non-potable water but through adequate research on existing treatment techniques, it is possible for rainwater harvesting technology to supplement our needs for potable applications. Potable applications include drinking, cooking, bathing, and dishwashing. Non-potable applications include toilet flushing, fire suppression, household cleaning, gardening, laundry washing, pool/pond filling, and vehicle washing (Crawford).

1.2 Objectives

The study aims to develop guidelines for a system that would generate water for potable and non-potable applications through rainwater harvesting. It aims to answer questions like "What tank size is recommended for a particular location that would provide N liters of water per day and that is R% reliable?" Different study areas will be chosen to represent the four climatic types of the Philippines. Given the parameters such as daily rainfall (supply), daily demand, and roof area, the relationship between tank size and reliability will be made to help users in deciding what storage size fits their sets of parameters and how reliable that tank size is. This decision-making process will be assisted by economic analysis through consideration of existing rainwater harvesting system in University of the Philippines – Diliman. To account for potable applications, water treatment techniques will be suggested in consideration of their effectiveness and costs. This study also aims to establish some methods to promote rainwater harvesting in the Philippines.

1.3 Significance of the Study

Rainwater is considered as a valuable resource that is currently underused and rainwater harvesting can be a means of minimizing pressure on water sources. But, lack of progress in rainwater harvesting is very observable due to lack of experience and absence of well-run demonstration sites (Ward, 2010).

Rainwater harvesting (RWH) technology is not that popular in Philippine context. Some users blindly select tank size to harvest rainwater creating an inefficient system unable to supply rainwater for the whole year. Others consider the "one size fits all" as the governing principle for tank sizing. In this approach, the whole area is considered as one homogeneous entity in the design. However if the parameters such as roof area, demand, and rainfall data are considered, their impacts on tank size should not be neglected.

In general, a house owner who can be a user for rainwater harvesting has very little or no guidance at all when selecting the rainwater tank. There are no set guidelines to select the optimum tank size for the Philippines that consider the varying rainfall for each climatic region, catchment area, and demand or type of end use. Also, more of the researches on this technology focus on large-scale systems; only few discuss the potential of RWH for small-scale systems such as residential areas.

Rainwater harvesting poses significant solution to water shortages. RWH can provide water at or near the point where water is needed as opposed to the current "life-line" situation. Hence, it breaks the consumer's reliance on a water supplier. Aside from its significance on water savings potential, RWH can reduce storm drainage load and excessive flooding.

Harvested rainwater can be used for non-potable purposes such as garden use, toilet flushing, and washing clothes. Also, it can support the users need on potable water such as a drinking source, which requires water of better quality. Roof rainwater is often of better quality, soft, and is very ideal for washing.

Results of this study can be used to optimally size RWH in situations where water users do not have access to computers and RWH Tank Size Calculators available in the internet. RWH can be costly and systems that meet a household's water needs are often expensive. It creates a necessity to maximize the use of rainwater through optimizing storage.
Also, this study may serve as a first step to enhance promotion of rainwater harvesting through our government and non-government institutions.

1.4 Scope and Limitations

Storage is considered as the most expensive part of a Rainwater Harvesting Facility. Proper determination of tank size based on factors such as rainfall, roof area and characteristics, and demand is necessary to identify the most economically feasible storage tank size. Utilizing commercially available tank sizes would mean varying reliability and cost. Therefore, it is a requirement to provide details on this relationship. Rainwater Harvesting must be engineered in order to produce water of varying quality from non-potable to potable applications. An incremental increase in quality means greater cost. Basically, economic analysis of design of water treatment will be based on what demand is expected and what quality the user prefers.

The study is limited to considering only the four study areas. It assumed that those areas represent the type of climate of their neighboring regions. The amount and length of rainfall used is limited to what is obtainable by Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) thru its Hydrometeorological Data Section. It is assumed that the owner has his own access to other parameters namely demand and roof area. This study is made for low-cost housing, with A-Frame Roof. Any result shown in this paper is only applicable for those sharing the same conditions and criteria as low-cost housing. Also, the study is limited to providing the user with treatment methods that the author thinks are relevant to achieve a certain water quality. No models have been made and tested during the entire duration of the study. In terms of economic analysis, the study considered the UP Building Research Service (BRS) Model House to come up with a cost analysis. It had been retrofitted in 2008 by Fajardo and Oliva in their study on Basic Components of a Rainwater Collection System for Household. In terms of material selection, this model utilized the cheapest and readily available materials in the market. It must be noted that prices of materials may vary depending on the location. UP BRS Rainwater Harvesting Model has been used because it is considered as one of the economical ways of storing and harvesting rainwater.

1.5 Framework of the Study

The processes involved in the implementation of this study is shown below.

