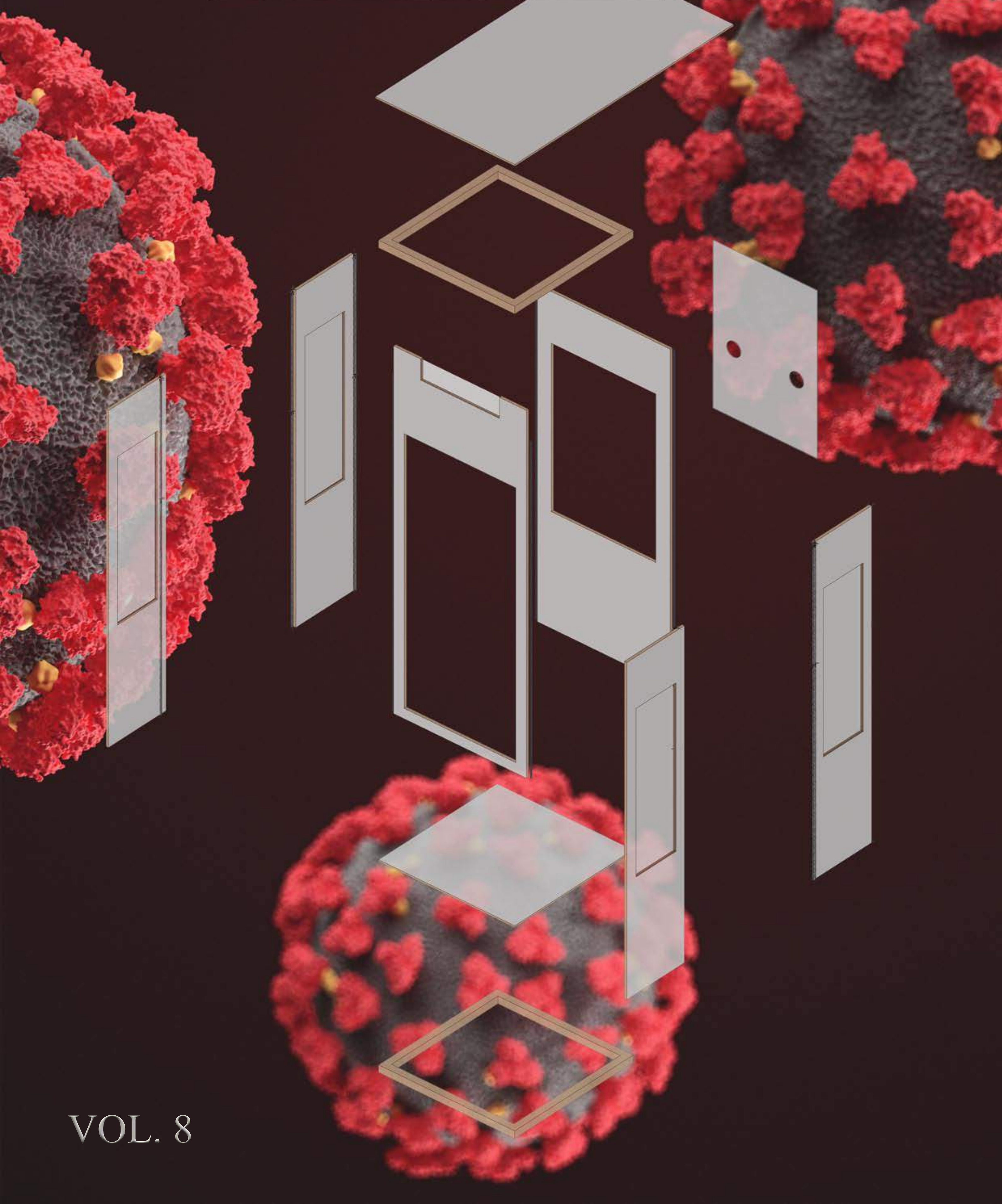
MUHON

Journal of Architecture, Landscape Architecture, and the Designed Environment



VOL. 8

MUHON

A Journal
of Architecture,
Landscape Architecture,
and the Designed Environment

University of the Philippines
College of Architecture

Issue no. 8

MUHON

A Journal of Architecture, Landscape Architecture, and the Designed Environment

MUHON is a forum for discussion of ideas on the designed environment published by the College of Architecture of the University of the Philippines in Diliman. This publication seeks original work and welcomes contributions related to a variety of issue areas. All submitted works should not have been previously published.

MUHON considers for publication research, technical and philosophical papers, as well as opinion essays. Written works should be well-organized, clearly written, interesting, coherent, intelligently argued, and accurate with regard to attributions.

MUHON serves as a vehicle for publishing creative and professional works of architects in the academe. These documented works must highlight new bodies of knowledge applied to or generated by the projects.

MUHON encourages prospective contributors to view their efforts as exercises on critical inquiry. Great emphasis will be placed on the idea content of the work, its scholarly depth, and on the development of arguments.

University of the Philippines College of Architecture
P.O. BOX 53, U.P. Diliman, Quezon City
1101 Philippines
upca.upd.edu.ph

Print ISSN : 1656-6505
Online ISSN : 2094-1277

Published and distributed by UP College of Architecture

Pool of International Reviewers

This eighth issue of MUHON is an internationally peer-reviewed publication. The views expressed here are those of the authors and are not necessarily those of the University of the Philippines College of Architecture, or the editors of this publication.

ABOUT THE COVER

The cover depicts the architectural response to the coronavirus pandemic—a deconstructed isometric of a portable specimen collection unit for a mobile COVID facility with the coronavirus looming in the background. The start of 2022 saw the emergence of a more contagious variant of COVID-19, the Omicron, which has caused panic and further medicalization of spaces. Architecture can play a crucial role in promoting infection control by building new spaces and retrofitting existing facilities to mitigate pathogenic transmission. Architecture can creatively transform existing spaces as functional health facilities. Architecture can help us adapt to the pandemic by offering innovative designs for the home, hospitals, and other business establishments with a safe, comfortable space, and conducive for recuperation and well-being.

Note: Isometric drawing illustrated by John Henry A. Comia taken from the research paper of Richard Martin Rinen and Ernest Jose entitled, "Designing the Mobile and Portable Specimen Collection Unit with Biosafety Features with Biosafety Features and Other COVID-related Design Responses" presented at the 2021 Annual Conference on Architectural Research and Education (ACARE) last June 19, 2021. The image of the coronavirus is from the database of Canva (Free Media License).

Contents

Editorial

Shift in the Urban Condition

Gerard Rey A. Lico, Ph.D.
galico@up.edu.ph

Our lives have drastically changed and continue to adjust as we navigate a world gripped with the dangers of the novel coronavirus. The ever-evolving nature of COVID-19 has fostered an environment that proves more and more precarious, leaving many of us vulnerable to the inhospitable realities of urban life. The prolonged need for vigilance towards our surroundings has made us more aware of the issues our urban condition faces. Environmental issues become more pronounced as the threat to human life is compounded with every onslaught of calamity. Bureaucratic red tape becomes more exasperating as we witness the birth pangs of automated government processes, only to be forced to take our spot in line at government offices—social distancing measures notwithstanding. The yearning for the outdoors necessitated more open spaces, better connectivity, and people-centric development is more apparent as we are encouraged to conduct our activities out in open air.

These circumstances necessitate the reexamination of how we interact and interface with our spaces—and challenge us to improve them. This volume of Muhon offers a refreshing glimpse into the potentials of the Philippine designed and built environment, offering analyses on various aspects of the urban condition and possible policy and design interventions to address certain issues within.

One of the issues presented pertains to efficiency of materials utilization. Some industrial by-products from metal production eventually contribute to the larger issue of waste management. Manoloto's research on slag cement as a partial substitute for Portland cement in concrete presents the possibilities of using a waste by-product of iron and steel production as a suitable and economical additive for local construction. The addition of slag cement contributes to increased strength and lower costs for concrete construction, while contributing to a better utilization of resources from metal production processes.

Streamlining of government bureaucratic processes is one of the main arguments for the shift to systematic automation. Parametric design and visual programming software offer a viable solution to aid in this automation process, especially for architectural safety and code compliance evaluations. Lopez and Balane explore the adaptability of Building Information Modeling (BIM) visual programming software as an automated code compliance check mechanism for R-1 or residential construction projects. The use of parametric design strategies for streamlining administrative processes is a crucial tool which would ensure better code compliance, while aiding local building officials in making construction approval procedures and code compliance more efficient and effective.

Flooding has been a perennial problem in the Philippine urban environment. Various measures over time have been implemented in varying degrees, and an encompassing evaluation of these interventions are now necessary. Rinen and Maki present a comprehensive overview of flood control and mitigation strategies implemented in the Philippines over the course of its history, analyzing the advantages and pitfalls of each major intervention presented in the paper. This is reflected along with the socio-political situation of each period presented, offering a nuanced understanding of the challenges faced by the country regarding flooding and what kinds of strategies have been prioritized overtime. The authors later offer recommendations for improved response and avoidance of such calamities for future implementation.

Informal communities are the most vulnerable sectors of the city, and often the target of relocation activities. Many such relocation projects however have failed due to their lack of consideration for the community's socio-spatial dynamics and its economic implications. Sicam's comparative study on the dynamics of spatial organization of resettled urban informal communities vis-à-vis their relocation sites emphasizes the often-forgotten economic implications of spatial transplantation in the lives of informal communities. Springboarding from Ulingan in Tondo, Manila and St. Martha Estate in Bocaue, Bulacan as case studies, the study underscores the need for more holistic design and planning strategies that go beyond addressing the need for security of tenure—taking into consideration the innate abilities of communities to self-organize and foster communal networks for shared capacity development.

Finally, this pandemic has placed most students to do online learning and work-from-home arrangements for employees, which contributed to less traffic in major cities like Quezon City. the Philippines ranked ninth in terms of the poor traffic situation in our country. Thus, the government should also have a plan on how to reduce traffic in the metropolis including traffic noise, which can cause health risks to commuters due to stress.

The study by Del Barrio, Sebastian III, Goduco, and Bo-ot tackle the potential of the Traffic Noise Model version 2.5 (TFNv2.5) in simulating and predicting traffic noise pollution levels using three sites within Quezon City as case study. Traffic volume count from the selected key locations were obtained to determine the impact of traffic noise. As cities develop through urbanization and in-migration, noise pollution can worsen. Computer programs like the FHWA Traffic Noise Model could offer innovative ways to solve or lessen the noise pollution during traffic.

Overall, this volume of Muhon proposes shifts in our urban condition, giving us possibilities that can be achieved through judicious and participatory design approaches, planning, and policy framing. Shaping the designed and built environment is grounded in the intersection of these processes. As we are faced with the uncertainties of the new norm, we are challenged to hope and create a better future framed in space for future generations.

Adaptability and Performance of Slag Cement As Partial Replacement to Ordinary Portland Cement in Concrete

Engineer John Arvin R. Manaloto[1]
jrmanaloto@up.edu.ph

Abstract

Portland cement is extensively used in the construction industry, making it one of the biggest construction expenditures in the Philippines and worldwide. It plays a vital role in concrete technology and is also the one used more often as compared to the other types of cement. In this study, the feasibility of partially replacing Portland cement with Slag cement, an industrial byproduct of iron manufacturing was investigated. This provides alternative and sustainable solutions to concrete design that could aid in the construction cost reduction. In this research, the effect of replacing Portland cement with 0 percent, 30 percent, 40 percent and 50 percent slag cement in concrete mix design were investigated for compressive and flexural strengths. For the determination of strengths, a Universal Testing Machine (UTM) was used to apply compressive and flexural loads to concrete cylindrical and beam samples, respectively. Water demand, slump and slump retention at constant water-cement ratio for the said proportions were also tested. The results show that concrete using slag cement has lower water demand as it achieves higher slump and better slump retention versus concrete using pure Portland cement. Moreover, with the increasing amount of slag cement replacement to Portland cement, the compressive and flexural strength of concrete increases. An optimum replacement of 50 percent slag cement to Portland cement in concrete is therefore recommended for both compressive strength and flexural strength designs.

Keywords: concrete mix design, Portland cement replacement, slag cement

John Arvin R. Manaloto is an Assistant Professor of the UP College of Architecture - Building Science Studio Laboratory. He graduated with Bachelor of Science Degrees in Geodetic Engineering and Civil Engineering from the Institute of Civil Engineering, UP College of Engineering and Bachelor of Science in Sanitary Engineering from the National University. He completed his Master's Degree in Civil Engineering (MS C.E.-Structural Engineering) at the National Graduate School of Engineering, UP College of Engineering. He is a PhD-Candidate in Civil Engineering (PhD C.E.-Geotechnical Engineering) at the NGSE, UP College of Engineering.

I. Introduction

With the wide use of Portland cement in many infrastructure developments in the Philippines and abroad, various alternatives are being considered and desired in order to reduce construction costs. Moreover, the trend for sustainable engineering advancement has been more favored and pursued.

Currently, the most common Pozzolan cement is Fly-Ash. Here again, intergrading is the common manufacturing process and the Pozzolan may account for 15 to 40 percent of the weight of the cement (Federal Highway Administration, 1995). Some advantages of using Pozzolan are improved workability, economy and sulfate resistance. Other advantages are reduced alkali-aggregate reaction, heat generation, volume change and bleeding. Examples of pozzolans are fly ash, ground granulated blast-furnace slag, and microsilica or silica fume. Slag cement, with its pozzolanic properties, has been identified to be a possible partial replacement to ordinary Portland cement. Being a byproduct from the iron manufacturing process, slag cement can be put to good use in concrete technology.

In the Philippines, there are some companies in the iron and steel industry that uses slag as a raw material for cement, iron and steel for road construction. These companies made an effort to effectively minimize potential environmental waste.

In 2020, ores, slag, and ash ranked fifth in the Philippines top ten exports with 2.7 percent as reported. Ores, slag, and ash were the fastest grower among the top 10 export categories, up by 40.6 percent from 2019 to 2020 propelled by higher international sales of nickel and iron ores and concentrates. The only other top export product to increase copper via a 23.4 percent gain. Additionally, the Philippines also imports slag from countries like India. In 2014–2015, the Philippines imported 18,000 tons of slag from India.

Cement companies such as Holcim Philippines produce blended cement volumes with ground granulated blast furnace slag (GGBFS). Raw materials for blended cement namely the GGBFS is imported and stored at their plant in Barangay Pulong Balibaguhan, Mabini, Batangas.

A. Statement of the Problem

There is a need for alternative solutions in concrete technology since Portland cement is a huge construction expenditure and is widely used.

Also, slag cement is a waste byproduct and can be put to good use in concrete due to its pozzolanic properties. By partially replacing Portland cement with slag cement in concrete, an alternative and sustainable solution can therefore be provided.

B. Objectives of the Study

1. Find out the effect of slag cement as replacement to Portland cement in concrete in terms of: (a) Compressive Strength; (b) Water Demand; (c) Slump; and (d) Slump Retention.

2. Check and evaluate the optimum slag cement replacement on the compressive strength and flexural designs.

3. Make a comparison of concrete design parameters of the slag cement combination to ordinary Portland cement.

C. Significance of the Study

It is great to present this to all the engineers, architects, contractors, consumers, and educators to inform and give them an alternative in the future to help them cut costs in construction and, at the same time, be part of the varied sustainable initiatives of using slag cement.

This study also lays down a great opportunity in the construction business and economy of the Philippines. Supporting and opening more steel producing businesses where wastes can be made to slag cement or establishing connections from slag cement - producing countries like South Korea and Japan will have a significant boost in the economy.

D. Scope and Limitations of the Study

1. The study focuses on the effect of slag cement replacement up to 50 percent to Portland cement at different concrete mix designs for compression and flexure.

2. The study uses a constant water to cement ratio approach just to primarily check if replacing part of cement in the design with slag cement using a defined water-cement ratio set by using pure ordinary Portland cement has an effect on the workability and strength of concrete.

3. The study is limited to the use of naptha based admixture. The researcher just would like to establish a certain pattern on the effect of different slag cement replacement to cement in different concrete designs.

4. The detailed economic and cost efficiency of the slag cement as a partial replacement is not included in this study. This study will only focus on the sample's compressive strength and other design parameters

5. The procedures in this study are based on the American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (ASSHTO) and British Method.

II. Review of Related Literature

A. Portland Cement in the Philippines

In concrete, the most commonly used is Portland cement. It is a hydraulic cement which sets and hardens through a chemical reaction with water and can do so underwater. Cement serves as "glue" that binds the concrete ingredients together and is instrumental for the strength of the composite. (Lee & Estrada, 2020).

David Saylor started the United States' concrete production in the early 1870s, in Coplay, Pennsylvania (Federal Highway Administration, 1995).

Portland cement is made up primarily of four mineral components: tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite. Each of which has its own hydration characteristics. By changing the relative proportions of these components, cement manufacturers can control the properties of the product (Lee & Estrada, 2020).

The primary product of cement hydration is a complex and poorly crystalline calcium-silicate hydroxide gel (CSH). A secondary product of hydration (in the production of cement) is calcium hydroxide, a highly crystalline material. The American Society for Testing and Materials (ASTM) defines five types of cement, specifying for each the mineral composition and chemical and physical characteristics such as fineness. The most common cement is Type I. Type III cement is used if more rapid strength development is required. The other types are characterized by either lower heat of hydration or better sulfate resistance than that of Type I cement such as calcium hydroxide, a highly crystalline material.

According to the research article entitled, "Analysis of Chemical Composition of Portland Cement in Ghana: A Key to Understand the Behavior of Cement" written by Bediako and Amankwah in 2015, Portland cement is the most commonly utilized cement in almost every part of the world. The understanding of the embodiment of Portland cement could lead to a more sustainable concrete and mortar design. It chemically reacts with water to attain setting and hardening properties when used in the construction of buildings, roads, bridges, and other structures. Portland cement was patented by Aspdin in 1824 and was named after the cliffs on the isle of Portland in England. Table 1 presents the summary of chemical data for a selection of Portland Cement.

Table 1. Summary of Chemical data for a selection of Portland cement

Component	Minimum	Average	Maximum
SiO_2	18.40	21.02	24.50
Fe_2O_3	0.16	2.85	5.78
Al_2O_3	3.10	5.04	7.56
CaO	58.10	64.18	68.00
MgO	0.02	1.67	7.10
SO_3	0.00	2.58	5.35
Na_2O	0.00	0.24	0.78
K_2O	0.04	0.70	1.66
Equivalent alkalis	0.03	0.68	1.24
Free lime	0.03	1.24	3.68

Source: Analysis of Chemical Composition of Portland Cement in Ghana

These chemical compositions can be used to further improve the characteristics of concrete in terms of slump, compressive strength, setting time, etc. by addition of certain material (composites) that would react to the given elements in Table 1 and/or by altering the said elements in terms of their ratios to the mixture.

A research paper by Miranda et al. in 2014 entitled, "Increasing the Compressive Strength of Portland Cement Concrete Using Flat Glass Powder" analyzes the compressive strength of Portland cement concrete in response to the incorporation of five percent, 10 percent and 20 percent of flat glass powder in place of sand, at water/cement (w/c) ratios of 0.50, 0.55, and 0.58.

The purpose of this study was to analyze the influence of partially substituting natural fine aggregate for flat glass powder on the compressive strength of Portland cement concrete. This is the first study focusing on the application of this type of waste glass as fine aggregate in Portland cement concrete.

Cylindrical test specimens (10 cm x 20 cm) were molded and cured as recommended by the Brazilian technical standard NBR 57389. The test specimens were first cured for 24 hours in the molds at an ambient temperature of 28.5°C. They were then released from the molds and immersed in water at 26.5°C to cure for seven, 14 and 28 days (Miranda, Bezerra, Politi, & Paiva, 2014).

In this study, the compressive strength of Portland cement concrete was found to increase in response to the use of waste flat glass powder, which has not been used as a fine aggregate. The concrete containing flat glass powder was found to be suitable for structural applications when prepared with a w/c ratio of 0.55 and waste glass content of 20 percent, and with a w/c ratio of 0.50, regardless of the percentage of glass used. The w/c ratio of 0.50 showed the best potential when substituting sand for waste glass (Miranda et al., 2014).

