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.

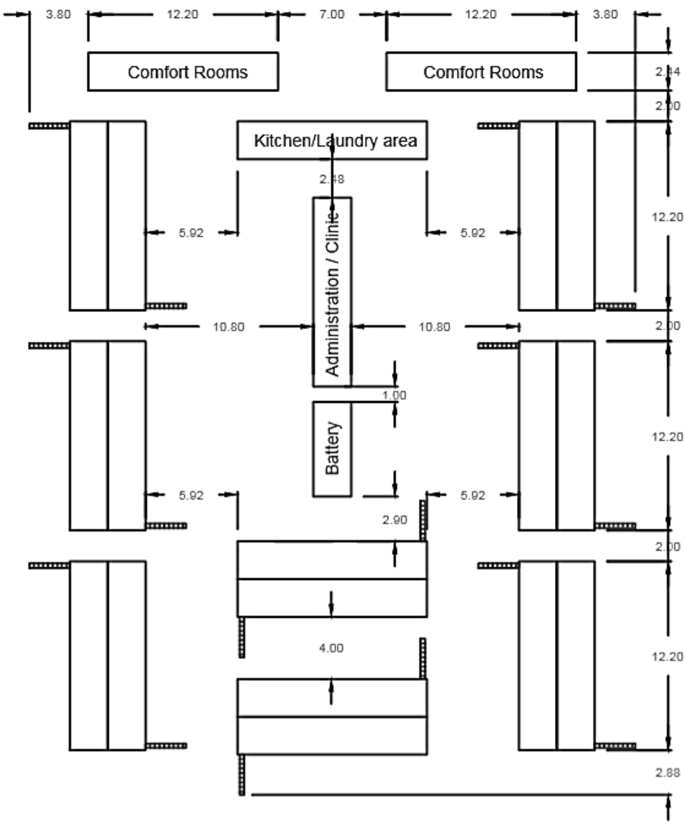

Figure 2 Sample proposed layout.

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 ....

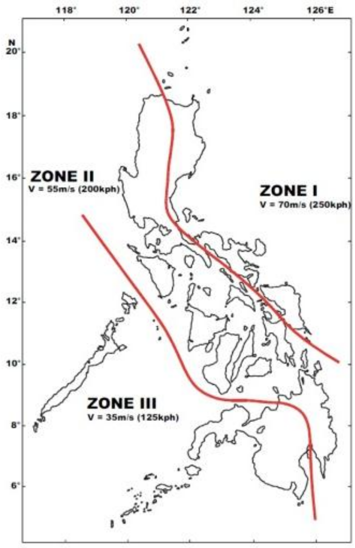

Figure 4 Philippine Wind Velocity Map

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

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.

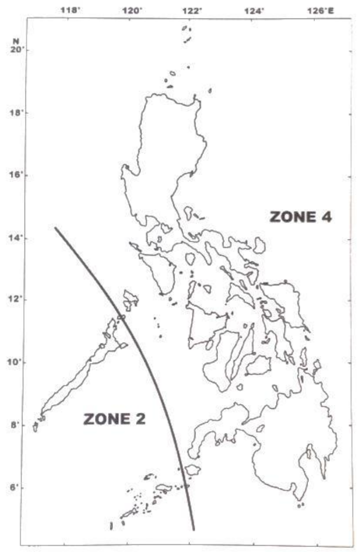

Figure 5 Seismic zone map of the Philippines

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).