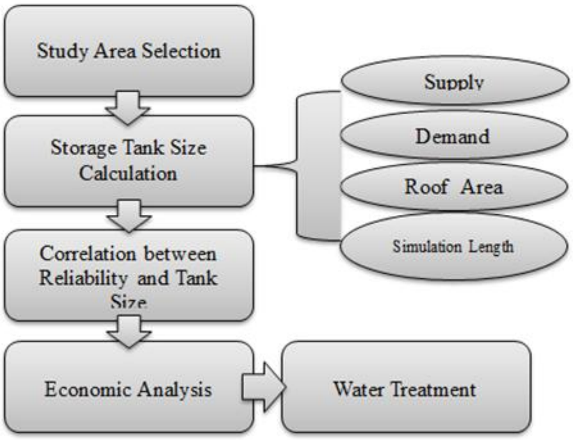

Figure 1 Framework of the Study

2 METHODOLOGY

2.1 Study Areas

Figure 2 Study areas representing the four climatic regions of the Philippines

Figure 2 shows the four areas chosen – one per each climatic region. These are Sangley, Cavite (Type I), Daet, Camarines Norte (Type II), Tanay, Rizal (Type III), and Davao City, Davao del Sur (Type IV).

2.2 Storage Tank Size Calculation

In calculating the required storage, we considered the following variables: supply (rainfall data); demand estimate, roof area and runoff coefficients. Each of these factors are considered vital to achieve accurate results.

2.2.1 Rainfall Data

Discretized six hourly rainfall were made available through Hydrometeorological Section of Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA). Varying length of rainfall were made available and used throughout the study.

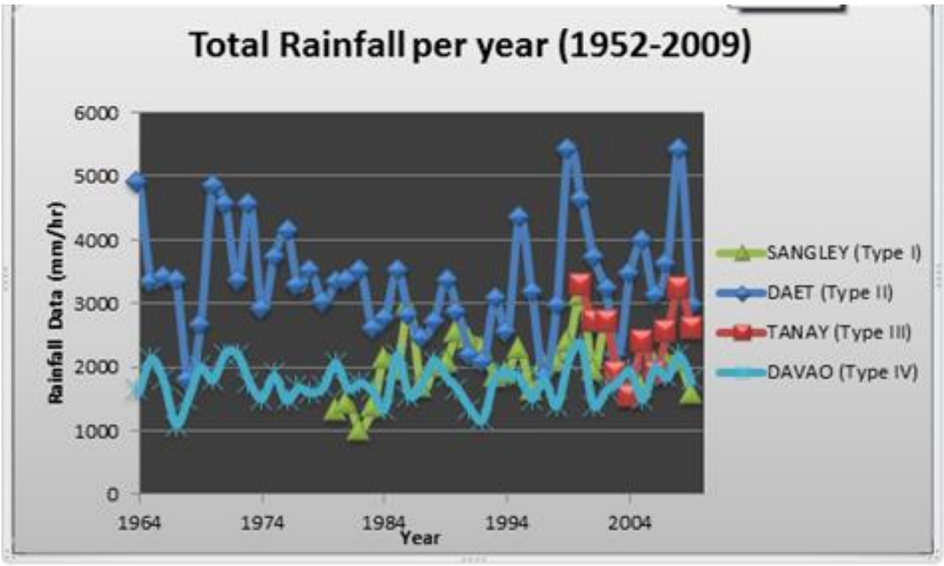

Figure 3 Comparison of total yearly rainfall recorded in the four stations

2.2.2 Demand Estimate

From the study of Inocencio, et. al., we found out that the recommended basic requirement is 54 L/capita. If we assume a household with four members, the total demand that will be used in the study is 216 L/day, approximated to 200 L/day.

However, this is just an assumption used in the study. In the event that the user is knowledgeable of their consumption, he is free to input his own data. The value shown is just used to simulate the harvesting system in case the demand roughly equals 200 L/day.

2.2.3 Roof Area and Runoff Coefficient

We assumed that our roof satisfies the requirement for rainwater harvesting that is, there is no need to retrofit the roof and its gutters. We have only to install our conveyance and storage system. For a family of four, we assumed a house roof area to be 100 m2 and its roofing material is of GI sheet type. Hence, we will use 0.90 for the run-off coefficient.

Table 1 Proposed Basic Water Requirement

Activity	**Proposed Requirement (liters/capita/day)**
Drinking	2.00
Personal Hygiene	23.00
Showering/bathing	
Hand/face washing	
Brushing of teeth	
Sanitation Services	20.00
Urinal/toilet flushing	
Toilet cleaning	
House cleaning	
Cooking and Kitchen	4.00
Food Preparation	
Dish washing	

Laundry	5.00
Total	**54.00**

2.2.4 Simulation Method

Given below is a sample spreadsheet used for simulating the rainwater harvesting system. For instance, consider this worksheet done solely for Tanay, Rizal. We first define the variables used. DT is the estimated demand; VT is the volume of water available at the tank at the start of time T; YT is the yield calculated using the YAS algorithm; c is run-off coefficient; I is the daily rainfall obtained from PAGASA; A is the roof area; QT is the discharge calculated using Rational Formula; and S is the assumed storage tank size. YAS Algorithm is performed for each time step for all the data available. In terms of Reliability, a value of 1 is given if the current volume of the tank satisfies the demand. In symbols, VT > D. Otherwise, value of 0 is given.