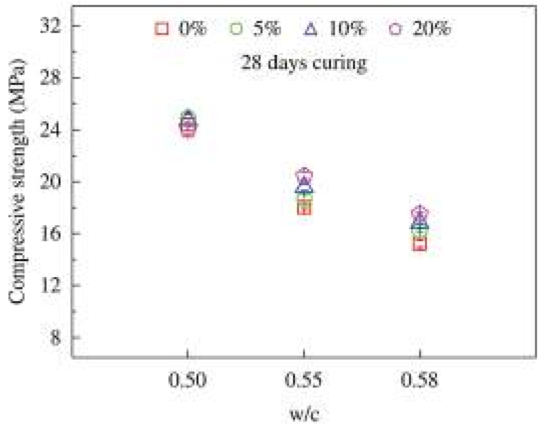


Figure 1. Compressive strength as a function of the w/c ratio after 28 days of curing.
Source: Increasing the Compressive Strength of Portland Cement Concrete Using Flat Glass Powder.

The findings presented indicate the promising potential of using flat glass powder as a fine aggregate in Portland cement concrete to produce an environmentally-friendly and structurally-applicable concrete.

An "Experimental Study on Strength Gaining Characteristics of Concrete using Portland Composite Cement" by Uddin, Jameel, Sobuz, Islam and Hasan in 2013 dealt with the investigation of strength gaining characteristics of concrete made with Portland Composite Cement (PCC) and Ordinary Portland Cement (OPC). This experimental study represents a general scenario of the strength gain characteristics of concrete made with PCC and OPC both at earlier and later ages. All properties of concrete ingredients were kept constant and cement type was varied with different composition. The work was performed using locally available materials such as stone chips, sand (coarse sand) and cement (Portland composite and ordinary Portland).

Strength developments of five concrete types have been investigated in terms of cement content and curing duration. Experimental observations on 495 specimens revealed that the early age strength of PCC concrete is lower than that of OPC concrete. Based on the test results, lack of proper pozzolanic reaction in the presence of fly ash in PCC concrete strength was lower at early age. The pozzolanic activity of fly ash also contributed to the strength gain at later stages of continuous curing. This study also concluded that drying ambient conditions reduced the strength potential of PCC concrete as the secondary (pozzolanic) reaction fails to contribute to the development of strength (Uddin et al., 2012).

Another experimental study focusing on "Compatibility of vegetable fibers with Portland cement and its relationship with the physical properties" by Marques et al. in 2016 studied the use of vegetable matrices as a sustainable technological alternative. The significant volume of agroforestry residues generated by agro-industrial and human activities is probably being inadequately deposited in the environment without sustainable reuse. From the technological and environmental perspectives, the use of residues from agro-industry in civil construction has gained relevance, because it promotes technical quality, decreasing the costs of energy and natural materials for the production of constructive elements, and also avoids damages to the environment.

The study evaluated the compatibility of vegetable fibers with cement using three methods of calculation and determined certain physical properties of the fibers and the curve of the temporal evolution of temperature for each composite. The following figures show the hydration curve of the different composite materials.

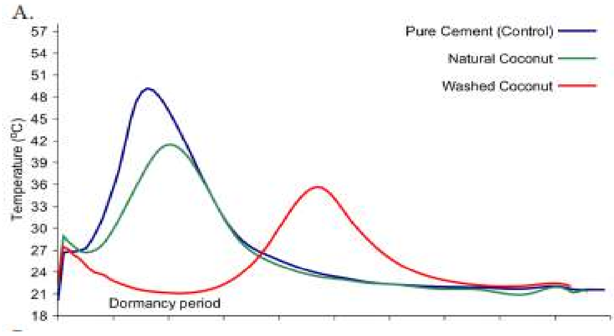


Figure 2. Hydration curves of natural and washed coconut fibers.

Source: Compatibility of vegetable fibers with Portland cement and its relationship with the physical properties.

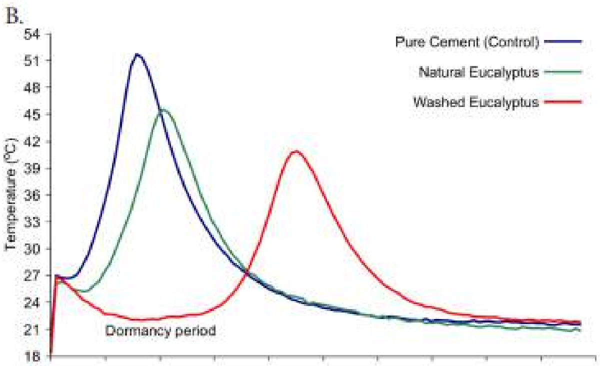


Figure 3. Hydration curves of natural and washed eucalyptus fibers.

Source: Compatibility of vegetable fibers with Portland cement and its relationship with the physical properties.

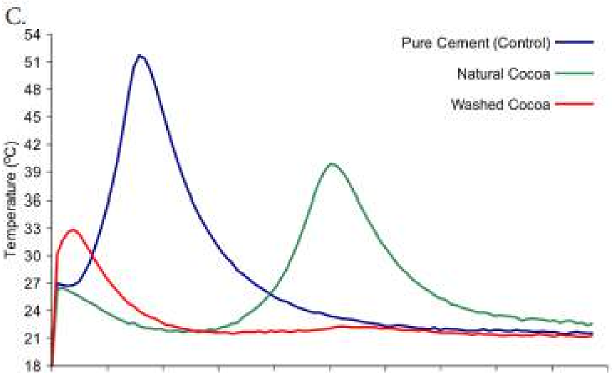


Figure 4. Hydration curves of natural and washed cocoa fibers.

Source: Compatibility of vegetable fibers with Portland cement and its relationship with the physical properties.

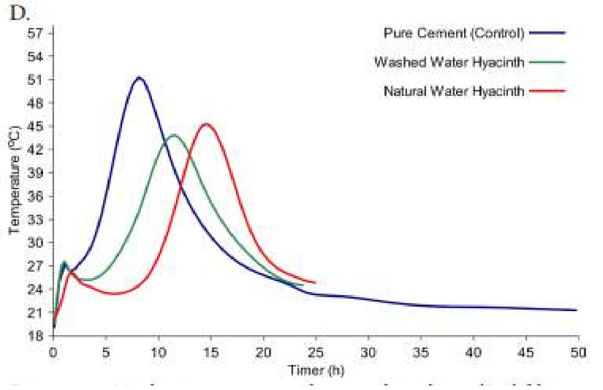


Figure 5. Hydration curves of natural and washed water hyacinth fibers.

Source: Compatibility of vegetable fibers with Portland cement and its relationship with the physical properties.

From the experiment, it can be concluded that there is a significant potential use for residues of washed fibers of eucalyptus, water hyacinth, coconut and cocoa. The pretreatment of washing of water hyacinth fiber did not alter the compatibility performance of the composites. The compatibility of the composites is favored by the decrease in the degree of swelling, packing density and specific mass. The physical properties of the studied vegetable fibers can be used as indicators in the selection of fibers and their pretreatment, aiming to use them in cementitious masses (Marques et al., 2016).

More importantly, the adherence regions found in the microscopic images that strengthen the fiber-cement link were directly associated with the depressions on the topographic profile of the surface of the fibers. The apparent irregularity found in the microscopic images of cement distribution in the composite may be related to the degree and the type of crystallinity in the cellulosic structure of the fibers (Marques et al., 2016).

This Philippine National Standard Specification for Portland cement PNS 07:2005 was prepared by the Bureau of Product Standards' Technical Committee on Cement and Lime (BPS/TC 3) and was approved for adoption as Philippine National Standard. Table 2 shows the types of Portland cement in accordance with its use.

Table 2. Classification of Portland cement in accordance with the following types.

Type	Use
Type I	For use when the special properties specified for any other type are not required
Type II	For general use, more especially when moderate sulfate resistance or moderate heat of hydration is desired
Type III	For use when high early strength is desired
Type IV	For use when a low heat of hydration is desired
Type V	For use when high sulfate resistance is desired

Source: Philippine National Standard Specification for Portland cement PNS 07:2005.

Each type of cement shall conform to the chemical requirements specified in Table 3 when tested in accordance with PNS ASTM C 114:2005. In addition, optional chemical requirements are shown in Table 4.

Table 3. Chemical requirements.

Cement type	I	II	III	IV	V
Silicon oxide (SiO_2) %, min.	-	20.0	-	-	-
Aluminum oxide (Al_2O) %, max.	-	6.0	-	-	-
Ferric oxide (Fe_2O_3), %, max.	-	6.0	-	6.5	-
Magnesium oxide (MgO), %, max.	6.0	6.0	6.0	6.0	6.0
Sulfur trioxide (SO_3), %, max.					
a. When (C_3A) is 8% or less	3.0	3.0	3.5	2.3	2.3
b. When (C_3A) is more than 8%	3.5	-	4.5	-	-
Loss in ignition, %, max.	3.0	3.0	3.0	2.5	3.0
Insoluble residue, %, max.	0.75	0.75	0.75	0.75	0.75
Tricalcium silicate (C_3S), %, max.	-	-	-	35	-
Dicalcium silicate (C_2S), %, min.	-	-	-	40	-
Tricalcium aluminate (C_3A), %, max.	-	8	15	7	5
Tetracalcium aluminoferrite plus twice the tricalcium aluminate $C_4AF + 2(C_3A)$ or solid solution ($C_4AF + C_2A$), as applicable, %, max.	-	-	-	-	25

Source: Philippine National Standard Specification for Portland cement PNS 07:2005)

Table 4. Optional Chemical requirements.

Cement type	I	II	III	IV	V	Remarks
Tricalcium aluminate (C_3A), %, max.	-	-	8	-	-	For moderate sulfate resistance
Tricalcium aluminate (C_3A), %, max.	-	-	5	-	-	For high sulfate resistance
Sum of tricalcium silicate and tricalcium aluminate, %, max.	-	58	-	-	-	For moderate heat of hydration
Alkalis (Na_2O + $0.658K_2O$), %, max.	0.6	0.6	0.6	0.6	0.6	Low-alkalicement

Source: Philippine National Standard Specification for Portland cement PNS 07:2005.

Each type of Portland cement shall conform to the physical requirements specified in Table 5.

Table 5. Physical requirements.

Cement type	I	II	III	IV	V	Test method
Air content of mortar, volume %, max.	12	12	12	12	12	PNS ASTM C 185: 2005
Fineness, specific surface, m²/kg (alternative methods):						
Turbidimeter test, min.	160	160	-	160	160	PNS ASTM C 115: 2005
Air permeability test, min.	280	280	-	280	280	PNS ASTM C 204: 2005
Autoclave expansion, %, max	0.80	0.80	0.80	0.80	0.80	PNS ASTM C 151: 2005
Time of setting						
Gillmore test:						
a. Initial set, minutes, min	60	60	60	60	60	PNS ASTM C 266: 2005
b. Final set, hours, max.	10	10	10	10	10	
Vicat test:						
a. Initial set, minutes, min.	45	45	45	45	45	PNS ASTM C 191: 2005
b. Final set, hours, max.	8	8	8	8	8	
Strength, minimum values shown for the ages indicated below						
Compressive strength						
3 days	12.4	10.3	24.1	-	8.3	PNS ASTM C 109/ C 109M: 2005
7 days	19.3	17.2	-	6.9	15.2	
28 days	27.6	27.6	-	17.2	20.7	

Source: Philippine National Standard Specification for Portland cement PNS 07:2005

B. Pozzolan Cement

Pozzolan is a siliceous or siliceous and aluminous material, which, alone, possesses little or no cementitious value but will react with water and calcium hydroxide to form compounds possessing cementitious properties. The most common Pozzolan is Fly-Ash.

A research by Al-Chaar, Alkadi, & Asteris in 2013 investigated the feasibility of "Natural Pozzolan as a Partial Substitute for Cement in Concrete." In this paper, the use of natural pozzolan as a partial cement substitute in concrete materials was investigated. By means of a test series, four mixes using three types of natural pozzolan, as well as a Class F fly ash, were evaluated. The effectiveness of each pozzolan in controlling alkali-silica reactions has been studied (Al-Chaar et al., 2013).

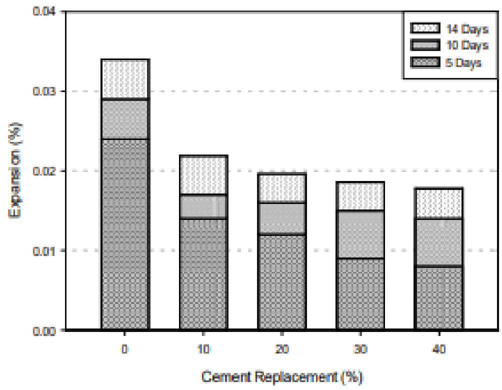


Figure 6. Effect of cement replacement with fly ash on ASR expansion

Source: Natural Pozzolan as a Partial Substitute for Cement in Concrete

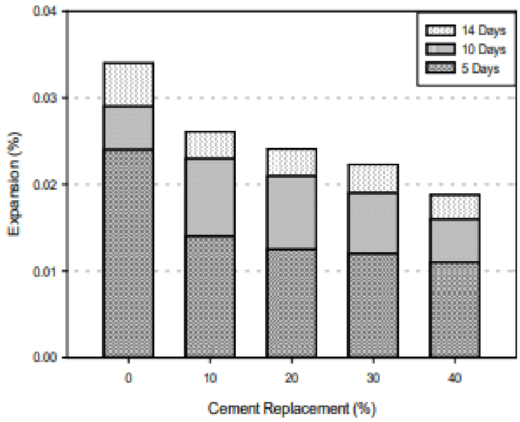


Figure 7. Effect of cement replacement with Pozzolan J on ASR expansion

Source: Natural Pozzolan as a Partial Substitute for Cement in Concrete

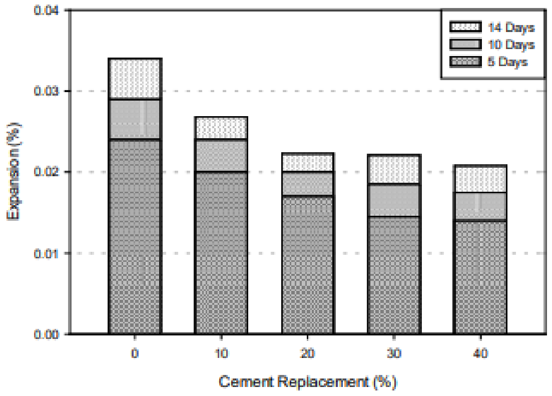


Figure 8. Effect of cement replacement with Pozzolan SI on ASR expansion

Source: Natural Pozzolan as a Partial Substitute for Cement in Concrete

Based on the results of the study, it can be concluded that Pozzolan S1 can provide a satisfactory substitute for fly ash and other natural pozzolans as tested against ASTM C618-00 [29]. It was clearly found to be effective in controlling ASR. It also produces about 15 percent less heat of hydration than Class F fly ash, whereas Class F fly ash produces about 30 percent less heat of hydration than Portland cement only. The chemical and physical properties of Pozzolan S1 are comparable to fly ash, and the one can be substituted for the other (Al-Chaar et al., 2013).

C. Slag Cement

Ground granulated blast furnace slag (GGBFS) or slag cement is a by-product from the blast furnaces used to make iron. Blast-furnaces are fed with controlled mixture of iron-ore, coke and limestone, and operated at a temperature of about 1,500°C. When iron-ore, coke and limestone melt in the blast furnace, two products are produced—molten iron and molten slag. The molten slag is lighter and floats on the top of the molten iron. Figure 9 illustrates the process of the production of Granulated Iron Blast Furnace Slag (GBFS) and Ground Granulated Blast Furnace Slag (GGBFS). The molten slag comprises mostly silicates and alumina from the original iron ore, combined with some oxides from the limestone. The process of granulating the slag involves cooling of molten slag through high-pressure water jets. This rapidly quenches the slag and forms granular particles generally not bigger than 5mm. The rapid cooling prevents the formation of larger crystals, and the resulting granular material comprises around 95 percent non-crystalline calcium-aluminosilicates. The granulated slag is further processed by drying and then grinding in a rotating ball mill to a very fine powder, which is GGBFS (Siddique & Khan, 2011).

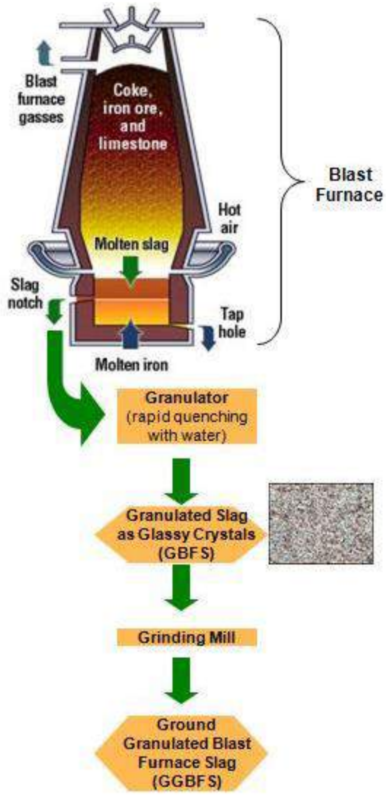


Figure 9. Production of Granulated Iron Blastfurnace Slag (GBFS) and Ground Granulated Blast Furnace Slag (GGBFS).
Source: Ground Granulated Blast Furnace Slag.

In general, GGBFS has the following composition: CaO (30 to 50 percent), SiO_2 (28 to 38 percent, Al_2O_3 (eight to 24 percent), and MgO (one to 18 percent). Increasing CaO ratio also increases the basicity of the slag, which manifests into an increase in compressive strength (Ifran et al., 2018).

Slag Cement, or ground granulated blast-furnace slag (GGBFS) is a recovered byproduct of the iron manufacturing process and can be used to replace a portion of Portland Cement in concrete mix design. Commonly, it is found in ready-mixed concrete, precast concrete, masonry, soil cement and high temperature resistant building products (Slag Cement Association, 2020).

The use of slag cement has demonstrated long-term performance enhancements like higher compressive and flexural strengths, allowing designers to reduce the environmental footprint of concrete while ensuring improved performance and workability (Slag Cement Association, 2020).

In a technical report by Ueki entitled "History and Utilization of Portland Blast Furnace Slag Cement," he analyzed existing structures dating back to 1970 to evaluate the long-term reliability and stability of slag cement. Cements used in the research were manufactured during 1963–1964, each of which had their own slag ratios. These were normal Portland cement, PBFSC Type A (20 percent slag ratio), PBFSC Type B (50 percent slag ratio), low-heat PBFSC (50 percent slag ratio), and PBFSC Type C (65 percent slag ratio).

Several tests were conducted which evaluated the compressive strength of the concrete, with or without admixtures, and its pore size distribution. It was determined that there was a directly proportional relationship between the increase in the ratio of slag cement, the concrete's long-term compressive strength and in the increase in pore size distribution proportion which all point to reliable stability (Ueki, 2015).

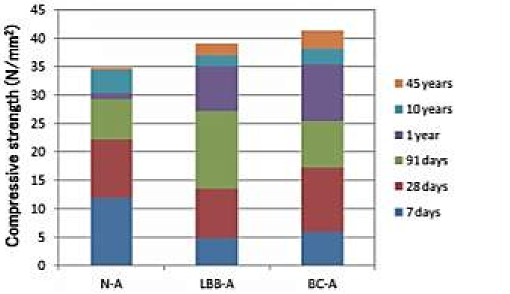


Figure 10. Compressive strength of AE concrete.
Source: History of Utilization of Portland Blast Furnace Slag Cement.