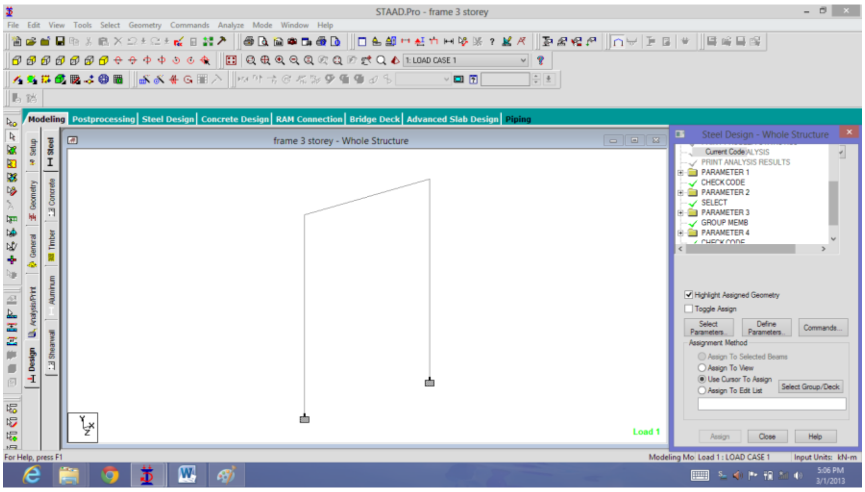

Figure 6 STAAD framing for the three-storey superstructure.

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.

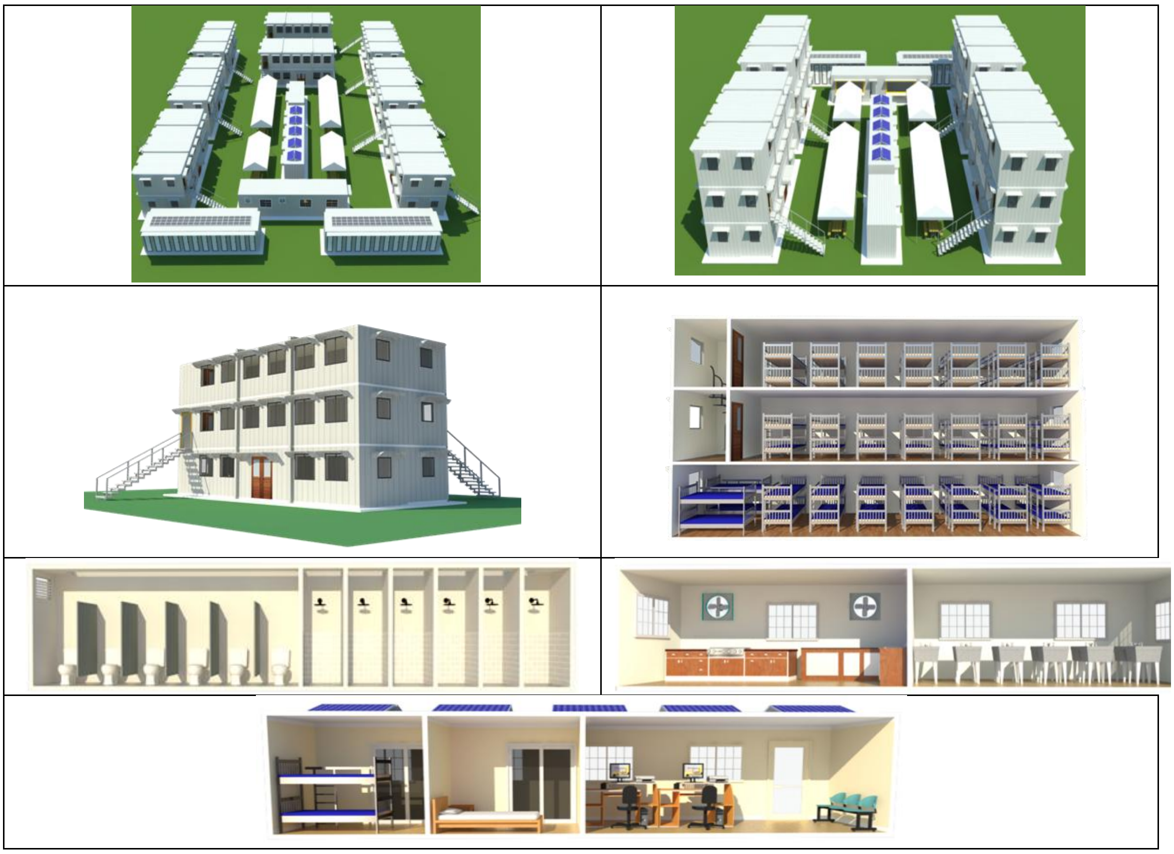

Figure 7 Clockwise from top left: Proposed 2-storey layout; Proposed 3-storey layout; Interior of the 3-storey abode; Common kitchen; admin office; Common toilet and bath area; Exterior of the 3-storey abode.

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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