Date	DT	VT	YT	c	I	A	QT	S	Reliability
1-Jan-00	200	180	0	0.9	2.00	100	180	1000	0
2-Jan-00	200	0	180	0.9	0.00	100	0	1000	0
3-Jan-00	200	0	0	0.9	0.00	100	0	1000	0
4-Jan-00	200	0	0	0.9	0.00	100	0	1000	0
5-Jan-00	200	0	0	0.9	0.00	100	0	1000	0
6-Jan-00	200	0	0	0.9	0.00	100	0	1000	0
7-Jan-00	200	126	0	0.9	1.40	100	126	1000	0
8-Jan-00	200	0	126	0.9	0.00	100	0	1000	0
9-Jan-00	200	0	0	0.9	0.00	100	0	1000	0
10-Jan-00	200	180	0	0.9	2.00	100	180	1000	0
11-Jan-00	200	0	180	0.9	0.00	100	0	1000	0
12-Jan-00	200	0	0	0.9	0.00	100	0	1000	0
13-Jan-00	200	0	0	0.9	0.00	100	0	1000	0
14-Jan-00	200	0	0	0.9	0.00	100	0	1000	0

Figure 4 Example of a Simulation in a Spreadsheet

2.3 Water Treatment

In consideration of both potable and non-potable applications of harvested rainwater, we consulted several literatures that discuss the applications of different water techniques to rainwater harvesting. We analyze each item and technique in consideration of the initial quality of harvested rainwater.

2.4 Economic Quality

A relationship of how cost varies with tank size and roof area using the information obtained for the UP BRS Model is made to generalize the expected cost for any rainwater harvesting facility. This general relationship is vital for the users to have an idea of the optimal rainwater tank size – that is, at what tank size will they benefit more (high reliability) but at the least cost possible.

We provide further analysis to determine at what storage tank size a user will be recommended to shift from half-area utilization to using the whole roof area. For an A-Frame or gable roof system, there are two options for rainwater harvesting. First is utilization of just one side of the roof system. In this case, a gutter can be installed in just one side to allow collection of rainwater. This means that only half of the roof area will be used for rainwater harvesting. The second option is to utilize the whole area and thus, it will require collection through the two gutter systems. Given that the half-area utilization will require a lower initial investment, our problem is to determine when it is economically justifiable to shift from half to whole area utilization. The simulation presented was ran for A = 50 m2 and A = 100 m2. The reliability resulting from these independent simulations are plotted with cost as their dependent variable. The point of intersection of the two graphs had been identified and considered as the "shifting point".

3. RESULTS AND DISCUSSION

3.1 Storage Tank Sizing

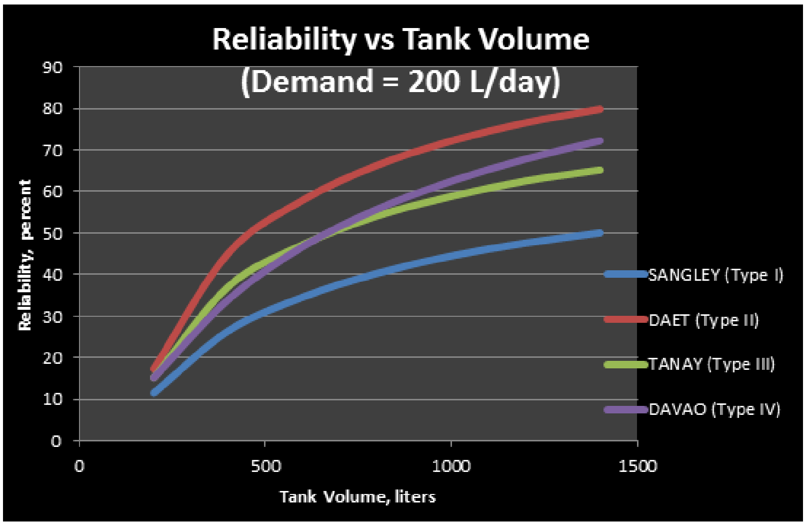

Figure 5 Reliability curves for each station (same demand, roof area, and runoff coefficient)

The following assumptions were made as requirements for the simulation: Demand is 200 L/day; Roof Area = 100 m2; Runoff's coefficient: 0.90; and Storage size increments: 200 L. This is maintained constant for all the study areas. Hence, the variable for the simulation is the rainfall data used. Using the YAS Algorithm, we found out that in general, Daet, as a representative of regions with Type II climate, gives the most reliable tank size if the four stations are compared. This is followed by Davao (Type IV), Tanay (Type III), and least reliability is observed for Sangley (Type I). Since the only variable used in the simulation is the rainfall data, these differences in the observed reliabilities will only be accounted to varying climate for each study area. Rainwater harvesting is more reliable for places where rainfall is well distributed throughout the year similar to types II and IV.

3.2 Water Treatment

The proposed treatment for harvested rainwater includes pretreatment, neutralization, filtration, and disinfection.