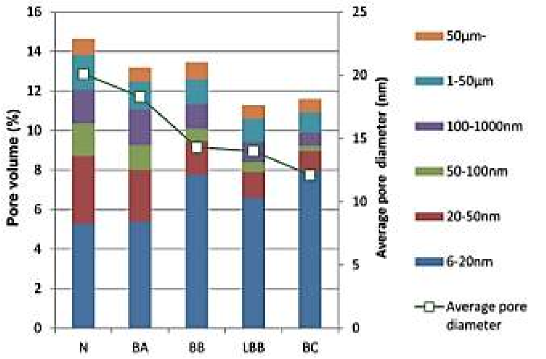


Figure 11. Pore size distribution.
Source: History of Utilization of Portland Blast Furnace Slag Cement.

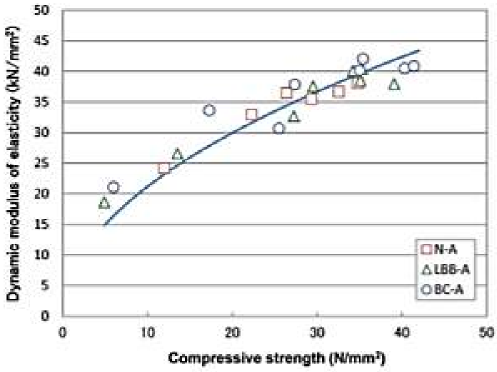


Figure 12. Relationship between dynamic modulus of elasticity and compressive strength.
Source: History of Utilization of Portland Blast Furnace Slag Cement.

Figure 12 shows the relation between compressive strength and dynamic elasticity modulus of AE concrete up to 45 years. With the increase in compressive strength, the dynamic elasticity modulus increased at the same time. It is considered that the dynamic elasticity modulus is not influenced by the presence or absence of slag and can obtain a stable concrete structure over a long period of time (Ueki, 2015).

An expanded study submitted to the University of Wisconsin—Madison Department of Civil and Environmental Engineering by LaBarca, Foley, & Cramer in 2007 entitled "Effects of Ground Granulated Blast Furnace Slag in Portland Cement Concrete" focuses on the use of slag cement as a replacement material for ordinary Portland cement (OPC).

This study aimed to determine variations in performance for grade 120 slag cement concrete using a range of materials common to Wisconsin highway pavement.

The performance of grade 120 slag cement concrete was generally comparable to OPC concrete in most cases. It was found, however, that variations in slag cement replacement level, coarse aggregate type, OPC brand, and mixing and curing conditions play a large role in the performance of hardened concrete (LaBarca et al., 2007).

It was found that the use of grade 120 slag cement did not have a significant effect on the tensile-compressive strength ratios compared to OPC concrete. Additionally, the effects of slag cement replacement on the actual split-tensile strength values were similar to the effects on compressive strength (LaBarca et al., 2007).

A study by Samad et al. in 2017 entitled "Strength development characteristics of concrete produced with blended cement using ground granulated blast furnace slag (GGBS) under various curing conditions" studied on the effect of partial replacement of cement with GGBS or slag cement on the strength development of concrete and cured under summer and winter curing environments. They selected three levels of cement substitution: 30 percent, 40 percent, and 50 percent.

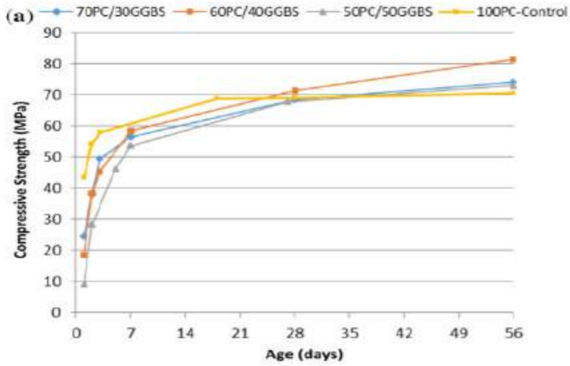


Figure 13. Compressive strength development of GGBS concrete under different curing condition 1.

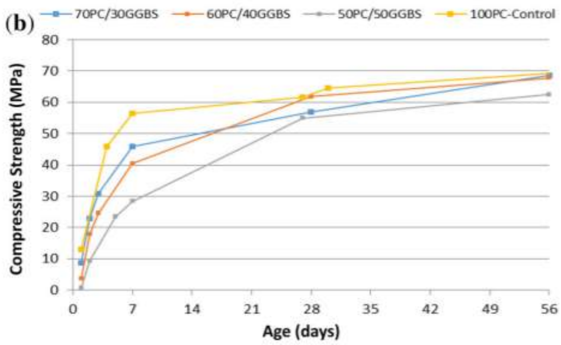


Figure 14. Compressive strength development of GGBS concrete under different curing conditions 2.

The strength development in blended concrete at the early ages decreased with the increase of GGBS content as compared to PC. There was a marked difference in strength gain between the compressive strength on the 3rd and 7th days; however, this difference was negligible at 28 days. This shows that initially the strength gain of GGBS concrete was slow but it enhanced rapidly between seven and 14 days. The specified strength of GGBS concrete at 28 days was more than 100 percent Portland cement mix, which supports its use for structural concrete and other major works (Samad et al., 2017).

It is concluded that the concrete containing 30 percent, 40 percent and 50 percent GGBS gains more strength than the PC concrete after the age of 28 days as seen in Figures 13 and 14 (Samad et al., 2017).

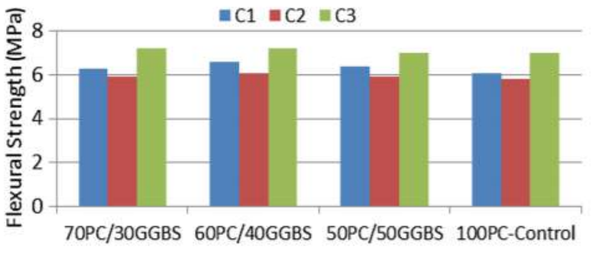


Figure 15. Flexural strength of GGBS concrete at the age of 28 days.
Source: Strength development characteristics of concrete produced with blended cement using ground granulated blast furnace slag (GGBS) under various curing conditions.

The flexural strength of the mixture also followed an increase as per the increase in compressive strength. It can be observed in Figure 15. The flexural strengths of the concrete mixes are designed equal at 28 days (Samad et al., 2017).

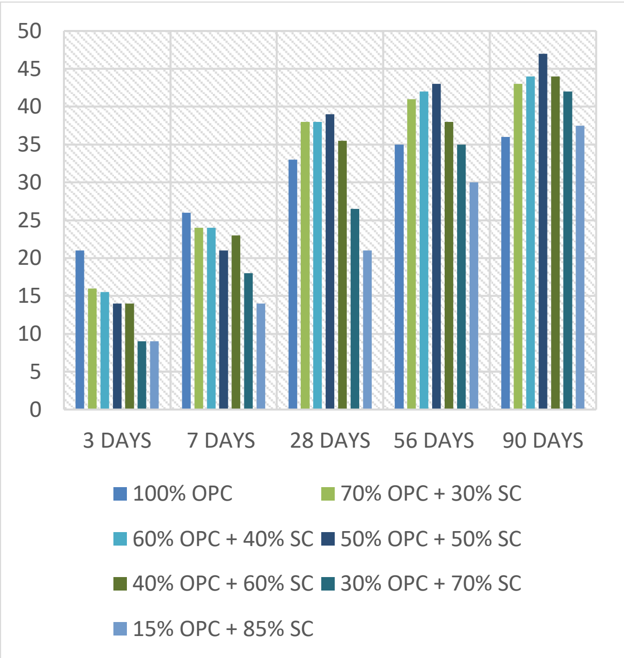


Figure 16. Effect of slag cement to the strength of OPC.

According to the Slag Cement Association in 2006, there is a principal advantage of using Slag cement for improved sustainability. They have developed suggested replacement levels according to its usage in accordance with the Leadership in Energy and Environmental Design (LEED) guidelines and standards. Table 6 shows the suggested Slag cement replacement percentage according to its application.

Generally, substitution at these high percentages can reduce cementitious requirements as Slag cement concrete may require less cementitious material to achieve ultimate strength. Thus, it reduces embodied energy and greenhouse gas emissions in concrete (i.e., the resource inputs and emissions outputs resulting from the manufacturing of concrete and its constituent materials (Slag Cement Association, 2006).

Table 6. Environmental Benefits Comparison of Slag cement and Fly Ash in 3000psi concrete.

Environmental Benefit (Substitution rate for Portland Cement)	Slag Cement (35%)	Slag Cement (50%)	Fly Ash (20%)
Carbon Dioxide Emissions Savings*	30%	43%	17%
Energy Savings	21%	30%	14%
Reduction in Extracted Materials	5%	7%	3%

Source: Slag Cement Association Manual: Slag Cement and the Environment.

Note: Percentages listed for savings in Carbon dioxide, energy and material are based on 100 percent Portland cement systems compared with systems containing Slag cement or Fly Ash substitution.

Table 7. Suggested Slag Cement Replacement Levels.

LEED-NC 2.1 Guide: Using Slag Cement in Sustainable Construction	
Concrete Application	Slag Cement*
Concrete Paving	25-50%
Exterior flatwork not exposed to deicer salts	25-50%
Exterior flatwork exposed to deicer salts with w/cm ≤	25-50%
Interior flatwork	25-50%
Basement floors	25-50%
Footings	30-65%
Walls and columns	25-50%
Tilt-up panels	25-50%
Prestressed concrete	20-50%
Precast concrete	20-50%
Concrete blocks	20-50%
Concrete Pavers	20-50%
High strength concrete	25-50%
Alkali-silica reaction mitigation	25-70%

Sulfate resistance	
• Type II Equivalence	25-50%
• Type V Equivalence	50-65%
Low permeability	25-65%
Mass concrete (heat mitigation)	50-80%

Source: Slag Cement Association Manual: Slag Cement and LEED.

Slag cement has been used in concrete projects in the United States for over a century. Earlier usage of slag cement in Europe demonstrated that long-term performance was enhanced in many ways. Based on these early experiences, modern designers have found that these improved durability characteristics help further reduce life-cycle costs and lower maintenance costs (Slag Cement Association, 2013).

Using slag cement to replace a portion of Portland cement in a concrete mixture is a useful method to make concrete better and more consistent. Among the measurable improvements are:

- Better concrete workability
- Easier finishability
- Higher compressive and flexural strengths
- Lower permeability
- Improved resistance to aggressive chemicals
- More consistent plastic and hardened properties
- Lighter color

III. Methodology

The main objective of the research is to check on the maximum proportion of the Slag cement as partial replacement to OPC in concrete.

The researcher adapted an experimental design as the study would focus on testing different mix proportions of slag cement versus the OPC in concrete. Upon gathering related literature of this study, the researcher devised an approach to determine the materials needed and its specification.

1. Gathering of different test results data relative to the study of slag cement.
2. Field instrumentations, experiments and laboratory testing of different mix proportions used in the design of concrete.
3. Testing of different mix proportions used in the design of concrete following the procedures in accordance with the American Society for Testing Materials (ASTM), and other guidelines of the Department of Public Works and Highways (DPWH).
4. Analysis and synthesis of both the physical and chemical properties gathered and other tested technical data.
5. Simulation and comparison of concrete engineering design parameters via Slag cement combination to ordinary Portland cement.

The results of both the physical and chemical tests that will be derived from the laboratory and instrumentation testing procedures as outlined and other available technical data will be subjected to statistical evaluation, synthesis and analysis. Moreover, concrete engineering design parameters via slag cement combination to ordinary Portland cement will be simulated and analytically compared.

Table 8. Different mix proportions used in the design of concrete.

Materials	PURE Type 1 Cement	70% Type 1 OPC 30% SC	60% Type 1 OPC 40% SC	50% Type 1 OPC 50% SC
Pure Type 1 OPC	300	210	180	150
Slag Cement		90	120	150
G-1 Agg.	595	595	595	595
3/4" Agg.	396	396	396	396
Vibro Sand	843	838	836	835
Water	180	180	180	180
Naptha Admix	3.0	3.0	3.0	3.0

Note: Concrete mix designs may vary depending on the quality of aggregates and admixtures in the area.

Table 9. At constant water-cement ratio, slump of concrete mixture with SC is higher vs. that of pure Type 1 OPC.

Slump	Pure Type I OPC	70% OPC + 30% SC	60% OPC + 40% SC	50% OPC + 50% SC
Slump initial (mm)	135	195	195	190
Slump 60 mins (mm)	65	95	110	110
Density (kg/cm³)	2322	2337	2324	2337

Note: Concrete using SC has lower water demand as it achieved higher slump and better slump retention vs. pure OPC.

IV. Results and Analysis

Slump Retention Analysis
300 kg Binder Factor
Compressive Strength Design

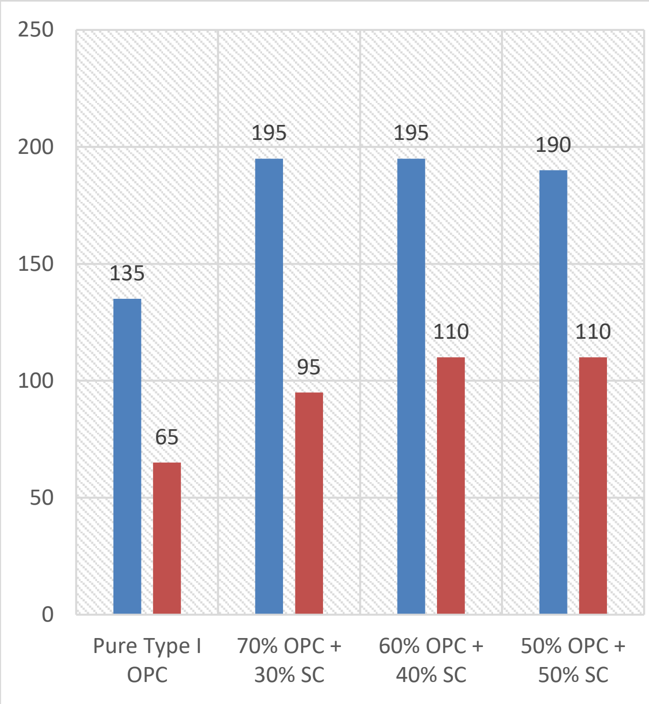


Figure 17. Slump retention analysis for 300 kg binder factor

Table 10. Actual photos of slump of different concrete designs

Table 11. A difference of 1000 psi or equivalent of 1 bag (40 kg) savings per cubic meter (m³) is realized if you replace your cement requirement by 40–50 percent SC.

Days (psi)	Island Cement	Island Cement with 30% SC	Island Cement with 40% SC	Island Cement with 50% SC
3 days (psi)	3363	2564	2387	2263
7 days (psi)	3877	3558	3150	2999
14 days (psi)	4064	4809	4907	4853
28 days (psi)	4987	5341	5838	5812

OPC Type I vs. OPC Type with different SC replacement
300 kg Binder Factor
Compressive Strength Design

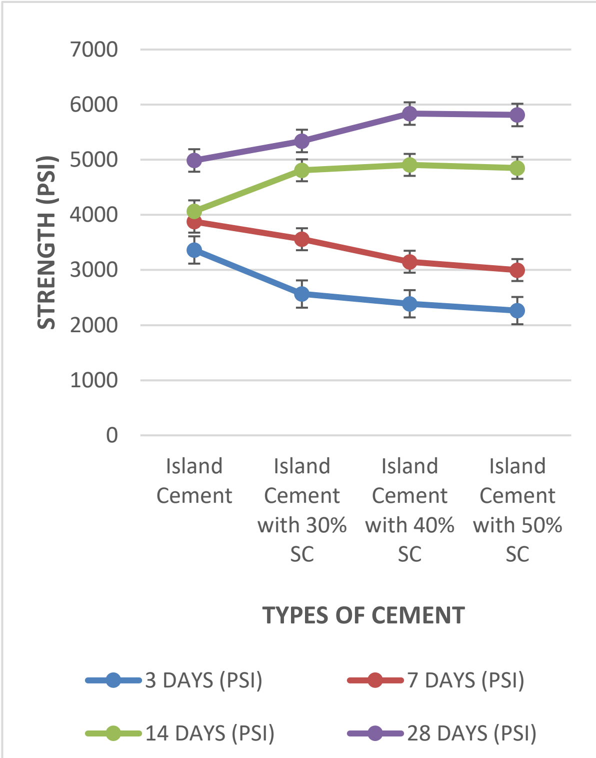


Figure 18. Compressive strength chart for 300 kg binder factor.

Table 12. Different mix proportions used in the design of concrete.

Materials	Pure Type I OPC	70% Type I OPC 30% SC	60% Type I OPC 40% SC	50% Type I OPC 50% SC
Pure Type 1 OPC	**400**	**280**	**240**	**200**
Slag Cement		**120**	**160**	**200**
G-1 Agg.	**595**	**595**	**595**	**595**
3/4" Agg.	**396**	**396**	**396**	**396**
Vibro Sand	**733**	**726**	**724**	**722**
Water	**190**	**190**	**190**	**190**
Naptha Admix	**4.7**	**4.7**	**4.7**	**4.7**

Note: Concrete mix designs may vary depending on the quality of aggregate and admixtures in the area.

Table 13. Higher slump, higher slump retention at constant water-cement ratio is observed in mixture with SC vs. Pure Type I OPC.

Slump/ Density	Pure Type I OPC	70% OPC + 30% SC	60% OPC + 40% SC	50% OPC + 50% SC
Slump initial (mm)	200	210	230	240
Slump 60 mins (mm)	140	150	180	195
Density (kg/cm^3)	2379	2385	2377	2371

Slump Retention Analysis
400 kg Binder Factor
Compressive Strength Design

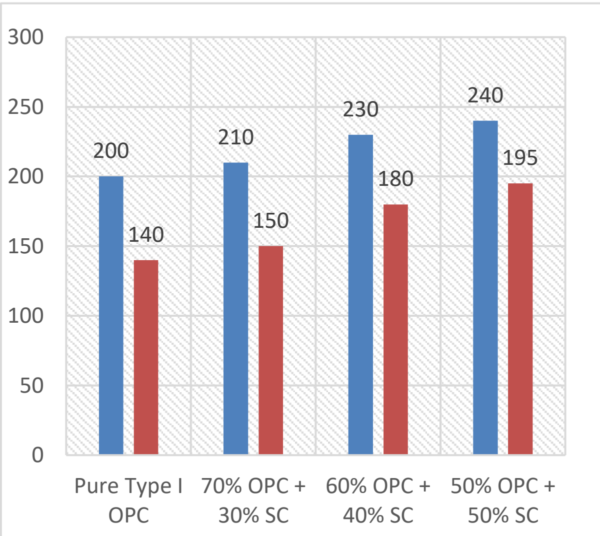


Figure 19. Slump retention analysis for 400 kg binder factor.

Table 14. Actual photos of slump.

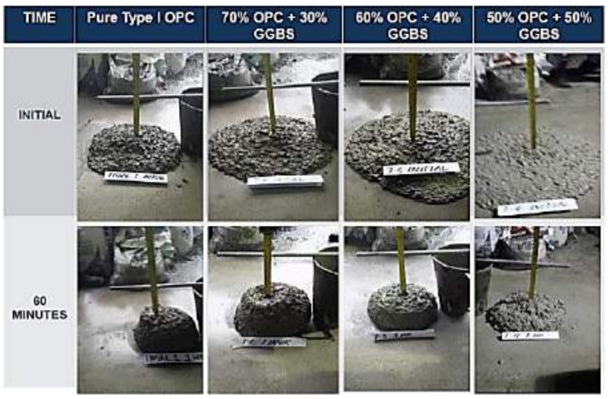


Table 15. Higher compressive strength of mixture with SC – savings of around 1 bag per cubic meter (m^3) at a replacement of 40–50 percent.

Days (Strength)	Pure Type 1 OPC	70% OPC + 30% SC	60% OPC + 40% SC	50% OPC + 50% SC
3 days (psi)	5022	4765	4481	3673
7 days (psi)	5492	5812	5767	5794
14 days (psi)	6167	7515	7666	7045
28 days (psi)	7036	8039	8323	8367

OPC Type I vs. OPC Type with different SC replacement
400 kg Binder Factor
Compressive Strength Design

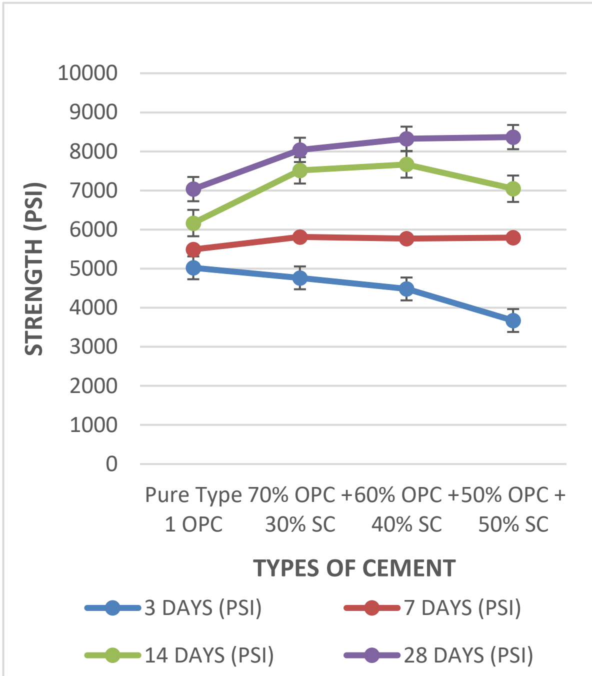


Figure 20. Compressive strength chart for 400 kg binder factor.

Table 16. Concrete mix designs.

Materials	Pure Type I OPC	70% Type I OPC 30% SC	60% Type I OPC 40% SC	50% Type I OPC 50% SC
Pure Type 1 OPC	480	336	288	240
Slag Cement		144	192	240
G-1 Agg.	595	595	595	595
3/4" Agg.	396	396	396	396
Vibro Sand	666	641	638	652
Water	190	190	190	190
Naptha Admix	6.6	6.6	6.6	6.6

Note: Concrete mix designs may vary depending on the quality of aggregates and admixtures in the area.

Table 17. Higher slump, higher slump retention at constant water-cement ratio is observed in mixture with SC vs. Pure OPC.

Slump/ Density	Pure Type I OPC	70% OPC + 30% SC	60% OPC + 40% SC	50% OPC + 50% SC
Slump initial (mm)	240	250	260	270
Slump 60 mins (mm)	220	230	235	240
Density (kg/cm³)	2379	2382	2416	2422

Slump Retention Analysis
480-kg Binder Factor
Compressive Strength Design

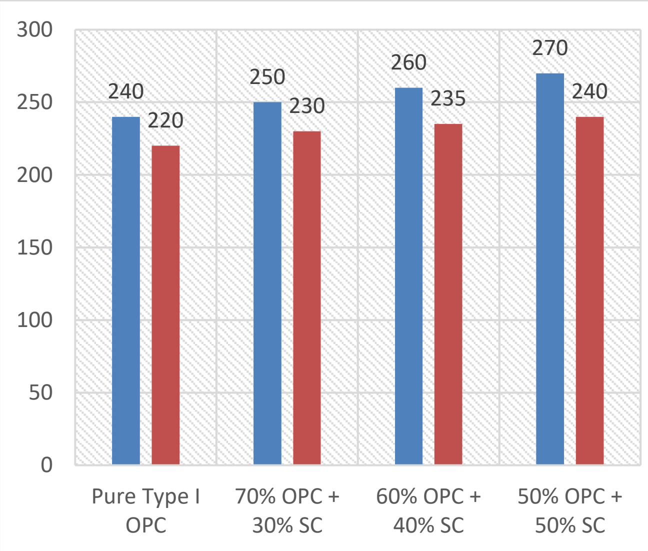


Figure 21. Slump retention analysis for 480 kg binder factor.

Table 18. Higher compressive strength of mixture with SC -- savings of around 1 bag per cubic meter (m³) at a replacement of 40–50 percent.

Days (Strength)	Pure Type 1 OPC	70% OPC + 30% SC	60% OPC + 40% SC	50% OPC + 50% SC
3 days (psi)	5599	6273	6495	6468
7 days (psi)	5876	6548	6832	7249
14 days (psi)	7586	7852	8749	8793
28 days (psi)	8474	8562	9370	9512

SC Type 1 vs. OPC Type 1 with Different PSP Replacement
480-kg Binder Factor
Compressive Strength Design

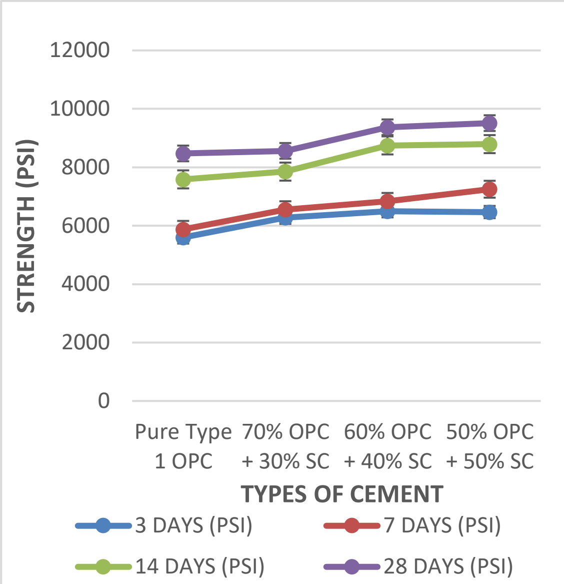


Figure 22. Compressive strength chart for 480 kg binder factor

Table 19. Flexural designs using SC at different replacement

MATERIALS	PURE TYPE 1 OPC	70% TYPE 1 OPC 30% SC	60% TYPE 1 OPC 40% SC	50% TYPE 1 OPC 50% SC
Pure Type 1 OPC	364	255	218	182
Slag Cement		109	146	182
G-1 Agg.	722	722	722	722
3/4" Agg.	152	152	152	152
Vibro Sand	778	772	770	768
Water	175	175	175	175
Naptha Admix	2.9	2.9	2.9	2.9

Note: Concrete mix designs may vary depending on the quality of aggregates & admixtures in the area.

Table 20. Higher slump, higher slump retention at constant water-cement ratio is also observed on mixture with SC vs. pure OPC in flexural designs

Slump	Pure Type 1 OPC	70% OPC + 30% SC	60% OPC + 40% SC	50% OPC + 50% SC
Slump initial (mm)	125	130	140	150
Slump 60 mins (mm)	80	95	105	115

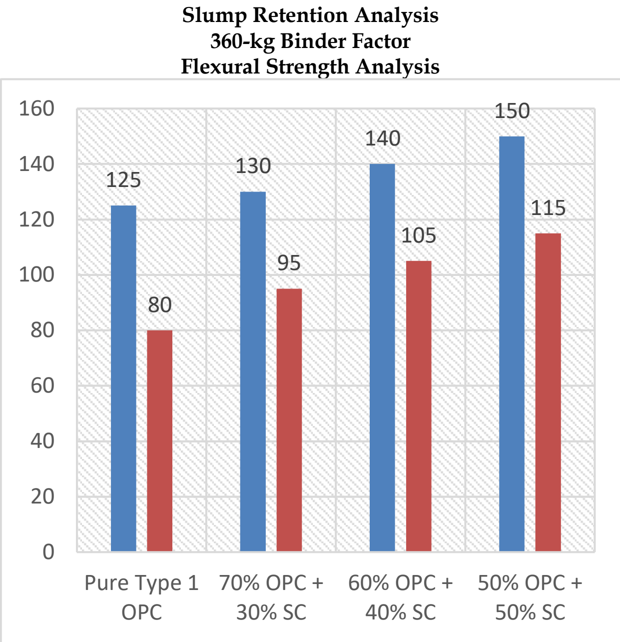


Figure 23. Slump retention analysis for 360 kg binder factor

Table 21. Same early strength observed on mixtures having 30–40 percent SC replacement to the flexural strength of concrete

	Pure Type 1 OPC	70% OPC + 30% SC	60% OPC + 40% SC	50% OPC + 50% SC
3 days (psi)	657	675	657	533
7 days (psi)	763	710	692	710
14 days (psi)	799	834	799	817

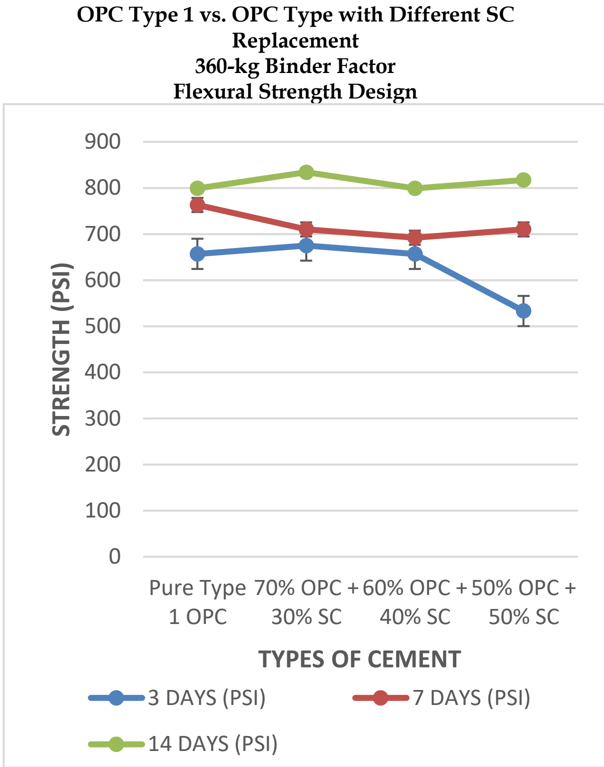


Figure 24. Compressive strength chart for 360 kg binder factor.

Table 8 shows the different mix proportions of Type 1 ordinary Portland cement and slag cement used in this study for the design of concrete for 300 kg. binder factor. Moreover, Tables 9 and 10 and Figure 17 show that the slump of concrete increases with increasing percentage of slag cement for the 300 kg binder factor. In addition, Table 11 and Figure 18 show that for the same binder factor, the compressive strength of concrete also increases as the slag replacement increases. The same trends are also shown for the following binder factors: 400 kg (Tables 12 to 15 and Figures 19 and 20); 480 binder factors (Tables 16 to 18 and Figures 21 and 22); and 360 kg (Tables 19 to 21 and Figures 23 and 24).

All technical data exhibited in the aforementioned table and figures can be utilized in calculating and estimating other engineering parameters that are very useful and material in the course of concrete mix design and other related concrete proportioning of elemental components in structural design.

The results show that the workability of concrete improves in the presence of slag cement.

The research was analyzed comparing the other mixture to that of the properties of Type 1 ordinary Portland cement. Results show that certain percentages of slag cement in the mixture has effects to the concrete's slump retention and compressive strength with regards to the binder factor. Hence, the workability of concrete with the presence of slag cement was observed.

For the slump retention analysis, as seen in Figures 17, 19, 21, and 23, concrete using slag cement has lower water demand as it achieved higher slump and better slump retention than that of the Type 1 ordinary Portland cement.

As for strength of concrete, as seen in Figures 18, 20, 22, and 24, it can also be seen that the strength improves as slag cement replacement approaches 50 percent. There is a difference of almost 1,000 psi or an equivalent of 1 bag per cubic meter (m^3) savings is realized at 50 percent slag cement replacement. The same pattern is observed on both compressive and flexural designs.

V. Conclusion and Recommendations

Based on the analysis of results, an optimum replacement of 50 percent is hereby recommended for compressive strength designs. On the other hand, for flexural designs, an optimum replacement of 30 percent slag cement is hereby recommended as the study shows no significant change observed in the flexural strength versus that of pure Type 1 ordinary Portland cement at early days. However, if 14 days is the basis of acceptance, 50 percent slag cement replacement is recommended. In addition, slag cement has a specific gravity slightly lower than Portland cement; therefore, slight changes also in the design should be implemented. Further noted that the cost benefit of a 50 percent slag replacement shows a savings of ½—one bag cement factor per cubic meter of concrete. However, for those designers, architects, engineers, contractors, and possible customers who are familiar in the design using fly ash, the same approach shall be done also to avoid under yield/over yield of the actual concrete mixture.

Further studies are recommended for the same design mix proportions with other available admixtures in the market focusing on the same factor and designs involving 10,000 psi and powder-type self-compacting designs using different slag cement replacement. It is also recommended to study on the understanding of the effect of slag cement versus a different fly-ash replacement vis-*à*-vis a combination of slag cement and fly-ash in design mix and to consider a detailed economic study of the cost benefit analysis of the said products and design mix.

VI. Acknowledgments

The author/researcher would like to thank Engr. Renz Marion S. Ontimare for his assistance in the conduct of both the chemical and physical tests, Engineer Marge Rea Erma C. Gonzaga, and Architect Jeanette P. Malizon for their help and untiring assistance in the preparation of the manuscript.

VII. References

ACI Committe 318. (2005). *Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05).* American Concrete Institute.

ACI Committee 211. (1991). 211.1-91: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (Reapproved 2002). 38. American Concrete Institute. Retrieved 2018, from https://pdfs.semanticscholar.org

Al-Chaar, G. K., Alkadi, M., & Asteris, P. G. (2013). Natural Pozzolan as a partial substitute for cement in concrete. *The Open Construction and Building Technology Journal*, *7*, 33–42. Retrieved June 2018, from https://www.researchgate.net/publication/270101034_Natural_Pozzolan_as_a_Partial_Substitute_for_Cement_in_Concrete

American Association of State Highway and Transportation Official. (2018). *AASHTO M85: Standard Specification for Portland Cement.* AASHTO.

American Society for Testing and Materials. (2018). *ASTM C150: Standard Specification for Portland Cement.* West Conshohocken: ASTM International.

American Society for Testing and Materials. (2018). *ASTM C33/C33M-18: Standard Specification for Concrete Aggregates.* West Conshohocken: ASTM International.

Association of Structural Engineers of the Philippines, Inc. (2015). *National Structural Code of the Philippines* (7th ed., Vol. 1: Buildings, Towers, and other Vertical Structures).ASEP

Brown, R. W. (2001). *Practical Foundation Engineering Handbook, 2nd edition.* Retrieved June 2018, from Access Engineering Library: https://www.accessengineeringlibrary.com/content/book/9780071351393/chapter/chapter5

Department of Public Works and Highways (DPWH). (2004). *DPWH: Standard Specifications for Public Works & Highways (Volume 2: Standard Specifications for Highways, Bridges and Airports).* DPWH.

Department of Public Works and Highways. (2016). *Department Order No. 133 , Series of 2016 : Amendments to DPWH Standard Specifications for Item 311 - Portland Cement Concrete Pavement.* Manila: DPWH.

Federal Highway Administration. (1995, March). NHI Course No. 13119: Portland Cement Concrete Materials. FHWA.

Federal Highway Administration. (1995). NHI Course No. 13119: Portland Cement Concrete Materials. FHWA. Retrieved 2018, from https://www.fhwa.dot.gov

Ifran, M., Chen, Y., Ali, M., Abrar, M., Qadri, A., & Bhutta, O. (2018). Geotechnical properties of effluent-contaminated cohesive soils and their stabilization using industrial by-products. *Fluid Flow in Fractured Porous Media, 6*(10), 203. https://doi.org/10.3390/pr6100203

Júnior, E. J., Bezerra, H.D., Politi, F. S., & Paiva, A. E. (2014, April 13). Increasing the compressive strength of Portland cement concrete using flat glass powder. (17). Sao Luis, Brazil: Materials Research. Retrieved June 2018, from http://www.scielo.br/pdf/mr/v17s1/aop_matres_218013.pdf

Kamran, N. (2015). Proportioning Concrete Mixes. (U. of. Washington, Ed.) Retrieved June 2018, from https://www.scribd.com/document/404219216/mix-pdf

LaBarca, I. K., Foley, R. D., & Cramer, S. M. (2007). *Effects of ground granulated blast furnace slag in Portland Cement Concrete (PCC) - expanded study.* Wisconsin Highway Research Program. https://minds.wisconsin.edu/handle/1793/53318

Luke S. Lee, P. P., & Hector Estrada, P. P. (2020). *Materials for civil engineering: Properties and applications in infrastructure.* McGrawHill Education. Retrieved May 2020, from Access Engineering Library.

Marques, M. L., Luzardo, F. H., Velasco, F. G., González, L. N., Silva, E. J., & Lima, W. G. (2016, April 4). Compatibility of vegetable fibers with Portland cement and its relationship with the physical properties. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *20*(5), 466-472. Retrieved from http://www.agriambi.com.br

McCormac, J. C. (2001). *Design of reinforced concrete* (5th edition ed.). John Wiley & Sons.

McGraw-Hill Companies, Inc. (2003). Concrete. (10th edition). McGraw-Hill Encyclopedia of Science and Technology.

Rebelo, J. (2014). *Evaluation of test methods for determining the water to cement ratio of fresh and hardened concrete* [Masteral thesis, University of Toronto], Library of Toronto. Retrieved June 2018, https://tspace.library.utoronto.ca/bitstream/1807/65599/1/Rebelo_Jonathan_201406_MASc_thesis.pdf

Samad, S., Shah, A., & Limbachiya, M. (2017). Strength development characteristics of concrete produced with blended cement using ground granulated blast furnace slag (GGBS) under various curing conditions. *Sadhana*, 42(7), 1–11. https://doi.org/10.1007/s12046-017-0667-z

SEAONC Construction Quality Assurance Committee. (2013). *Guidelines for reviewing concrete mix designs.* SE University.

Siddique, R., & Khan, M. I. (2011, March). Ground granulated blast furnace slag. *Waste Materials and By-Products in Concrete*, *163*(2), 121–173.

Slag Cement Association. (2006). *Slag cement and LEED*. Retrieved June 2018, from https://www.slagcement.org/aboutslagcement/is-28.aspx

Slag Cement Association. (2013). *Slag cement*. Retrieved June 2018, from https://www.slagcement.org/aboutslagcement/is-01.aspx

Uddin, M. A., Jameel, M., Sobuz, H. R., Islam, M. S., & Hasan, N. M. (2012, August 19). Experimental study on strength gaining characteristics of concrete using Portland composite cement. *KSCE Journal of Civil Engineering, 17*(4), 1–8.

Uddin, M. A., Jameel, M., Sobuz, H. R., Islam, M. S., & Hasan, N. M. (2012, August 19). Experimental Study on Strength Gaining Characteristics of Concrete using Portland Composite Cement. *17*(4).https://doi.org/10.1007/s12205-013-0236-x

Ueki, Y. (2015). *History and utilization of Portland blast furnace slag cement* (Nippon Steel & Sumitomo Metal Technical Report No. 109). Nippon Steel and Sumitomo. https://www.nipponsteel.com/en/tech/report/nssmc/pdf/109-19.pdf

Wang, C.-K., Salmon, C. G., & Pincheira, J. A. (2010). *Reinforced concrete design* (7th edition ed.). John Wiley & Sons Inc.

Developing an Automated Philippine National Building Code Compliance Check for R-1 Projects in BIM Using Visual Programming[1]

Karen Therese F. Lopez [1]
arch.ktlopez@gmail.com

Ronald S. Balane [2]
rsbalane1@up.edu.ph

Abstract

The construction industry is inefficient and has plenty of communication and coordination issues that can lead to an increase of 20–25 percent on project delivery costs (Allen & Shakantu, 2016). The design process is tedious and filled with revisions. The issue of code compliance amidst these changes and revisions further complicates the process. Code compliance checking can be cumbersome. This is mainly because most designers check 2D text and documents manually, which is very error-prone. Building Information Modeling or BIM is a 3D parametric-based methodology that is now being used by around a third of the construction industry in the Philippines (ASEP, 2013). It is strongly being used by other countries and has a high adoption rate worldwide (Kalfa, 2018). Programming and visual programming further enhances the capability of BIM to automate tasks and manipulate data. This can be used to create an actual automated code compliance check tool to address issues of compliance with building standards. The purpose of this study was to create an automated code compliance checker of the National Building Code of the Philippines for R-1 projects. The results for the automated code check were then compared with the results of the manual code check of the 2D documents of the projects, to evaluate if the developed automated code compliance checker was accurate, efficient, and feasible. The results showed that the percentage discrepancies between the two forms of code checks did not exceed 6 percent, most of which were from human modeling errors. Moreover, the automated code check took approximately five minutes per project compared to the manual code check that took approximately one hour. The developed automated code compliance checker is usable at its current state and it has potential for improvement in the future.