First Flush Diverters and Leaf Guards are required for pretreatment purposes. The first flush diverter will be designed as stated in Fajardo and Oliva's*Design Guidelines of Rainwater Collection System for Household Usage.*

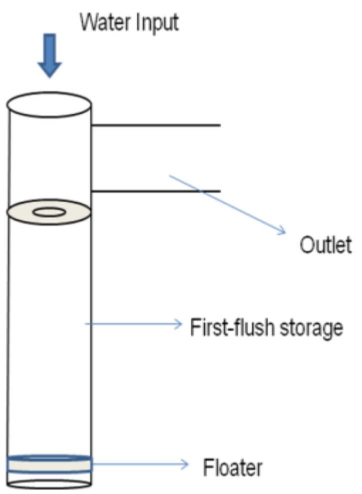

Figure 6 First Flush Diverter

To determine the size of the first-flush storage, we implement the recommendation according to the Texas Water Development Board's Texas Manual on Rainwater Harvesting since there is no any developed method for doing so. According to this manual, in areas where impurities are limited to just dusts or birds' droppings, we estimate the size of the diverter to be 0.41 liters per square meter of collection surface. The quality of water after this stage is sufficient for gardening and toilet flushing applications. These applications do not require any treatment procedure.

For dishwashing, laundering, and bathing, higher quality is required. Hence, we propose the following water treatment techniques – neutralization and filtration.

Neutralization is required to raise the pH of harvested rainwater given that it is naturally acidic. Acidic harvested rainwater may result to corroded metals. We recommend using PVC (plastic) pipes instead of corrodible conduits. Listed on Table 2 is the recommended amount of alkali reagents required to neutralize 1000 gallons of water. It must be added at periodic intervals, preferably once every week. If however, there is little or no fresh rainwater collected during a given week, addition of reagents might not be necessary (Young).

Table 2 Recommended amount of Neutralizing agent to raise the pH of harvested rainwater

Reagent	Chemical Formula	Amount required to neutralize 1000 gallons of rainwater
Limestone	$CaCO_3$	2 oz.
Quick Lime	CaO	1 oz.
Hydrated Lime	$Ca(OH)_3$	1 oz.
Soda ash	$NaCO_3$	1 oz.
Caustic Soda	NaOH	1.5 oz.

The Filtration technology to be recommended in this study is based on Kiran, et. al. study entitled, *Feasibility of Collecting Rainwater at NTU (Nayang Technological University).*

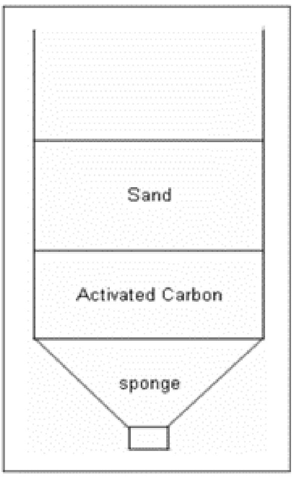

Figure 7 Filtration with varying media – sand, activated carbon, and

This filter is designed to improve the pH, turbidity, and remove impurities. Two general filtration techniques are coupled here to design the system. These are mud-pot and activated carbon filter systems. The proposed system consists of three varying layers – a layer of sand, activated carbon, and sponge. Sand layer is significant primarily because it filters larger solid particles present in the rainwater. This may be further improved by considering multiple layers of sand with varying grain sizes. On the other hand, the activated carbon layer contains a highly porous zeolite, allowing this layer to capture very fine particles that have passed through the sand layer. Furthermore, it has a capability of adsorbing heavy metals and ammonium. It removes also organic contaminants and foul odors. The sponge at the bottom filters off more particles in the rainwater. Sponge acts as a stopper, preventing the sand and the activated carbon to go through with the water. This enables water to spend more time through the layers above.

If rainwater will be used for potable applications such as drinking and cooking, we need to introduce disinfection methods

In this study we propose two disinfection methods. First is Solar Disinfection. In this method, clear plastic or glass bottles are filled with water and then, is exposed to sunlight. This destroys most germs that cause disease. It must be noted that the temperature of the water must not reach as high as 50 oC. For tropical regions, like the Philippines, we need to expose our cleared bottles filled with water under the sun for five hours around midday. If, the water is cloudy, two days is required. We fill the bottle three-fourths full and vigorously shake it to speed up the process.

We will incorporate disinfection through boiling with this process to further treat the harvested rainwater. Boiling is a traditional method of treating water that can kill all germs that cause disease. For this method to work, water must be brought to a rolling, bubbling boil. It is required to boil harvested rainwater for one to three minutes. One disadvantage of this method is that, it will make the water taste flat. It can be fixed by shaking the water in a bottle or adding a pinch of salt for every liter of water boiled.

It is expected that after doing the processes mentioned above, the quality of water is within the standards for drinking water. However, we require that test be done for the treated water to determine if indeed, it is safe to drink. Tests include but are not limited to pH, turbidity, and microbiological tests.

3.3 Economic Analysis
Shown n Table 3 is the estimated cost of the UP BRS Model House along Magsaysay St., UP Diliman Quezon City.

We use those values listed above to come up with an estimate equation relating the total cost of a rainwater harvesting system. We identify the major variables as tank size and roof area. A factor of safety of 1.2 is used for estimation because of other considerations that may not been taken into account correctly by the researcher. Hence we have the following equation:

$$C=10S+30A+1500 \quad (1)$$

whereC is the total cost in pesos, S is the storage size calculated using the simulation, and A is the area of the catchment system

We use this equation to plot cost vs. reliability for a given demand. For instance consider, the plot shown below which considered two roof areas, 50 and 100 sq. meters.

Table 3 Cost Estimation of a Rainwater Harvesting System

Quantity	Item Description	Unit Price	Total Price
3	Plastic Tank	550.00	1650.00
8	3 x 10 Dragon PVC Pipe	180.00	1440.00
1	Heltex Solvent Cement 100 cc	70.00	70.00
7	3" 90 deg Dunhill Elbow	44.00	308.00
2	3" Tee Dunhill Elbow	48.00	96.00
3	Faucet Hose	170.00	510.00
1	1/2 x 10 Moldex Pipe	70.00	70.00
2	1/2" Moldex F. Adaptor	11.00	22.00
6	1/2 x 4 Amazon Screen per meter	115.00	690.00
3	Labor	400.00	1200.00
2	1/4 x 2 Angle Bar (per 6 m)	560.00	1120.00
2	16 mm Deformed Bar (per 6 m)	316.00	632.00
2	Steel works	400.00	800.00
TOTAL			**PhP 8608.00**

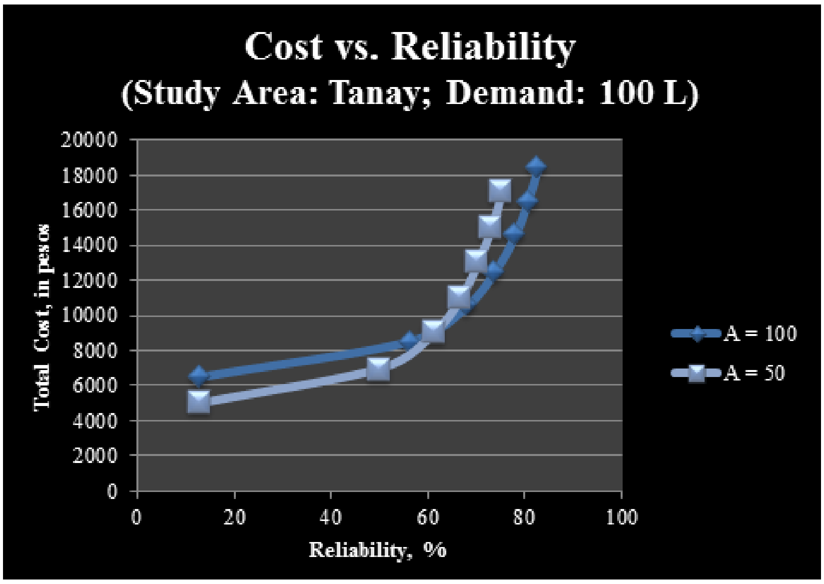

Figure 8 Cost vs. Reliability for 50 and 100 sq. meter roof

We plotted cost versus reliability computed for each storage size (interval of 200 L). We considered two roof areas, 50 m2 and 100 m2. We identify at what point a user will shift from 50 m2 to 100 m2 area for utilization. This is the intersection of the two graphs. In this example it is identified as the point with reliability at approximately 60 %. This corresponds to a tank size between 400 to 600 L. But since we are considering tank sizes in multiples of 200 L, we recommend using 600 L for this condition.

In this study, we found out that for any study area and for any demand, a minimum of 600 L tank size indicates that it is more economical to utilize the whole roof, 100 m2 rather than half of it.

3.4 Recommended Procedures for Technology Dissemination

To promote rainwater harvesting in the Philippines, we propose installation of demonstration projects, promotion through education and public awareness programs, training programs, research and development, and proper networking between government and non-government institutions.

4. CONCLUSIONS

1) Rainwater harvesting is an acceptable alternative source of water for all applications that we can think of including gardening, toilet flushing, bathing, washing, cooking, and drinking.
2) A simple rainwater harvesting is composed mainly of a catchment system, conveyance system, and storage however concentration is more on the storage.
3) Sizing depends on the following factors: demand, supply, roof area, and length of simulation.
4) We considered four study areas to account for the variability in terms of climate of the provinces in the Philippines. Of these areas, rainwater harvesting is most reliable for Daet and least for Sangley. This is mainly due to the nature of rainfall recorded in Daet..
5) Generally, rainwater is a clean water source. However, as it is being transported from catchment to storage, it gets contamination decreasing its quality. Hence, we proposed the following methods to address water quality problems. Leaf guards and first flush diverters are required to initially remove large debris from the harvested rainwater. We introduced neutralization by adding chemicals and filtration through a system with varying media – sand, activated carbon, and sponge. If potable applications are required, such as cooking and drinking, disinfection through solar disinfection and boiling is required. Harvested rainwater up to this point need to be tested first before anyone is allowed to drink it.
6) Using the UP BRS Model, we identified that the cost of retrofitting amounted to P 8,608.00. We used this data to provide a general relationship between cost and two other variables – roof area and tank size. We assumed a linear relationship because we have inadequate sources of information to assign with any other type of relationship. We used this equation to plot cost and reliability. We used this graph to identify at what point a user will shift from a 50 m2 to 100 m2 roof area. This turning point is identified to be constant at 600 L tank size.
7) Lastly, we have identified some ways on how we can promote rainwater harvesting as an alternative water resource in the Philippines. These include education and awareness programs, demonstration projects, and networking between government and non-government institutions.