Keywords: BIM, Visual Programming, Compliance Check, Building Code, Automated.

[1] Karen Therese F. Lopez is a licensed architect who co-founded Arkalo, an architectural firm. She took her Master of Architecture degree in the UP Diliman, where she is currently a faculty member. Ms. Lopez's expertise is in BIM and other architectural software.

[2] Ronald S. Balane has an MA in Urban and Regional Planning and a BS in Architecture from the UP Diliman. He is currently an Assistant Professor and is a registered and licensed Architect. His research interests include new building materials and use of computers in architecture.

I. Introduction

The construction industry is one of the most inefficient sectors worldwide. It is filled with problems that are caused by communication and coordination issues (Allen & Shakantu, 2016). This is also apparent in the Philippines, where delays and issues plague the sector.

Code compliance is one of the problems in the country. It is important because it ensures that a building is stable, reliable, and usable. Unfortunately, many designers and owners disregard the code because of its inconvenience both in the implementation and the tedious process of manually checking the code (Preidel & Borrmann, 2016).

Code compliance checking is the process of checking if a building design conforms with the standards and codes that the building is subjected to. Designers and inspectors usually do this by manually checking 2D technical and textual documents and comparing them with the numerous standards and codes written in text (Preidel & Borrmann, 2016). Many codes can be subject to misinterpretation. In addition, there are plenty of codes that conflict with one another, making the process not only tedious but cumbersome and error-prone (Kim et al., 2011).

A survey by the International Code Council and National Association of Home Builders found that more residential buildings have code violations than commercial buildings. (International Code Council and National Association of Home Builders, 2013). Of note, most approved building

[1] This article is a summary of a graduate thesis for Master of Architecture completed in June 2020, A.Y. 2019–2020 under faculty adviser, Prof. Ronald S. Balane from the Building Science Studio Lab.

permits in the Philippines are that of residential projects (Philippine Statistics Authority, 2018).

Building Information Modeling or BIM is a 3D based methodology of producing Architectural, Engineering, and other Construction professional's drawing and output (Matejka & Tomek, 2016). There are several software programs available that are considered BIM tools like Autodesk Revit and Graphisoft ArchiCAD. Architecture, Engineering, and Construction or AEC professionals are already utilizing BIM for their construction projects. Some claim BIM as the solution for the construction industry's woes since it eases the process of the workflow and improves communication and visualization in projects (Allen & Shakantu, 2016). BIM makes data readily available, which helps in the coordination of design and construction issues as well as in the actual work. This is because it allows the use of standard components, which saves time and makes production more efficient (Dowsett & Harty, n.d.; Kuehmeier, 2008; Reizgeviˇcius et al., 2018). However, available BIM software also has numerous limitations which can be bypassed by support software or add-ins, like visual programming.

Visual programming is a process wherein a user may develop programs with tools, buttons, or nodes on screen that may be connected like a flow chart, which displays logical paths and associated code blocks. It functions the same way as a text-based programming or coding but is easier to understand and is more suitable for designers, architects, and engineers. Visual programming offers a lot of opportunities for the AEC. It can automate repetitive tasks, maneuver data, give access to parametric design and more complex 3D, and can even test performances (Santos, 2015; Anderle & Allen, 2017).

With the available technological tools in the AEC industry like BIM and visual programming, there is a possibility of having an actual automated code compliance checker that is convenient, flexible, and feasible.

II. Methodology

Ample research was done to study how to use visual programming in BIM. Studying the National Building Code of the Philippines was also necessary to be able to create an automation that is accurate.

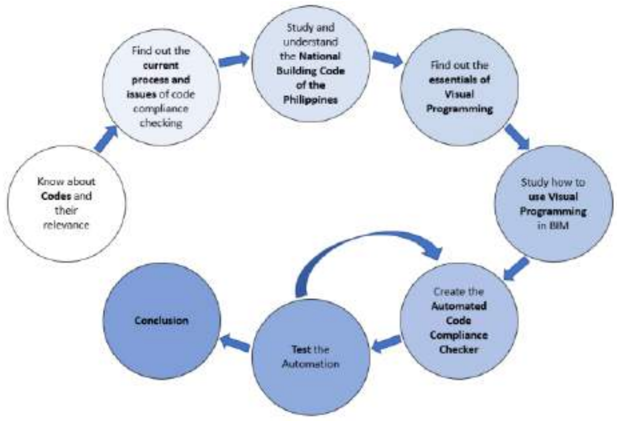


Figure 1. General Methodology.

The types of codes from the National Building Code for R-1 projects were compiled and organized. The codes were separated per element in accordance with the elements available in Revit.

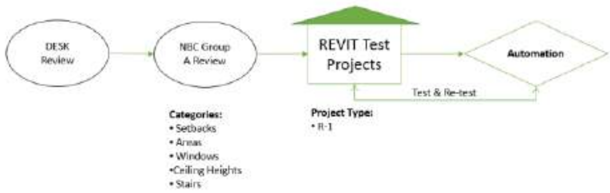


Figure 2. Categories for Automation.

The automation was filled with modeling and experimental studies because of the necessity of creating multiple BIM models for the testing and creation of the automated code checker.

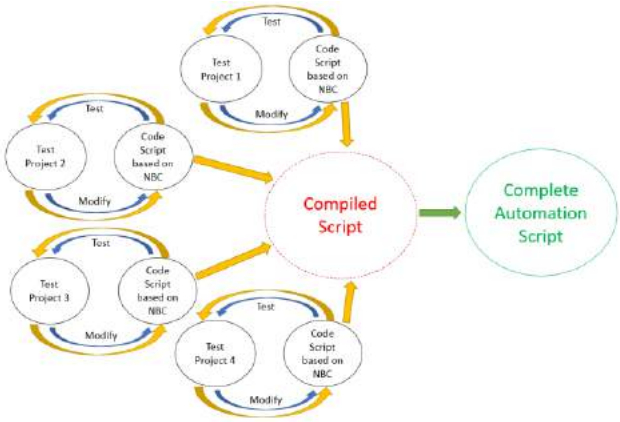


Figure 3. Automation Methodology.

Five actual approved R-1 projects were gathered to be used for the testing of the research. A reliable practicing senior design consultant was asked to manually check the 2D documents of those five projects. While the 3D model of those five projects were used to test the developed automated code compliance checker. The results for the automated code check were then compared with the results of the manual code check.

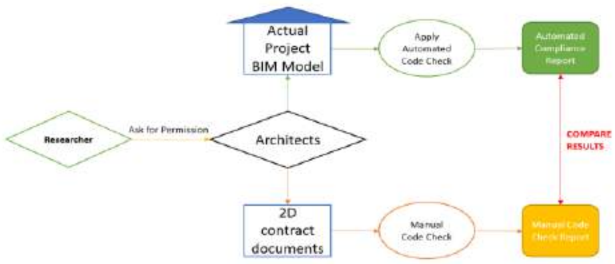


Figure 4. Testing Methodology.

This final test was used to see if the automation was useful, convenient, accurate, and flexible.

III. Gathered Data

A. Codes, Compliance, Permitting, and Revisions

Codes are a necessity because it ensures the safety and functionality of a structure. This is especially important for disaster prone countries since many damages on structures occur because of non-compliance to the code (Cox et al., 2006).

Given the changing times, construction practices, and requirements, codes should be frequently changing. However, most developing countries neglect the code leading to outdated rules and regulations.

Codes are also often confusing and conflict with other codes which could lead to misinterpretations that lead to rework and double handling. The National Building Code of the Philippines and other codes in the country like the Fire Code are not exempted from this issue. Codes should not only be harmonized and consistent with one another, they should also be simplified and easy to understand.

Compliance to the code is legally required. Unfortunately, in the Philippines, compliance is rather low because of the lack of budget and overworked building officials and inspectors. This is also the reason for the lack of code enforcement in the country. Plenty of times, compliance becomes reactive rather than proactive (Cuntapay, 2009).

To check compliance, most designers manually check their drawings and cross check those with all the codes their projects are subjected to. Some would opt to check the code before and after planning. It is also recommended that the designers know the code well so that they will avoid design choices that could go against the code requirement in the process of designing or planning their projects. Designers should also coordinate with the local government unit to make sure they abide by all local laws and special requirements.

The process of permitting in the Philippines is quite simple but it can become complicated depending on the building official or the handler. Some local government units also require different things so requirements can differ per city. Moreover, corruption is known to plague the process. Ideally, codes must be updated and coordinated with other approving bodies to negate confusion and to have consistency.

Construction projects with approved building permits in the country are mostly residential buildings. Residential buildings also have more code violations than commercial buildings (International Code Council and National Association of Home Builders, 2013).

Projects always go through revisions because of the many factors and issues in planning and design. Changes could occur not only because of code compliance but also because of other factors like value engineering or site adaptation. Most of the revisions in projects involve walls. Walls always change and even the slightest movement in walls affect other elements in a building like the room areas and ceilings. Any revision made could mean rechecking drawings to check if it is still compliant or not which can be tedious and time consuming.

B. Technology

The technological hardware and software were very essential for this study since it highly utilized computers. The study primarily used an Intel Core i7 at 3.4 GHz desktop with 16.0 GB RAM and a Windows 10 operating system. A laptop with Intel Core i5 at 1.00 GHz with 12.0 GB RAM and a Windows 10 operating system was also used occasionally. Both computer systems can create and run the automation with no problems.
BIM is a 3D based methodology of producing drawings and plans for the AEC. It has plenty of advantages because it is parametric and automated. This is likely the reason why there is a large increase in BIM usage rate worldwide. The table below shows some of the advantages and disadvantages of BIM.

Table 1. BIM Advantages and Disadvantages.

Advantages	Disadvantages
Increased efficiency	Licenses and equipment required are expensive
Reduced errors and rework	Takes time to train people and to implement
Reduced manpower	It is hard to shift to BIM especially for the older generation
Better presentation and clearer design	Return of Investment takes time
Better coordination	Dependence on user expertise

The study made use of Autodesk Revit Architecture. Revit is one of the most used BIM software as seen in the table.

Table 2. BIM Software Usage.

BIM Software	User Percentage
Revit BIM	67.08
ArchiCAD	31.69
Bentley BIM	14.79
Other	20
Tekla Structures	5.99
Digital Project	4.05
Nemetschek AllPlan	2.29

Adapted from: 'Review of BIM Software Packages Based on Assets Management,' by Kia, 2013, Retrieved from https://www.researchgate.net/publication/253058808_Review_of_Building_Information_Modeling_BIM_Software_Packages_Based_on_Assets_Management.

The version used for the study initially was Revit 2019. The research then shifted to Revit 2020. The shift was seamless with just a few edits in the automation script. There were no issues or problems that occurred.

Visual programming is a means for visual professionals like architects, designers, and engineers to write computer code even without profound knowledge on programming. Most visual programming tools are free and accessible. With visual programming, the manipulation of data within BIM to be able to apply a set of rules and be automated becomes possible. Tedious tasks like renumbering and creating sheets becomes easy and efficient to do.

The Visual Programming tool that was used for the study was Dynamo which is compatible with Revit. It is already included in Revit 2017 and above as an add-in which can be seen in Revit's ribbon panel in the Manage tab. It is free to use and can easily be downloaded on its website, dynamobim.org.

Figure 5. Dynamo.

Dynamo packages were also downloaded for the study. These are also free and can easily be downloaded in dynamopackages.com.

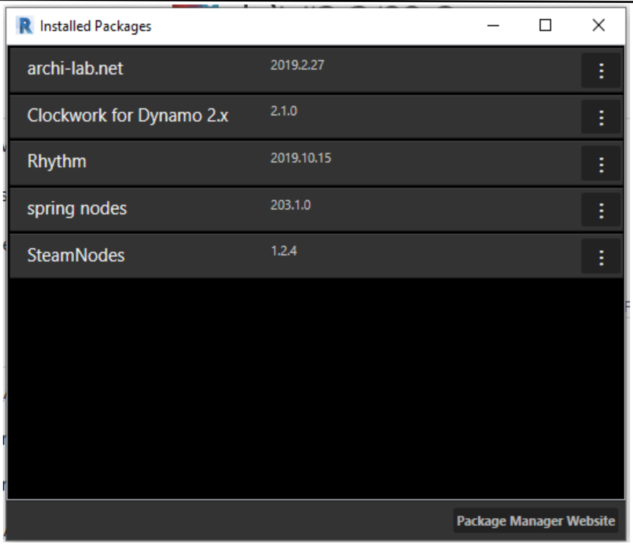


Figure 6. Dynamo Packages.

The initial version used for the study was Dynamo 2.0.1 but when the research shifted to Revit 2020, the Dynamo version was also updated to Dynamo 2.1.0. The only change that had to be done when the shift happened was the update of the selection nodes in the script.

C. R-1 Projects

The researcher gathered five actual projects that have approved building permits and are already built. All of them are R-1 single detached residential structures that are at the mid to high end range of construction. They are all quite different which is good for the automated code check test since different issues could arise from different kinds of setups. These projects were used for the testing of the automated R-1 building code compliance check.

All the necessary 2D construction documents were also provided by the five architects of the five projects. These are the documents that were approved by a building official. The specific documents that were sent were the Site Development Plan, Floor Plans, Elevations, Sections, Reflected Ceiling Plans, and the Window Schedules.

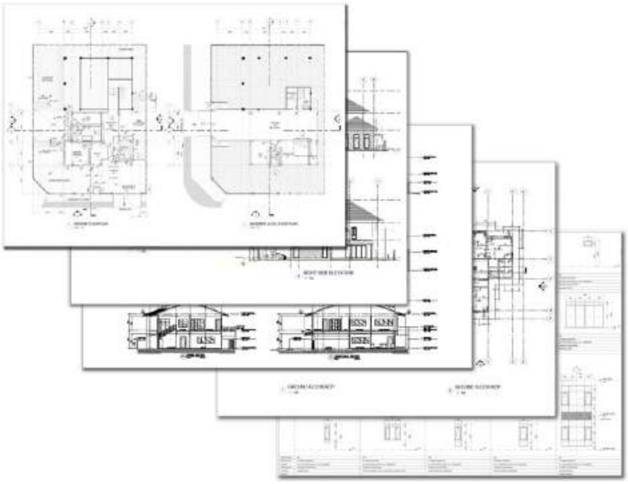


Figure 7. 2D Documents.

All of the projects were produced in BIM but only two of the five used Revit so the other three models had to be made from scratch.

Figure 8. 3D Revit BIM models of Actual Projects.

IV. Results and Analysis

Creating the automated code compliance checker involved the creation of customized parameters and plenty of data manipulation with Dynamo.

The automation of the codes was pretty complicated and involved plenty of additional parameters, gathering of parametric and automated data, and workarounds. Most of the scripts were difficult to do despite the mastery of Revit and its features.

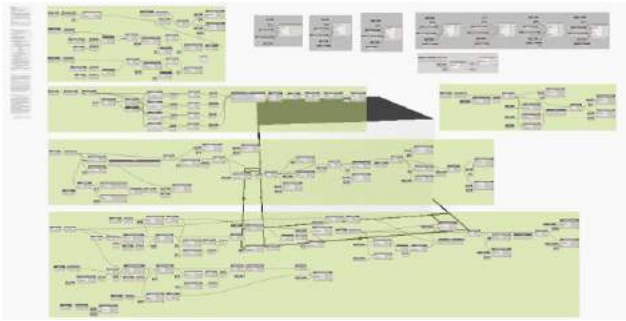


Figure 9. Automated Code Compliance Checker Script in Dynamo.

A. Automation

Parameters created in Dynamo will be in a separate script and will be run in the Revit model first before the main automation script. For some parameters that were created like the "Type" and "Natural Ventilation" parameters for the rooms, the user or the designer must manually input these parameters. After the first script which has the parameters are applied in the Revit model, the user should input the correct data in some of the parameters.

In case the designer is unavailable to input the correct data for some of the parameters that need data, the most stringent default values can be automatically placed.

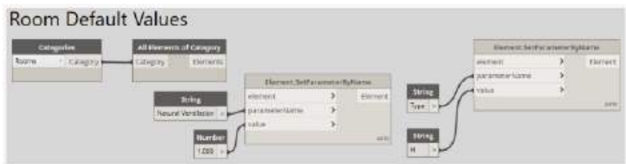


Figure 10. Area Script – Room Parameter Default Values.

1. Percentage of Site Occupancy (PSO)

Automating the Percentage of Site Occupancy or PSO compliance at first seemed simple enough but was a little more complicated than expected. Luckily, Revit has a property line element with an automatically generated area.

Floor elements in Revit are used for both the structural slab, landscape, pavements, and finishes. Not all of those would be considered as part of the built area which is bounded by the PSO. Since Revit has an automatic parameter which can be used to state if a floor is structural or not, that parameter can be used to figure out if a floor is part of the built area. Floor elements in a particular level which are structural will be considered as part of the built area.

Using the total area of the lot area generated from the automatic parameter of the property line element and the total area of the structural floor area in the first level, figuring out if a project is compliant with regards to the PSO becomes possible.

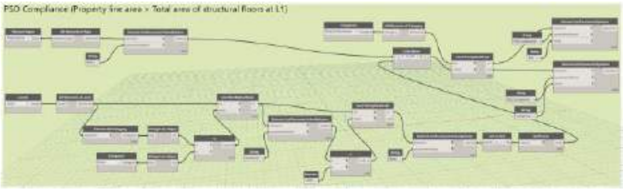


Figure 11. Dynamo – PSO Compliance Script.

2. Setbacks

Automating the setbacks were even more complicated than the PSO especially since orientation must be considered for the front, side, and rear setbacks. Revit has no innate parameter which states which side of its property line is the frontage of the lot. A complicated script which involved getting the vector value of the midpoint of each side and evaluating the location of these values had to be done to figure out which side is facing what side.

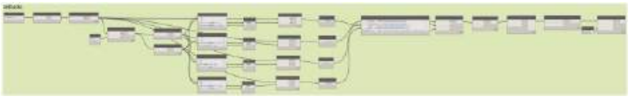


Figure 12. Dynamo – Setback Script.

3. Room Area and Window Opening Area

The room area and window area automation required several Booleans and new parameters to figure out if a room is compliant or not. The script made use of the room's automatically generated room area and a new parameter that would dictate what type of room the room was based on the types in the building code.

It also made use of a tool that could select objects within or by the room. In this case, it selected the windows of the room. From there, the automatically generated height and width of the windows were taken and multiplied with each other to get the area of the window. All the areas of the windows within the room were taken to extract the total window opening area per room. A new parameter was also created to determine if the room was naturally or artificially ventilated since the requirements within the code are different depending on its type of ventilation.

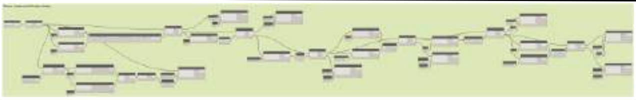


Figure 13. Dynamo – Room Area and Window Area Script.

4. Ceiling Height

In the Ceiling Height automation, the script made use of a tool that could gather elements within the room just like the one used for the window opening automation. In this case, the elements selected were the ceiling and the floor.

The basis of the result will be the highest floor and the lowest ceiling of a room. Thus, if the result is not compliant, it will not necessarily fail compliance since the highest floor and the lowest ceiling may not be in the same axis. This is the reason why the result will show "Check" instead of "Fail".

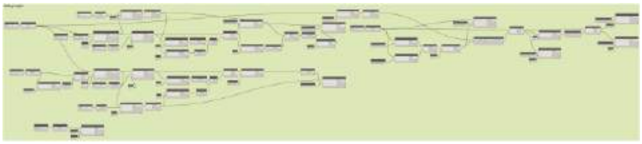


Figure 14. Dynamo – Ceiling Height Script.

5. Stairs

For the Stairs, the script will be applied on stair runs instead of the main stair since each stair run can have different risers, treads, and width. Checking the individual stair runs instead of the main stair will be more accurate. Stair Runs are nested within the main Stair family in Revit so the Compliance parameter created for all elements will not appear in the nested elements. A separate Compliance parameter for the Stair Runs had to be created. The "Actual Riser Height", "Actual Tread Depth", and "Actual Run Width" parameters of the stair runs in Revit are automatically generated. They are accurate but the Width and Tread will not have values if the Stair was created by sketch. The solution was to make stair runs with a missing value on any of the three parameters fail compliance. The user can then manually check these stairs.

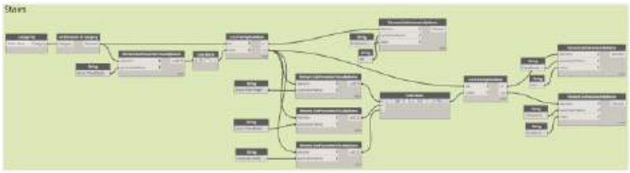


Figure 15. Dynamo – Stair Script.

B. Testing

The manual code check took some time before completion. The architect consultant checked the documents using its PDF file which is both an advantage and a disadvantage. The difficult thing with checking PDF files instead of an actual paper is that the checker was not able to simply use a ruler or a scale to measure the drawings. The advantage however is that the drawings can easily be zoomed in and out and are much clearer than having it printed. Moreover, since the PDF files are properly scaled, the consultant was able to place or import the PDF file to a CAD program. From there the consultant was able to measure the rooms or windows digitally. This is more accurate and at times easier than measuring an actual drawing in a sheet or paper.

The average time taken for the consultant to manually check the drawings was around an hour per project. Project 2 took much longer because it had more rooms than the other projects.

Table 3. Manual Check – Time Taken Average.

	P 1	P2	P3	P4	P5	Ave
Time Taken to Check	1 hour	1 hr and 30 mins	1 hour	1 hour	1 hour	1 hr and 6 mins

For the time taken of the automated code check, it was definitely quicker. The average time taken to run it was four minutes and 23 seconds as seen in the table below.

Table 4. Automated Check - Time Taken Average.

	P1	P2	P3	P4	P5	Ave
Time Taken to Check	4 mins and 35.53 secs	5 mins and 30.43 secs	4 mins and 2.43 secs	3 mins and 58.89 secs	3 mins and 47.81 secs	4 mins and 23.02 secs

It is safe to say that the automated code check will only take around five minutes, but this will obviously vary depending on the file size of the model, the computer speed, and other variables. One factor that made it longer to run the code check in Project 2 was the fact that it had more rooms than the rest. The part where the data had to be manually inputted took at least 40 seconds longer than the rest of the projects. So basically, the more rooms and the more complicated a project is, the longer it will take to run the automated code compliance checker. However, it will be safe to assume that it will take most projects less than 10 minutes. Do take note that time taken can also increase significantly depending on the status of the model.

Some issues on both types of code checks found were due to human and modeling errors. At one instance, the 3D model was lacking some windows that were in the 2D documents. In another instance, the manual code checker forgot to include a few windows in the computation of the total window opening of a room. Some elements were also used incorrectly like the image below where the lavatory counter was made using a Floor element.

Figure 16. Project 1 – 3D Floor Error.

Despite a few issues, the results of both code checks were similar with no compliance percentages differences greater than 6 aside from Project 2 which had an outdated model.

Table 5. Manual and Automated Check – Compilation

		Project 1		Project 2		Project 3		Project 4		Project 5	
		Manual	Automated	Manual	Automated	Manual	Automated	Manual	Automated	Manual	Automated
PSO Compliance		C	C	C	C	C	C	C	C	C	C
Setback Compliance	**Front**	C	C	C	C	C	C	C	C	C	C
	Right	C	C	C	C	C	C	C	C	C	C
	Left	C	C	C	C	C	C	C	C	C	C
	Rear	C	C	C	C	C	C	C	C	C	C
BHL Compliance		C	C	F	F	F	C	F	C	C	C
Room and Opening Area Compliance %		82.35	82.35	67.57	62.16	82.61	78.26	64.00	69.23	79.17	79.17
Floor to Ceiling Compliance %		64.70	64.70	94.59	86.49	100	100	88.00	88.46	95.83	91.67
Stair Compliance %		100	100	100	100	100	100	100	100	100	100
Approximate Time Taken to Check		1 hour	4 mins and 35.53 secs	1 hour and 30 mins	5 mins and 30.43 secs	1 hour	4 mins and 2.43 secs	1 hour	3 mins and 58.89 secs	1 hour	3 mins and 47.81 secs

The automated code check was actually able to detect more code violations than the manual code check as seen below.

Table 6. Automated Check – Percent of Accuracy.

	Manual Code Check Average Compliance % (MC)	Automated Code Check Average Compliance % (AC)	Discrepancy (MC-AC)
Site	90.00	96.67	-6.67
Room and Opening Area	75.14	74.23	+0.91
Floor to Ceiling	88.62	86.26	+2.36
Stair	100	100	0

Discrepancies with positive values means that the automated code check was able to detect more code violations than the manual code check; while the negative values mean it detected less. While many of the detected violations that the automated code check found but not in the manual code check were false violations due to modeling errors. The automated code check still had some correct values that the manual code check was not able to detect. Regardless of some discrepancies, the result of both code checks is similar as seen in the graph below.

Figure 17. Code Check – Average Compliance Result Percentage.

A quick manual check of the results of the automated code check can also be accomplished to ensure that the generated result is accurate. Doing so will take approximately five to 10 minutes which will vary per person. A modified time taken which includes the quick manual check for the automated code check can be seen in the figure below.

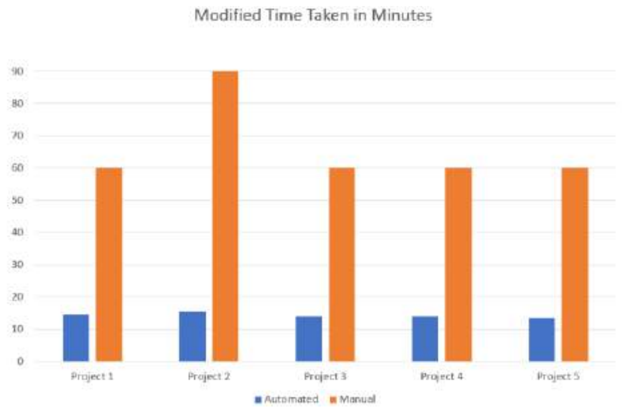


Figure 18. Code Check – Modified Time Taken in Minutes.

Even by doing that, the automated code check will still be considerably faster than the manual code check since the latter took at least an hour even with the use of excel and CAD.

C. Synthesis

A summary of the automated code compliance checker's strengths, weaknesses, opportunities, and threats are stated in the table below.

Table 7.1. Automated Code Check – SWOT Analysis.

Strengths	Weaknesses	Opportunities	Threats
Quick process.	Some setup or model cleaning may be necessary which can take time.	Faster process will mean better efficiency.	Inadequate equipment and large model sizes can drastically slow down the process.
High accuracy.	Errors may occur that will require a manual check. Results are affected by the accuracy of the model.	Greater chances of the avoidance of non-compliance in projects or designs.	Possibility of missed errors and false compliance

Table 7.2. Automated Code Check – SWOT Analysis.

Strengths	Weaknesses	Opportunities	Threats
Flexible and editable rulesets.	Difficult to edit for people with no background in Dynamo or Revit.	Has the capability of adding more rules in the script depending on the specific codes of a specific project?	Manipulation of the script could lead to a possibility of the creation of false compliance by editing the script accordingly
Uses a specific BIM software so there will be no need to convert the model.	Can only be used on Revit models.	This was created using visual programming, so it is possible to apply similar rules to other BIM software.	Updates and changes in Revit may require the constant updating of the Dynamo script.
Makes use of available and popular technology for the AEC.	Dependence on proper equipment, licenses, and experts.	Increased usage rate of BIM for the past few years makes the desire for an automated code check within BIM likely.	Shifting methods and practices can occur that may not be favorable to BIM.

The Automation of the code is convenient and useful as seen in the results especially if a designer is already using Revit. However, there are still several general key factors and possible issues that are not too obvious but still need to be emphasized and looked at.

First is the model and user variability. An incorrect manner of modeling like the use of generic masses that do not make use of Revit's innate parameters will inevitably make the automation fail in some aspects. People will do things differently and generic models or incorrect elements are sometimes being used by Revit users who are not yet adept to the software. If modeling issues are applied to any model, there will likely be problems wherein the automation script will not be able to come up with an accurate result. This issue can be solved if the user becomes aware or knowledgeable of the correct practices in modeling using BIM.

The automated code check script made use of the innate parameters within Revit whenever it could be applicable to most models. However, automatically generated parameters are not always present. There were instances wherein an automatic parameter was not present for a particular code. This meant that the automation script had to create these parameters which further complicated the script. Moreover, it added tasks for the user to do since they will have to input the fields for some created parameters as opposed to simply running the automated code check script. At this point, this is inevitable unless Autodesk adds such parameters in the future.

With regards to linked models, some models will likely have separated models that are linked with one another. This could cause some issues with the automated code check since the script may not be able to read all the elements of a linked model. Also, linked models may have different levels, families, elements, and the like which could also cause issues and duplicates. A workaround for this could be by exploding the links in a single file, but that will not solve the duplicate problem so a model cleaning may be necessary before running the automation. Luckily, Revit has a feature wherein, if the family name is the same, a copied family from a different Revit project will have the option to use the features of the family within the local Revit file as opposed to creating a duplicate of that same family. It is even possible to replace the one in the local Revit file with the family being copied.

While it is ideal to be able to have an automation script using default settings and default parameters, in actuality that will not be the case. In the automation script, some nodes that were used were from Dynamo packages like clockwork, archilab, springnodes, and more. These had to be downloaded since they were not included in the default nodes within Dynamo. The good thing with Dynamo is that all those packages are open source and easily accessible. The Dynamo community is also very helpful and answers most questions in its forum.

Another issue that could not be avoided are issues within Revit itself. While doing the setback automation, a Revit API issue wherein floors, hatches, and the like which has a sketch as boundaries, cannot be generated with a hole in Dynamo. The workaround is to create an opening on the floor to create the hole but that will not work for hatches. It is also plausible to manually create the hole in Revit and not in Dynamo. Although this specific issue did not conflict with what was needed for the R-1 codes, technical issues could be a problem for future automated code checks.

Given the following concerns that were mentioned about the automated code compliance checker, a clear guide that is easy to understand was created. The guide will allow any user that is not the researcher to be able to easily use the automated code compliance checker. The guide was created in accordance with the possible issues that may occur. Appropriate images were also added to better guide the user.

The guide has four parts: Before You Get Started, Instructions, Changes, and Disclaimer as seen in the images below.

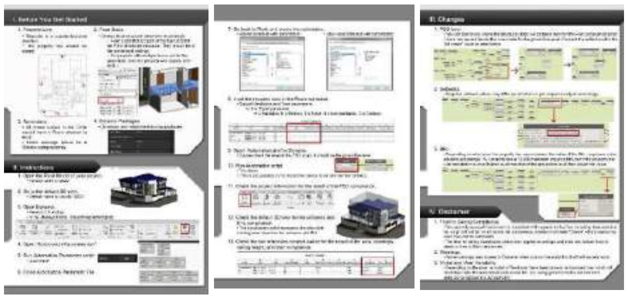


Figure 19. Guide for the Automated Code Check.

In the first part, the guide briefly discusses the things that must be done with any Revit model before starting the automated code compliance checker. It specifically discusses the property line issue and its quick recreation to solve its issue. The first part of the guide also discusses that the model's floor slab structural parameter should also be checked for the PSO compliance.

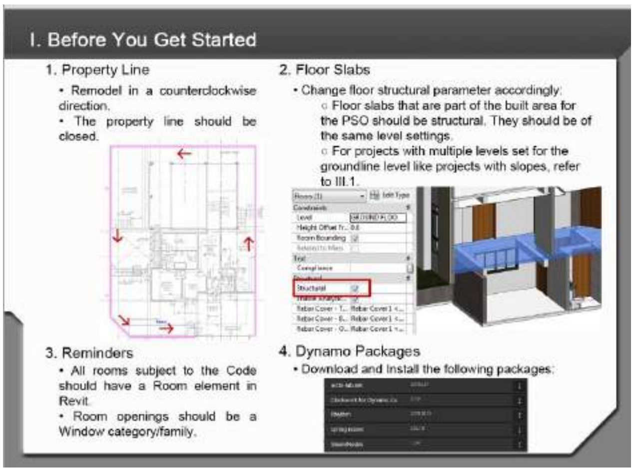


Figure 20. Guide – Before You Get Started.

The second part provides the instructions on how to use the automated code compliance checker. From opening the model to opening the Dynamo add in and scripts to running the scripts. All the required instructions will be covered.

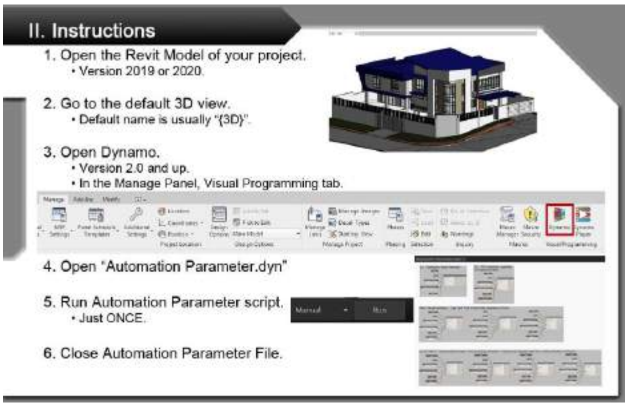


Figure 21. Guide - Instructions 1.

The schedule that must be created in Revit and the parameters that the user will have to manually fill in are all clearly discussed in the guide so that the user will not miss anything.

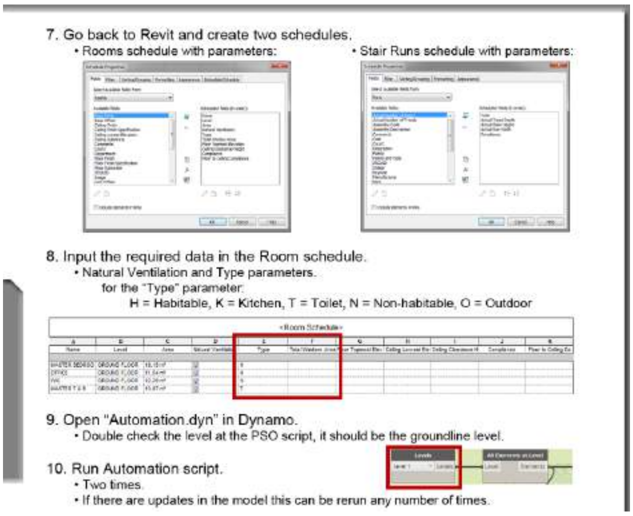


Figure 22. Guide – Instructions 2.

After the scripts are run, there are also instructions on how to check the results of the compliance report as seen in the image below.

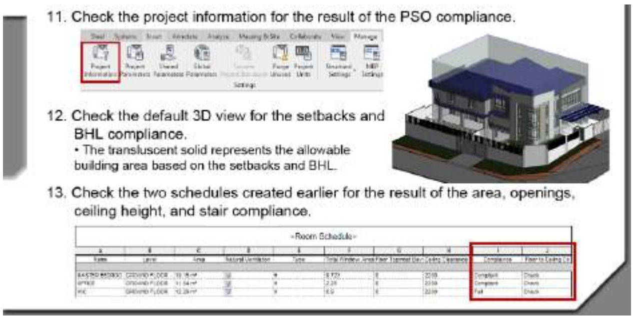


Figure 23. Guide – Instructions 3.

The third part discusses the changes that can be made depending on the particular project's situation and if there are local laws or other codes that have different values. Particularly, it discusses how to add levels for the PSO compliance, how to adjust the setback values especially for projects with multiple frontages, and the need to adjust the BHL value depending on where the property line was modeled.

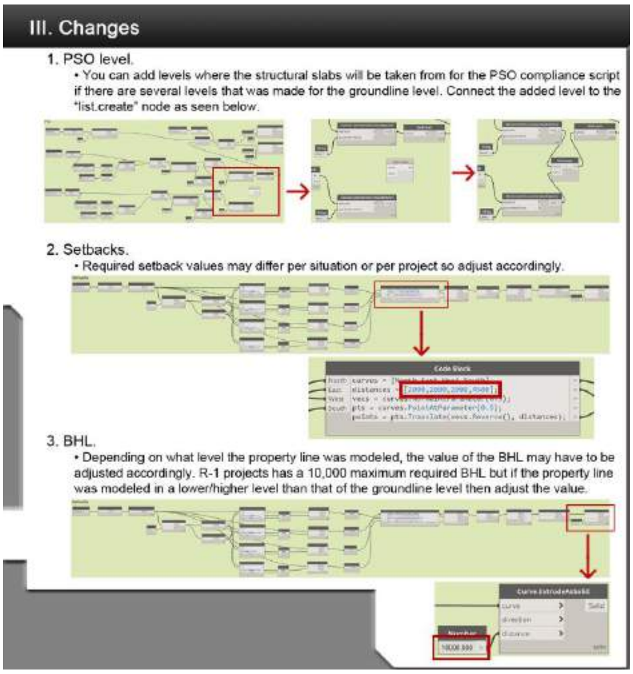


Figure 24. Guide – Changes.

For the last part, it discusses all the misconceptions that could arise with the automated code compliance checker. The floor to ceiling compliance issue is discussed and it also discusses the warnings that may appear.

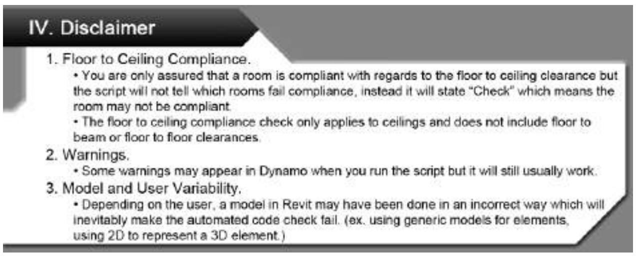


Figure 25. Guide – Disclaimer.

Notes within the Dynamo script were also placed to show the same instructions found in the guide as seen below.

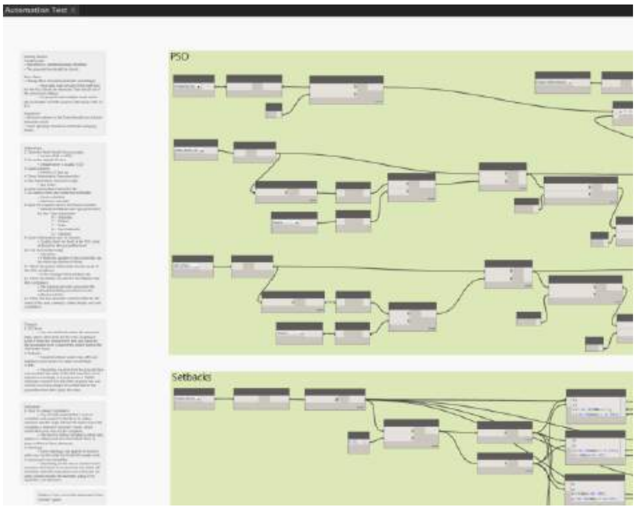


Figure 26. Dynamo – Notes.