ACKNOWLEDGMENT
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LABORATORY SCALE EXPERIMENTS TO MEASURE SEDIMENT YIELD IN COCO-FIBER REINFORCED SLOPES

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Abstract: This study was done to evaluate the performance of coco fiber geotextiles (cocomat) and their suitability with the slope of the soil when used for soil erosion control. Three cocomat designs were used – stitched fiber cocomat (SFC) and two woven S400 and S700, each with different mesh sizes. Samples of the three designs were tested to determine their technical properties. Prior to the laboratory rainfall simulation, soil specimen was made to pass through a 4-mm sieve to achieve a uniform aggregate size distribution. Soil specimen was then placed in the study plot and treated to be representative of field conditions. The cocomat-reinforced soil plots and bare soil plots were tested using two different soil slopes. Effectivity against soil erosion was measured based on rill occurrence, sediment concentration, and sediment yield. Comparison of the performance of cocomat-reinforced plots and bare plots showed that all cocomat designs are effective in reducing soil erosion at 30º while, at 40º, S400 cocomat failed to surpass the threshold value. The experiment procedure was also outlined for easy replicability by other cocomat suppliers in testing the performance of their products.

Key words: coco-fiber, erosion control, cocomats

1 INTRODUCTION

1.1 Background

Soil erosion occurs naturally in the environment due to elements like wind, water, and gravity. However, due to rapid expansion of human activities like grazing, cutting down of trees, land conversion, etc., soil erosion could occur at a much faster rate. Impacts of soil erosion could translate to substantial environmental and economic losses. As such, it is seen as a problem that should be provided with efficient and cost-effective solutions.

One common method is the use of geotextiles. Geotextiles are permeable fabrics, synthetic or natural, that has the ability to reinforce slopes and control soil erosion. To effectively control soil erosion, geotextiles must be able to protect the soil from eroding elements like rainfall, runoff, and wind. It must also be able to trap suspended sediments in the water without hindering the water to pass through. The selection of geotextile to be used is dependent not only on its effectiveness. According to Gray and Sotir (1996), the reasons for the widespread use of the geotextiles include availability, ease of installation, familiarity, advertising and promotion, existence of standards, and acceptance of specifiers. Usual practice is to use the most suitable and economically-efficient material. Also, with the addition to environmental degradation as an aftermath of the processes done to produce synthetic materials, focus is shifted on the research and utilization of natural materials for sustained development. Natural materials can be as efficient as other synthetic materials, with less negative impacts on the environment. Natural fibers are also biodegradable and a good moisture retainer and soil enhancer. Being so, the fibers can be applied in combination with plants with good soil-retaining capability, thereby, adding to slope stability and enhancing aesthetics.

Among the natural materials used as a geotextile is coconut fiber. It is produced from coconut husks (*Cocus Nucifera*) which are waste materials in the coconut industry. The process of extracting fiber from coconut husk is called retting, wherein husks are submerged in water storage tanks for a period of time. In the process, water interacts with the fiber matrix to remove impurities (Vishnudas et al, 2006).

Coco fiber has the highest tensile strength among fibers and retains much of its tensile strength when wet. Because of its high tensile and wet strength, cocomat can be used in very high flow velocity conditions. Fibers also have high durability and slow biodegradation. These properties are attributed to its high lignin content (Vishnudas et al, 2006).

Cocomat can be woven or nonwoven. Woven mats can be of different mesh sizes. In nonwoven mats, loose fibers are arranged randomly and then mechanically entangled by needle punching. Physically, woven and nonwoven mats differ in that more open area means more loose mesh and, therefore, lower density. Nonwoven mats are normally denser than woven mats.

1.2 Objectives of the Study

This study primarily aimed to evaluate the effectiveness of cocomat in reducing soil erosion and determine the suitability of the design with the slope of the soil to be reinforced. Furthermore, this aimed to identify the technical properties of cocomat relevant for use in soil erosion control and the test methods to determine these properties. The experiment procedure was also outlined which can be used by other cocomat supplier to test the performance of their products.

1.3 Scope and Limitations

This study primarily focused on the performance of cocomat for soil erosion control. However, due to equipment limitations and time constraints, it was limited to two soil slopes and three cocomat designs. Wind effects were not considered in the analysis since experiment was done in an indoor laboratory. Also, since the soil specimen was transported from the field to the laboratory, it is assumed that treatment of the specimen was enough to be representative of field conditions. Test results are suited only to the materials that were acquired from the source and not to those by other manufacturers.

It was assumed further that the cocomat will be complemented by vegetation so that erosion will be continuously mitigated by the time the cocomat has degraded.

2 METHODOLOGY

2.1 Materials

Three designs of cocomat were used for the experiment: stitched fiber cocomat (SFC) and two woven S400 and S700. The cocomat used were manufactured by the Soriano Multi-Purpose Fiber Corporation. The summary of the technical properties of cocomat used is listed in Table 1. The experiment was done at the Hydraulics Laboratory of the Flood Control and Sabo Engineering Center of the Department of Public Works and Highways in Pasig City, Metro Manila. The rainfall apparatus used is a fixed-type simulator manufactured by Maruto Testing Machine Co., Ltd. Freesia Macros conventional oven was used to dry sediments to determine moisture content. The soil plot has an effective size of 1.5m x 1.0m (length x width). Runoff was collected in plastic containers and filtered to separate sediments through a filter cloth.

Table 1 Technical Properties of Cocomat Used

Property	**S400**	**S700**	**SFC**
Color	Brown	Brown	Brown
Mass per Unit Area (g/m²)	400	700	1790
Thickness, mm	8.17	8.08	17.81
Machine Direction	534	388	57
Cross- Machine Direction	366	427	30

2.2 Experimental Set-up

Each soil plot condition was replicated five times for every slope, giving a total of 40 experiments. Each experiment consisted of four phases. A phase of the experiment starts from collecting soil specimen up to post-rainfall simulation activities. Phase 1 involved application of simulated rainfall on bare study plot. Phase 2 involved the study plot reinforced with SFC, Phase 3 with S400, and Phase 4 S700. Each phase is further divided into two sub-phases. Sub-phase 1 was done with study plot slope of 30º and sub-phase 2 with study plot slope of 40º. The cocomat and soil specimen used for one run were replaced with another cocomat and specimen for the subsequent run. Soil morphology was observed before the soil specimen is excavated from the soil plot.

The soil plot was properly bounded by a frame made of wood with height of approximately 50cm. The runoff on the study plot was conveyed to containers through a collecting trough installed at the outlet.

2.2.1 Soil Specimen Preparation

Soil specimen must be erodible enough to favor runoff generation and rill occurrence. The specimen used was classified as ML under the Unified Soils Classification System (USCS). It has a natural optimum moisture content of 0.32 and a maximum dry density of 1.382 g/cm³.

Prior to the rainfall simulation, the soil specimen was made to pass through a 4-mm sieve. This was done to achieve uniform aggregate size distribution. The sieved soil was filled to the study plot to a height of 30cm. Soil was filled at every 10cm. and compacted using a 100N force to achieve a bulk density of 1.35 ± .05 g/cm³. To reduce variability in compacting, the soil plots were pre-wetted by spraying approximately 5 liters of water over the plot area and then left to equilibrate overnight. Soil samples from the soil plot were oven-dried for 12 hours to determine the initial moisture content.

2.2.2 Installation Methods
The soil plots were also treated so that the top surface was even. Cocomat were carefully laid to the top surface, gently stretched and pressed to come in close contact with the soil. Aluminum rods were used to secure the contact between the two. The plots were then placed on the stand configured to the desired slopes.

2.2.3 Rainfall Simulation
The rainfall apparatus has an effective rainfall area of 10.0m x 5.0m and effective rainfall height of 8.0m. The control box was adjusted to give a discharge of 5.0 ± 0.05 m^3/s corresponding to a rainfall intensity of 125.0 ± 5.0 mm/hr. Each simulation lasted for 50.0 minutes, with the runoff collected at 10-minute intervals. To verify the adjusted intensity, four rain gauges were stationed near the four corners of the soil box. Rainfall gauge measurements were taken after every 10.0 minutes.

2.2.4 Post-Rainfall Simulation Activities
Soil morphology is observed after every rainfall simulation. Used cocomat were discarded while the used soil is sun-dried for one day. Due to the limited volume of soil specimen, the sun-dried soil was used for subsequent rainfall simulation.

Runoff was collected in a plastic container. Samples and container weights were recorded. Then filter cloths were used to separate the collected sediments from the water. The filtered sediments were air-dried overnight and then weighed.

2.3. Contractors' Survey
On the usability of the cocomats against soil erosion, three Contractors were interviewed about their experience in the use of cocomats.

3 RESULTS AND DISCUSSION

3.1 Calculations
The data obtained from the experiment were runoff generation, rill occurrence, sediment concentration, sediment yield, and effectivity against erosion. Runoff generation was measured by subtracting the total weight of the containers used from the total weight of the collected runoff. Rill occurrence was visually observed after every rainfall simulation. Sediment concentration (in grams/liter) was computed for each interval of collection by dividing the mass of the air-dried sediment (in grams) by the volume of water (in liters). Sediment yield (in grams/(square meter*hour) was obtained by dividing the mass of the air-dried sediment by the surface area of the soil plot (in square meters) and time (in hours).

From the sediment yield, the effectivity against erosion was computed by dividing the difference of bare plot sediment yield and cocomat sediment yield by the bare plot sediment yield, and then multiplying by 100%.

3.2 Rill Occurrence
For the two soil plot slopes, rill occurrence was only visible on the bare plots. For the bare plots, rain dropped directly on the soil, causing soil particles to be detached and thrown into the air over a few centimeters. These detached particles were more prone to be eroded downslope. The infiltration capacity of the soil was also easily reached which consequently caused reduction in the infiltration rate. Due to this, more water moved downslope as runoff. Along its path to the outlet, runoff collected sediments. Note that the detached particles were easily dislodged by the runoff. As runoff increased and became more concentrated, it gradually formed channels that further developed into rills. For the soil plots reinforced with cocomat, direct throughfall was partially prevented. This resulted to the decrease in the transfer of the momentum from the raindrop to the soil particles which mean that less energy is available to dislodge the particles. After removing the cocomat, it was observed that the soil beneath it followed its pattern. More particles were eroded from the soil in between the ropes as compared to the soil directly under them.