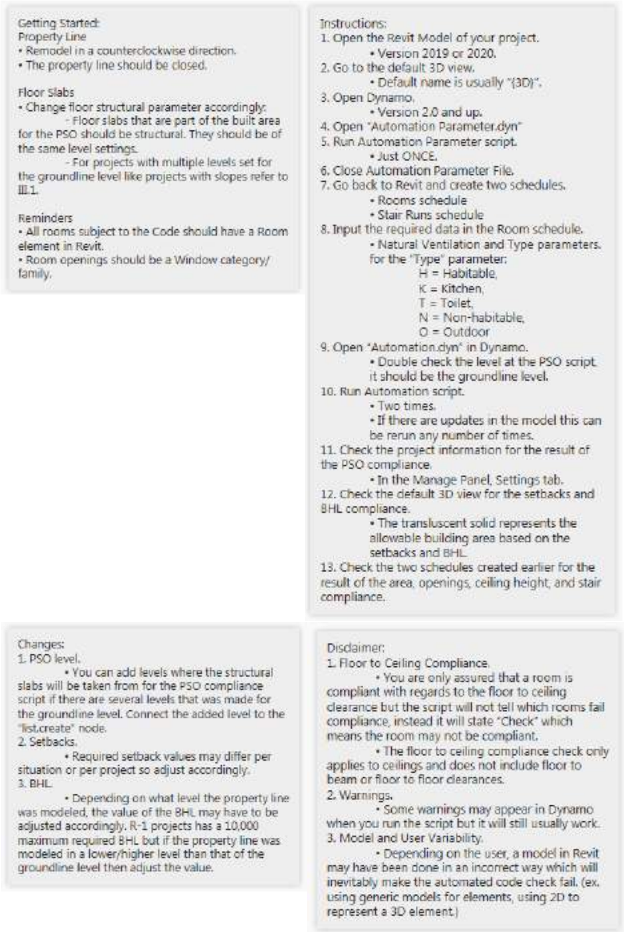


Figure 27. Dynamo – Notes: Details.

This guide will basically make sure that any user will be able to use the automated code compliance checker so that concerns that were found will be less of a problem.

V. Conclusions and Recommendations

The testing of the automated code compliance checker had desirable results which makes the development attempt successful. Result percentage variations between the two forms of code checks did not exceed six percent. Furthermore, the automated code check took only around five minutes per project or around 15 minutes including the quick manual check. Compared to the manual code check that took around an hour, the automated code check is considerably faster. There were some concerns that still need to be addressed but many of those concerns can be solved or have workarounds. The automated code compliance checker is already usable at its current state and it can still be expanded and improved on in the future.

The actual creation of the automated code check script takes up a lot of time and determining which nodes to use is more complicated than it seems. A mastery of Revit is necessary for someone to be able to properly use Dynamo for Revit especially for complicated rulesets like building codes. The solution for the study was to create a guide on how to use or edit the script especially if it has to be used for other or special projects. Since the script was already created, most changes would be on the values like setbacks, the percentages, or different clearances which have actual numbers within the script that are editable. This makes the automated code checker quite flexible and it can accommodate special codes or specific local laws that a particular project may have. The flexibility and accessibility of the developed automated code checker is very important since this is what the other available automated code checker lacked. The created guide is necessary for other users to be able to freely edit the script according to the needs of their project since script writing is not easy to do or study.

For future studies, solving some issues like the floor to ceiling compliance that considers the axis instead of just the minimum ceiling and the highest flooring can be done to be able to make sure that a room is compliant with regards to the ceiling or not. Other technical issues can be smoothed out to be more seamless and convenient. A research on the proper modeling practices in coordination with the automated code compliance checker can also be done for a future study so that models will no longer require fixing.

Furthermore, future studies can look into expanding the covered codes like adding minimum door widths, number of exits, distances to exits and more. This study can also be used as a template to create an accessible automated code compliance checker for other types of projects like commercial projects, offices, industrial projects and more. It can even be possible to include elements of the other fields like the structural and mechanical elements. Moreover, adding in the other codes like the fire code or the socialized housing code is also an option. Basically, there are plenty of possibilities that can be done to expand on this study, but this could be the basis or foundation for those other studies.

Visual programming itself is very useful and it is highly recommended for BIM users to also learn how to use visual programming tools. It can make plenty of tedious work much easier to do and the possibility of automizing many processes can make work very efficient.

Considering how important compliance is, another possibility is to pitch the automation to the government to gain access to funds that will enable the development of every permutation.

References

Allen, C., & Shakantu, W. (2016). *The BIM revolution: A literature review on rethinking the business of construction* [Conference presentation]. 11th International Conference on Urban Regeneration and Sustainability, 920–930

Anderle, M., & Allen, R. (2017). *Improve Your Team Efficiency: 20 Practical Uses of Dynamo for Revit.* Medium. Retrieved October 4, 2018, from https://medium.com/autodesk-university/improve-your-team-efficiency-20-practical-uses-of-dynamo-for-revit-f5f4a6313ab8

Association of Structural Engineers of the Philippines, Inc. (2013). *Educating Green Building Stakeholders About the Benefits of BIM - The Philippines Experience*. Medan, Indonesia

Autodesk. (n.d.). *Revit products*. Autodesk. Retrieved July 16, 2019, from https://knowledge.autodesk.com/support/revit-products/learn?sort=score

Building and Construction Authority. (2013). *Singapore BIM Guide*. Coronet. Retrieved October 4, 2018, from https://www.corenet.gov.sg/media/586132/Singapore-BIM-Guide_V2.pdf

Choi, J., & Kim, I. (2017). *A Methodology of Building Code Checking System for Building Permission based on open BIM* [Conference presentation]. 34th International Symposium on Automation and Robotics in Construction.

Cox, R. F., Issa, R., & Ligator, J. (2006). *Top ten Florida residential building code violations*. Gainesville, Florida: M.E. Rinker, Sr. School of Building Construction.

Davenport, T. (1992). Process innovation: Reengineering work through Information Technology, Harvard Business School Press, Boston. design and LEED® rating analysis. *Automation in Construction*, *20*(2), 217–224.

Dimyadi, J., & Amor, R. (2013). *Automated Building Code Compliance Checking - Where is it at?* https://doi.org/10.13140/2.1.4920.4161

Ding, Lan & Drogemuller, Robin & Rosenman, Mike & Marchant, David & Gero, John. (2006). Automating code checking for building designs-DesignCheck. *Clients Driving Innovation: Moving Ideas into Practice* (pp. 1-16). CRC for Construction Innovation. Retrieved July 10, 2019, from https://pdfs.semanticscholar.org/d6ae/240667b08ea077a9e6950cbd3fd8cfa04534.pdf

Dowsett, R. M., & Harty, C. F. (n.d.). *Evaluation the Benefits of BIM for Sustainable Design - A Review.* http://www.reading.ac.uk/web/files/tsbe/Dowsett_TSBE_Conference_Paper_2013.pdf

Eastman, C., Lee, J., Jeong, Y., and Lee, J. (2009). Automatic rule-based checking of building designs. *Automation in Construction*, *18*(8), 1011–1033. doi:10.1016/j.autcon.2009.07.002

Greenwood, D., Lockley, S., Malsane, S., & Matthews, J. (n.d.). *Automated compliance checking using building information models*, 266-274.https://www.irbnet.de/daten/iconda/CIB20057.pdf

Kalfa, M. (2018). Building information modeling (BIM) systems and their applications in Turkey. *Journal of Construction Engineering, Management & Innovation, 1*(1), 55-66. Retrieved July 16, 2019, from https://www.researchgate.net/publication/325422848_Building_information_modeling_BIM_systems_and_their_applications_in_Turkey.

Khemlani, L. (2005). CORENET e-PlanCheck: Singapore's automated code checking system. *AECbytes "Building the Future"*. Retrieved November 15, 2012, from http://aecbytes.com/buildingthefuture/2005/CORENETePlanCheck.html

Khemlani, L. (2011). AECbytes Building the Future. *AGC's Winter 2011 BIMForum*, Part 1.

Kia, S. (2013). *Review of Building Information Modeling (BIM) Software Packages Based on Assets Management.* Retrieved July 16, 2019, from https://www.researchgate.net/publication/253058808_Review_of_Building_Information_Modeling_BIM_Software_Packages_Based_on_Assets_Management

Kilkelly, M. (2018). *What is dynamo and 5 reasons you should be using it.* Archsmarter. Retrieved October 4, 2018, from https://archsmarter.com/what-is-dynamo-revit/

Kim, J., Clayton, M., & Yan, W. (2011). Parametric Form-Based Codes: Incorporation of land-use regulations into Building Information Models. *ACADIA Regional 2011: Parametricism,* 217-223. http://papers.cumincad.org/data/works/att/acadiaregional2011_025.content.pdf

Kuehmeier, J. (2008). *Building Information Modeling and its Impact on Design and Construction Firms.*

Mallach, A. (2013, March 26). *5 Things Cities and CDCs Don't Get About Code Enforcement.* Retrieved February 16, 2019, from https://shelterforce.org/2013/03/26/5_things_cities_and_cdcs_dont_get_about_code_enforcement/

Matějka, P., & Tomek, A. (2017). Ontology of BIM in a Construction Project Life Cycle. *Creative Construction Conference 2017,* 1081–1087.

McAuley, B., Hore, A. and West, R. (2017) *BICP Global BIM Study - Lessons for Ireland's BIM Programme Published by Construction IT Alliance (CitA) Limited*, 2017. https://doi.org/10.21427/D7M049

McGraw Hill Construction. (2014). *SmartMarket Report: The business value of BIM for construction in major global markets*.

ICN-Solutions. Retrieved from https://www.icn-solutions.nl/pdf/bim_construction.pdf

McGraw Hill. (2009). The business value of BIM: Getting Building Information Modeling to the bottom line, *SmartMarket Report*, 2008

Merlan, J. (2018, October 21). *Dynamo for Revit: What it is and why you should use it.* Unifilabs. Retrieved February 5, 2019, from https://unifilabs.com/dynamoforrevit/

Moullier, T. (2014). *Improving building code implementation and compliance for more resilient buildings in developing countries: considerations for policy makers.*

Nguyen, T., & Kim, J. (2011). Building code compliance checking using BIM TECHNOLOGY. *2011 Winter Simulation Conference,* 3400-3405. https://dl.acm.org/doi/10.5555/2431518.2431922

Philippine Information Agency. (2017, September 22). *Review Committee created to strengthen current Building Code.* Retrieved February 13, 2019, from https://pia.gov.ph/news/articles/1000386

Philippine Statistics Authority. (2018, December 19). *Construction Statistics from Approved Building Permits: Third Quarter 2018.* Retrieved February 27, 2019, from https://psa.gov.ph/content/construction-statistics-approved-building-permits-third-quarter-2018-preliminary-results

Preidel, C., & Borrmann, A. (2016). *Towards code compliance checking on the basis of Visual Programming Language*. ITcon. Retrieved October 2, 2018, https://www.itcon.org/papers/2016_25.content.01707.pdf

Reizgevicius, M., Ustinoviˇcius, L., Cibulskien˙e, D., Kutut, V., & Nazarko, L. (2018). Promoting sustainability through investment in Building Information Modeling (BIM) Technologies: A Design Company Perspective. *Sustainability*,*10*(3), 600. https://doi.org/10.3390/su10030600

Santos, S. (2015). *Dynamo: The Secret to Working Smarter and Making Your Life Easier.* ArchDaily. Retrieved October 4, 2018, from https://www.archdaily.com/773079/dynamo-the-secret-to-working-smarter-and-making-your-life-easier.

Seembu. (2016, October 14). *How to get a building permit in the Philippines.* Medium. Retrieved December 3, 2018, from https://medium.com/@seembu/how-to-get-a-building-permit-in-the-philippines-f4ae3684c06d

Sweet, R. (2014). Reversing Babel, *Construction Research and Innovation Magazine, 5* (2). https://doi.org/10.1080/20450249.2014.11873932

The Economist. (2017). *Efficiency Eludes the Construction Industry.* Retrieved September 25, 2018, from https://www.economist.com/business/2017/08/17/efficiency-eludes-the-construction-industry

Thompson, G. N. (1947). *The Problem of Building Code Improvement. Law and Contemporary Problems*, 12(1), 96-110. Retrieved February 15, 2019, from https://scholarship.law.duke.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=2292&context=lcp.

US Department of Energy. (n.d.). *Compliance.* Energy Codes. Retrieved July 12, 2018, from https://www.energycodes.gov/compliance

Uraiqat, B. (2013, January 30). Cyborg architects - the effect of digital design technologies on modern architectural design and representation. *Uraiqat.* Retrieved December 1, 2018, from http://uraiqat.blogspot.com/2013/01/cyborg-architects-effect-of-digital.html

Wengerd, O. (2015, January 12). This is how much more you'll pay for Autodesk software. *WorldCAD Access.* Retrieved January 27, 2019, from https://www.worldcadaccess.com/blog/2015/01/this-is-how-much-more-youll-be-paying-for-autodesk-software.html

Yan, H., Damian, P. (2008, 16–18 October). *Benefits and barriers of Building Information Modelling* [Conference presentation]. Proceedings of the 12th International Conference on Computing in Civil and Building Engineering, Beijing, China.

Flood Control Projects in the Philippines: A Historical Overview

Richard Martin E. Rinen [1]
rerinen@up.edu.ph

Norio Maki [2]
Maki.norio.8v@kyoto-u.ac.jp

Abstract

Floods have been a natural occurrence in the Philippines since the pre-Hispanic time because most settlements are in very close proximity to bodies of water. These floods often result in calamities that are aggravated by the uncontrolled urbanization which brings about even bigger problems. In order to mitigate the effects of flooding, especially in highly urbanized areas, different flood control projects have been undertaken by the Philippine government. But, despite these efforts, the problem persists and continues to threaten the growing population especially with climate change. This paper looked into different projects in combating flooding from the Hispanic period to the present. This is done by looking into flood control projects through the archives of the Bureau of Public Works (Department of Public Works and Highways) and other literature and categorizing them as risk reduction strategy or risk avoidance strategy. As a result, it can be noted that in the past, the placement of towns and villages and even the design of houses and buildings took into consideration flooding and other natural phenomena in their location and design, an effective risk avoidance strategy as in the case of the relocation of San Juan in Batangas. However, with the establishment of the Bureau of Public Works flood control projects focused mainly on costly structural solutions or risk reduction strategies as in the case of the Manggahan Floodway. Failure to finish and/or maintain these projects render them ineffective just like what happened during Typhoon Ondoy. Therefore, the most effective solutions in mitigating the effects of flooding are mostly non-structural in nature, however, there are situations where structural solutions are inevitable and therefore a combination of strategies with focus more on risk avoidance strategies should be considered.

Keywords: disaster, disaster preparedness, risk avoidance, flood control, risk reduction

Richard Martin E. Rinen is an assistant professor at the University of the Philippines where he also graduated with B.S. Architecture and Master of Architecture degrees. He is a PhD candidate for the degree in Architecture and Architectural Engineering at the Graduate School of Engineering in Kyoto University under the Disaster Prevention Research Institute.

2 Norio Maki is a Professor of Disaster Prevention Research Institute, Kyoto University from 2005. His current research interests are disaster reduction planning, emergency management system, a long-term recovery process from 1995 Kobe earthquake, 2004 Niigata Earthquake, and 2011 Tohoku earthquake, and crisis management.

I. Introduction

The Philippines is an archipelagic nation situated along the Pacific Ring of Fire. It is composed of more than seven thousand islands and islets which are divided into three geographical regions called Luzon, Visayas and Mindanao. These groups of islands extend from the Balintang Channel on the north to the Sulu and Celebes Seas on the south and South China Sea on the west and the Pacific Ocean on the east. Due to its location, the Philippines is vulnerable to hazards such as tropical cyclones that usually form in the Pacific Ocean aside from earthquakes, volcanic eruptions and others. These tropical cyclones are characterized by heavy rains which are influenced mainly by the monsoons coming from the northeast (Amihan) and southwest (Habagat). An average of twenty tropical cyclones visit the country each year of which seven or eight make a landfall and inflict considerable damages to lives and properties. These cyclones are also characterized by strong wind forces that bring about storm surges and heavy rainfall resulting in inundation of river basins and low-lying areas. They also cause erosion and slope failures both in rural and urban areas. These floods are worsened by population growth, in-migration, urbanization and economic development that have an adverse impact on the environment (Pante, 2015). Aside from the obvious devastation, floods also increase runoff, reduce water quality and damage water supply infrastructure according to the United States Agency for International Development (USAID). However, it is argued also that these floods are not merely natural phenomena but mostly political, demographic and socioeconomic according to Piers Blaikie (1994) and Mark Pelling (2003) as cited by Pante (2015). If the causes of flooding are not merely natural, then it is believed that human interventions can alleviate its effects. And that brings out the question of "what must be the best practices in mitigating floods?" which is the aim of this paper. In September 2009, the country was hit by typhoon Ketsana, local name Ondoy, which brought 150-year return flood water over Metro Manila and nearby municipalities in the downstream with a rainfall which lasted for 12 hours. This brought changes to the way the Philippines look at disasters particularly at flood disasters. As a result, the National Disaster Coordinating Council (NDCC) which was reactionary was changed to a more proactive approach in dealing with disasters as the National Disaster Risk Reduction and Management Council (NDRRMC) known as Republic Act 10121.

In the Philippines, flooding is one of the major problems affecting all sectors of society, especially the poorest and most vulnerable; specifically, those who live in low-lying areas and informal settlements near or on bodies of water in major cities like Metro Manila. This situation has not only become a problem on flooding but a problem in drainage and sanitation as well. There have been 169 flood events recorded since 1968 to 2019 that affected almost 35M people (EM-DAT, 2019). With the threat of the changing climate, it is expected to be happening more frequently and gravely in the years to come.

Typhoon Ketsana (local name Ondoy) in 2009 was a wake-up call among Manileños and the rest of the country that flood is still a reality which brought about the re-examination of non-structural flood mitigation measures such as flood forecasting and disaster preparedness and response; investigation on the extreme flooding events to land use and water resources; impact assessment of extreme floods to the urban ecological environment; and performance evaluation of existing flood control structures, all as part of an integrated water resources management program (Gilbuena, 2013).

There were flood control projects undertaken by the government and there are still projects to be implemented under the Department of Public Works and Highways since its establishment during the American Era. This paper argues that it is important to take a look at these projects in order to determine different approaches and find out which ones are effective and/or appropriate in the Philippine setting. And therefore, a look at flood protection strategies is very important to weigh for a better approach to mitigate flooding.

II. Related Literature

Flood research in the Philippines has been done but no research chronicles the flood control projects from pre-colonial up to the present. However, the following research have contributed to build up this paper's importance and contributed to the data needed to support the goal of the research. Bankoff (Bankoff, 2007) traced the occurrence of disasters in the Philippines to the lack of mutuality between the environment and human activities over time. His research focused mainly in Metro Manila and chronicled the history of flooding from 1691 to 1911 as recorded in the archives of the Manila Observatory. This work proves that flooding is not just a recent phenomenon in the Philippines. Chias (Chias & Abad, 2012) studied old maps and other archival literary materials to trace how the cities in the Philippines developed from small native communities during the Spanish colonization. She concluded that Spain colonized and controlled the territories by establishing the foundation of sites and the creation of a road network to link each. While Ocampo (Ocampo, 1992) recorded the growth of cities in the Philippines particularly that of Manila from the start of the Spanish period, Commonwealth and Post-war period. His study showed how the esteros have been part of the Spanish and American plans to be improved and used for transportation and recreation, however, in the next generations they were neglected and became the eyesores in the city that needed the quick fix solutions as the informal settlers who live in them. This shows that a change of mindset among decision makers need to occur for this to be controlled. Gilbuena's (Gilbuena, 2013) study found that existing flood control structures in Metro Manila failed during Typhoon Ketsana (Ondoy) due to inappropriate designation of land use particularly the encroachment of informal settlements causing drainage problems and the lack of maintenance. His conclusion, however, focused on disaster preparedness and mitigation via structural flood mitigation measures such as proper maintenance of existing flood control structures and early warning systems and did not reiterate the importance of land use as a more sustainable solution and as a major factor for flood control structures to function during disasters; an important point that was implied in his findings and is the focus of this paper.