3.3 Sediment Concentration and Sediment Yield
The summary of the mean sediment concentration and mean sediment yield for the 30- and 40-degree slopes are presented in Tables 2 and 3, respectively. The data is graphically represented in Figures 1 and 2.

Table 2 Mean Sediment Concentration(g/L) from Soil Plots at 30º

Time (min)	0	10	20	30	40	50	Overall
Bare Plot	0.00	63.74	34.01	35.59	31.95	31.09	35.67
Plot w/ 400	0.00	12.13	4.22	4.96	4.22	5.06	5.47
Plot w/ 700	0.00	11.46	2.14	2.40	1.75	1.68	3.71

Plot w/ SFC	0.00	0.02	0.00	0.02	0.09	0.07	0.04

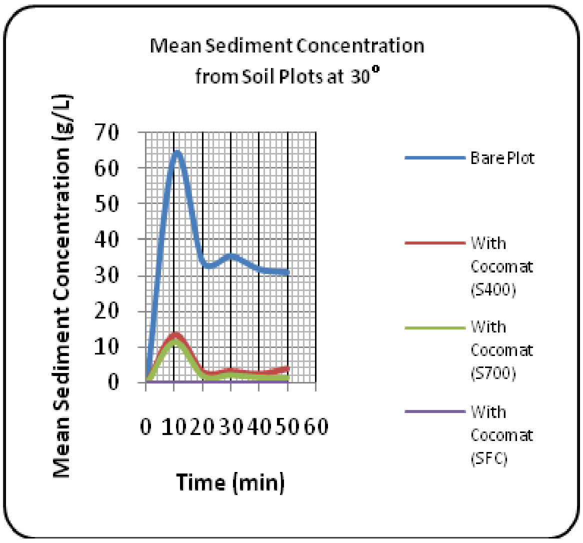

Figure 1 Sediment Concentration at 30°

Table 3 Mean Sediment Concentration(g/L) from Soil Plots at 40°

Time (min)	0	10	20	30	40	50	Overall
Bare Plot	0.00	69.42	36.62	28.46	25.00	24.80	32.54
Plot w/S400	0.00	22.49	12.73	9.41	10.41	9.90	11.36
Plot w/S700	0.00	7.01	1.50	1.31	1.57	1.94	2.31
Plot w/SFC	0.00	1.39	0.29	0.15	0.45	0.23	0.55

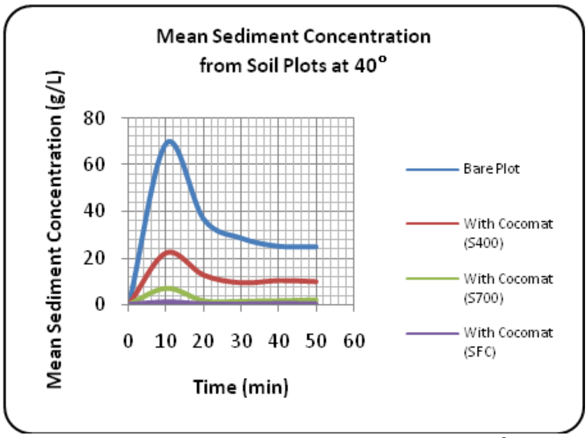

Figure 2 Sediment Concentration at 40°

From the graphs, it is evident that the cocomats were effective in decreasing the amount of sediments that flowed with the run-off. Using the bare plot as the control group, we can compare the amount of reduction of sediment yield for the different types of coco mats. The more mass of cocofiber per unit area, the more that it can hold sediments in place. For the 30^0 slope, the difference in the behavior between the SF400 and SF700 is not so marked. For the 40°, the graph shows a marked reduction when using SF700 compared to SF400. For both slopes, the stitched type (SFC) is highly effective in holding sediments, thus preventing erosion.

3.4. Contractors' Survey

The result of the surveys showed that the following contractors previously used cocomat for soil erosion control projects:

- ME Sicat Construction, Inc
- Leighton Contractors Asia
- First Worldwide Marketing Corporation

From their perspective, the advantages of cocomats over other conventional methods are

a. cheaper cost of materials;
b. materials are readily available since many suppliers are engaged in the industry; and
c. it is very good for landscaping.

However, there are also some problems – cocomats are highly combustible, inconsistency in the quality of material, lacking in skilled workers for proper installation – that they encountered.

4 CONCLUSION

The study was able to demonstrate that the cocomats were effective in preventing soil erosion based on the laboratory experiments that were used. Of the three types, the stitched or the non-woven type has the least amount of sediment yield during a run-off. The study also outlined the experimental set-up and conditions that can be used in testing the effectivity of geotextiles against erosion.

It was recommended by the contractors that workers should be trained on proper installation techniques and cocomats should be tested in accordance to specifications to prevent soil erosion for higher embankment.

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