III. Research Methods

Archival research was done from the records of the Department of Public Works and Highways, formerly known as the Bureau of Public Works through its publication from 1912 (Quarterly Bulletin) to the present (Annual Report). Other records were gathered from different literatures to cover the period before the abovementioned publications existed. The flood control strategies recorded in literary works and the official publication of the bureau were tabulated and categorized into two: risk reduction and risk avoidance of which only some projects will be mentioned in the presentation of the findings for the sake of brevity. The generally accepted definition of risk avoidance and risk reduction was used as follows; risk avoidance deals with eliminating any exposure to risk that poses a potential loss and risk reduction deals with reducing the likelihood and severity of a possible loss. Two major projects deemed to best represent the type of each approach were further identified and compared in terms of effectiveness. From the data gathered, conclusions and recommendations were drawn in order to guide decision makers to formulate a better strategy for flood control. The illustration below explains the research framework.

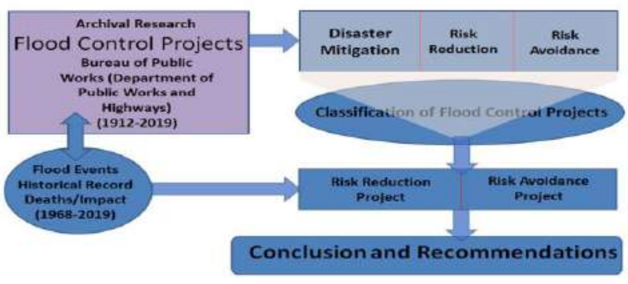


Figure 1. Research Framework.

IV. Findings

Flooding in the Philippines has been chronicled by Bankoff (Bankoff, 2000) showing that flooding is a regular occurrence in the Philippines due to its location, topography, climate, the global crisis of climatic change and rising sea level and other human induced factors. A record of flood events from 1691 to 1900 have been gathered by Bankoff from the archives of the Manila Observatory (Bankoff, 2007) and this was continued with the available data from EM-DAT from 1960 to 2019 accessed in May 2019 (Figure 3). It is noticeable that the occurrence of flood is continuously increasing which is partly attributable to the more accurate recording of events. As a response, the government in all the forms it has taken throughout history responded accordingly with the given technology and resources of the time.

For ease of presentation of the findings, major events in Philippine history were divided into four periods namely: Hispanic Period (1521-1898), American Era (1898-1946), World War 2 to Marcos Regime (1946-1986), and Post-Marcos to Present (1986-2019).

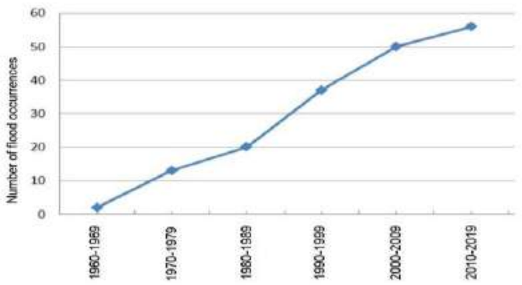


Figure 2. Flooding Record from 1960-2019 EM-DAT, May 2019

A. Hispanic Period

"It was no marvel that they left it, because the few Indians who dwelt there, about seven hundred inhabitants in all, were scattered in thirty villages situated at the foot of some mountains toward the sea – in a land subject to overflow, with many creeks or little rivers to cross which the Indians did not take the trouble to build bridges. There was no open road from one village to another." (Aduarte, 1640)

The Philippine archipelago was under Spanish rule beginning in 1521. The first Spanish settlement was built in Cebu Island and then expanded into more than two hundred new cities following the traditional grid structure according to the provisions of Leyes de Indias (Indies Legislation) enacted in 1573 by King Philip II of Spain to whom the archipelago was also named after. The most important was Manila (1571), which was founded over an existing native commercial settlement. The cities were established mainly on the coast which later became port cities. They then moved inland which were soon connected through a network of roads, railroads and navigational routes. The establishment of new cities was guided by simple principles according to their function and to urban type to which flood and earthquake protection has been a consideration as evident in the urban development as well as the height of the housing and main buildings and even the bell towers. However, early settlements have been decided on where they were carried by the ocean current or where they took shelter from storms (Chias, 2012). This is an example of how nature and its limitations have been a major consideration for development. A very good example of such consideration is the old town (Pinagbayanan) of San Juan in Batangas which was established along the coast of Tayabas Bay in the 1840s during the late Spanish Colonial Period. Popular history recounts its relocation seven kilometers inland to its current location from 1869 until the new town was established in 1890 because of seasonal flooding. Geoarchaeological landscape data from two stone houses and the old church complex are used alongside ethnohistorical accounts to explore this period further. Archival documents recorded the conflict between the priest and the residents in transferring the town. By integrating these data, it shows the power of the church and resilience of the townspeople. This argument analyzes how two prominent groups responded to the same flooding event in the context of local resilience and resistance to Spanish demands. The results are tied to the larger context of Spanish colonial occupation of the Philippines (Tesoro, 2017).

From 1780 to 1893, the hacienda administrators built forty-five irrigation dams with tunnels, waterways, and irrigation canals in order to channel available water sources to excellent use, that way securing rice paddies during extended drought periods. They appropriated considerable sums of money for breaking up untilled lands, putting up mangrove embankments, draining swamps, and building vital road arteries and streets. One of the evident irrigation projects that still exist today is Prinza Dam which was "built in the 18th century to irrigate the surrounding rice fields of Las Piñas & Bacoor. It is a gravity dam on the Zapote River found on the border between Barangay Talon Dos, Las Piñas and Barangay San Nicolas, Bacoor. This is a man-made irrigation dam with its walls made out of adobe (height ranging from 25-30 stacks) and some parts of the flooring made out of cobblestones. Series of buttresses support its perimeter walls and balete trees and bamboo grasses contribute to the enhanced structural integrity of the dam. This dam and its attached water distribution system is an outstanding feat of hydrological engineering. The dam serves as a passageway for commuters from Bacoor and Las Piñas respectively" (City Government of Bacoor, 2017).

Figure 3. Remains of the houses in Pinagbayanan (San Juan, Batangas).

Source: Philippine Daily Inquirer, August 21, 2011

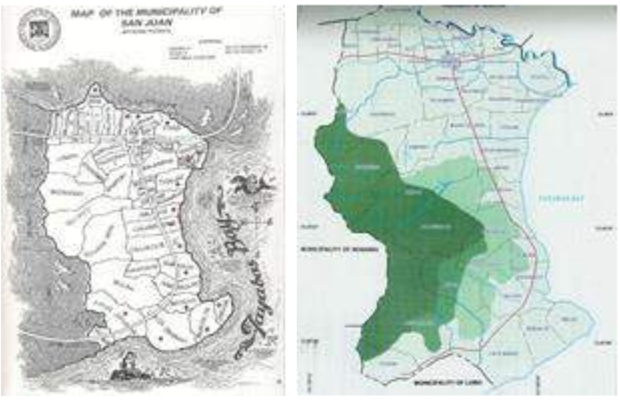


Figure 4. Location Map of the old town Pinagbayanan. UP-

According to Huez de Lemps as cited by Bankoff, as early as 1882, the refurbishment of the drainage system in Manila based on the network of esteros was drawn as the most practical solution given the financial resources at that time. This was only partially realized until the eve of the 1896-98 Philippine revolution (Bankoff, 2000).

B. American Era

In 1898, the Spaniards ceded the Philippines to the Americans through the Treaty of Paris alongside Puerto Rico and Guam. The Americans immediately recognized social and environmental problems in the Philippines including poor quality housing, polluted waterways, widespread poverty and lack of a national education system to name a few (Morley, 2011). As part of the response to these problems, the Americans created big plans for the cities in the image of the idealized City Beautiful with Burnham's Plan of Manila as a start. This plan was meant to improve the physical city by means of constructing new road systems, using waterways for transportation, beautification of the city's waterfront, and construction of parks, parkways and buildings with Pasig River as the key design driver (Zaide, 2018). Although there was no explicit flood control plan under the Burnham plan, a citywide drainage system was built in Manila for the first time in 1909 (Pante, 2015). This plan also included the reclamation of portions of Manila Bay as reported by John D. Fitzgerald of Australia (Vernon, 2011). The plan recognized the balance between living, working and recreation, however, the formalism of the City Beautiful Movement failed to consider the socio-economic concerns of the working class of Manila (Zaide, 2018). Aside from the city of Manila, Burnham also made the plan for the city of Baguio on the north, the summer capital of the Philippines. Baguio's undulating terrain posed a challenge to Burnham's "controlling principle" and decided to make his plans "obedient to nature" and therefore cannot be a formal layout of the City Beautiful street plan but rather adaptive to the "terrain's warp and weft" (Vernon, 2011).

Figure 5. Frinza Dam.

Source: http://bacoor.gov.ph/tourism/prinza-dam

Figure 6. Flooded Santa Ana, Manila circa 1914.

Source: Eduardo de Leon (Pinterest)

Although the Bureau of Public Works was already in existence in 1867 under the Spanish Civil Government whose function was to encourage insular trades and transportations, it was only formally established in 1905 to take charge in constructing roads, bridges and buildings in the country. As part of the Division of Irrigation is the "Flood Control and Drainage Section responsible for investigation, survey, planning, design, construction and repair of river and flood control and drainage projects, both communal and regional in scope, and the dredging of river for flood control" (Bureau of Public Works, 1958).

Several projects have been undertaken during the American Era in Manila and other parts of the country focusing on dredging operations along the Pasig River, and several esteros such as Binondo, Reina Regente, Escolta, Magdalena, Paco (Bureau of Public Works) and others from 1915 continuing onwards until the Second World War. The table below from the Quarterly Bulletin of the bureau shows some of these projects in 1919 although these activities as well as river walls have been built as early as 1912 when the bureau built "Angat River Protection Wall to Protect the city of Baliuag against further encroachments of the Angat River" in Bulacan (Bureau of Public Works, 1912).

There were also technologies employed such as the one done for "Tanhay, on Kilometer 33 of the Dumaguete North Road, where the district engineer started a river-control project to prevent the Roman Catholic Church and other valuable property from being destroyed by undermining from the Tanhay River flood waters. This project consists of anchoring bamboo mattresses loaded with rock and sunk in place, at approximately a right angle from the line of embankment, which will tend to divert the stream flow from being destroyed" (Bureau of Public Works, 1912). Such examples of indigenous ways combined with engineering technology were successful in preventing floods at that time. Flood control projects during the American Era covers the entire country from Northern Luzon to Mindanao. One of the biggest dams in the Philippines, the La Mesa Dam which supplies most of the water demands in Metro Manila at the present, was also built in 1929 as well.

Dredging operations, 1919.

Location.	Total from 1902-1918.	Fiscal year 1919.	Total.
	Cubic meter.	*Cubic meter.*	*Cubic meter.*
Lower Pasig River	6,008,596	386,804	6,395,400
Outer Harbor	2,459,348		2,459,348
Upper Pasig River	675,045	19,206	694,251
Inner Basin	408,953		408,953
Binondo Estero	52,816		52,816
Estero da la Reyna	232,922		232,922
Paco Estero	26,965.40	1,107	28,072.40
San Miguel Estero	56,796	769	57,565
Provisor Estero	27,744		27,744
Marine R. R. Engineer Island	30,865	2,444	33,309
Talim Island (City)	1,071		1,071
Outer Bar	760,931	277,220	1,038,151
San Sebastian Estero	3,556	4,193	7,749
Magdalena Estero	16,580		16,580
Engineer's Island Canal	30,180		30,180
Vitas Estero	296,150	29,516	325,666
Quiapo Estero	12,507		12,507
Cegado Estero	35,509		35,509
Pandacan Estero	172		172
Estero de San Lazaro	22,975		22,975
Corregidor Bay Q. M.	54,956		54,956
Iloilo River	1,594,399.50	313,250	1,907,649.50
Cebu Harbor	212,684	36,967.50	249,651.50
Mariquina River	7,290		7,290
Balete Estero	21,646		21,646
District of Cavite	20,876.25		20,876.25
Tondo Beach	9,013		9,013
Santibañez Estero	19,762		19,762
Tanque Estero	10,500	12,780	23,280
Tacloban Wharf	34,105.50	400	34,505.50
Zamboanga	29,880		29,880
Cotabato River	11,350	38,112	49,462
Earnshaw's Slipways		2,208	2,208
Total	13,186,143.65	1,124,976.50	14,311,120.15

Figure 7. Sample Table of Flood Control Projects.

Source: Bureau of Public Works

Figure 8. Temporary Bank Revetment, Magat River Control, Bayombong Nueva Ecija.

Source: Bureau of Public Works

Figure 9. The "Sausage" A Novel method for preventing river overflow on the Tumaga River.

Source: Bureau of Public Works

C. WWII to Marcos Regime

The era after World War Two is of great importance when it comes to flood control because it was at this time that rebuilding after the war began. According to the report of the Bureau of Public Works secretary Prospero C. Sanidad, from 1948 to 1949, works were undertaken for ports and harbors and sea protection walls, irrigation systems, waterworks and river control works. River and flood control priorities included the Pampanga River control and the Agno River control as well as the Manila Flood Control Program, during which time a master storm drainage plan was completed. Three major flood control projects were built during the presidency of Elpidio Quirino, Agno River control, Pampanga River control and Manila flood control and drainage project. And in 1958, a plan for the reclamation of a portion of Manila Bay was proposed along Dewey Boulevard and broadened by Manuel L. Quezon. Three major dams were built including Ambuklao Dam in 1950–56, Agusan Dam in 1956–57 and Angat Dam in 1961–67. Many authors wrote how they see the efforts done by the government through very critical eyes saying that the Marcos regime focused on infrastructure as a means to build up its power. "The state efforts to control floods pursued two aims: to tame nature and to discipline human nature." The first aim considered flooding as not just part of a natural order and therefore can be resolved through technical measures. The second aim is to discipline the people to eradicate "bad" attitudes deemed to contribute to flooding and to nurture socially responsible behavior. Of course, the first aim failed due to the difficulty of implementing the second. The goal to make the waterways free of obstructions is hampered by the existence of informal settlements along riverbanks who were often "blamed for floods." Therefore, they also became the primary targets of the state's flood control efforts (Pante, 2015). The government focused on beautifying the city of Manila but forgot to include "the nameless and faceless urban poor, who lived in their thousands in squatter communities along the esteros" (Warren, 2013). Mrs. Marcos, who was the governor of Manila, sees the squatters as an eyesore. The typhoons and floods that occurred in the Marcos years were labeled 'natural disasters' by the authorities in Manila. But in fact, it would have been more appropriate to label them un-natural or man-made disasters because of the nature of politics in those unsettling years" (Warren, 2013). The typhoons experienced during the 70s and 80s made the real problems very obvious, particularly in highly urbanized parts of the Philippines like Manila. There was an exponential growth of the population and rural-urban migration and the government failed to address the needs for housing of the growing squatter communities who dwelled out of sight of the path of the capital's crushing progress. These communities thrived in low lying and vulnerable areas that are directly in the path of typhoons and prone to flooding. Instead of solving these problems, the government focused on building world-class hotels, convention and cultural centers, chain drug stores, schools, hospitals and clinics, and shopping centers. The government fell into what can be called a national "quick-fix" relief aid syndrome. "The Marcos regime, from a purely political standpoint, could only think about short term effects, rather than thinking and operating on longer-term environmental scales in dealing with urban flooding as a serious and growing development challenge for Manila. The proclamations of a state of calamity benefitted the Marcos administration. The manipulation of disaster relief funds by the Marcos politicians and their ability to reap political and social capital from their risk management of floods" has been manipulated by the media. The Marcos administration was the prime beneficiary both economically and politically (Warren, 2013). Despite these points of view, it is only toward the end of the Marcos regime that the biggest Flood Control Project materialized is the Manggahan Floodway which was finished in 1986 after Marcos was ousted from power. The second phase which is the Paranaque Spillway, however, was not built by the next administrations up to the writing of this paper and is not in the priority projects even of the present administration of Duterte although comprehensive studies and plans have already been laid out by the Japan International Cooperation Agency (JICA) in 2018 patterned from the original concept drawn by the office of Ar. Felino Palafox Jr. shown in figure 13. This spillway was supposed to draw off floodwater from Laguna Lake into the ocean, preventing the flood disasters that now affect Metro Manila according to Ar. Felino Palafox (Palafox, 2017 as confirmed in an interview with him in 2019). Without the spillway, the construction of the Manggahan Floodway only created risk transference as the floodwater from Metro Manila is directed toward the Laguna Lake which floods the towns along the lake as shown in the study of Saguin (Saguin, 2017).

Figure 10. Manggahan Floodway.
Source: Bureau of Public Works

several edifices that still stand today but he also undertook major projects for flood control. The Magat Dam in Isabela was constructed in 1975 and finished in 1982 for irrigation and power generation. In 1978, flood control programs were given substantial budgets for a total of 3.5 billion pesos due to flood damage which was estimated at 30 million pesos. The proposed projects were the Manggahan Floodway, Napindan Hydraulic Control System, Parañaque Spillway, and Marikina Dam. However, the last two were not built or even started during his 20-year regime.

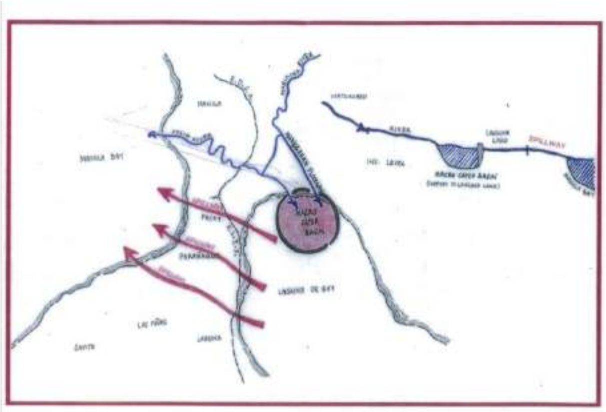


Figure 11. Paranaque Spillway Original Concept Diagram by the office of Ar. Palafox.

D. Post Marcos to the Present

After the Marcos regime, Corazon Aquino halted all projects with the name Marcos stamped to it including the flood control projects. Thus, according to some reports, only the first three parts of the Manggahan Floodway were completed in 1983, 1984 and in 1996; the Marcoses were ousted from power in 1986. The second phase which was supposed to be the construction of a spillway from Laguna de Bay to Manila Bay in case the lake overflowed in a massive flood was one of those projects that was scrapped by the Cory administration (Billington, 2009).

Figure 12. Napindan Hydraulic Control.
Source: Bureau of Public Works

Figure 13. Manggahan Floodway.
Source: Flicker.com

programs for the urban poor are evident as the Manggahan Floodway is not spared from the encroachment of informal settlements as shown in figure 15. This scenario puts more people in vulnerable situations.

Figure 14. Estero de Paco before and after the clean-up and relocation of the Informal Settlers.

Major flood control projects have been accomplished by the next administrations like the continuation of projects already started during the former regimes and immediate relief to respond to a disaster; such as the construction of the protective dikes in Pampanga to prevent further destruction by lahar after the Mount Pinatubo eruption in 1991; the rehabilitation of Ormoc City after the flash flood that devastated the city, also in 1991. Most of the projects as well remain to be either on the drawing board or partly built due to lack of funding. Therefore, although the plans are supposed to mitigate flooding, partly built projects become a false security and create more damage to lives and properties. An example of these projects includes the proposals for major rivers such as the Cagayan River Basin of which the plans laid out by Nippon Koei International Consulting Engineers still remains partly constructed and the continuing sedimentation of the river causes flooding and obsolescence of the Magat Dam, and therefore needs special attention.

After Typhoon Ketsana (Ondoy), rehabilitation of the Pasig River and its tributaries was one of the successful projects undertaken under the Pasig River Rehabilitation Commission (PRRC) in Manila. The effects on flooding of this project are yet to be seen but the project received international recognition in 2018 when the effort was awarded as the Asia River Prize Award. Along with it was the relocation of informal settlers along the rivers and esteros; clearing them from garbage that blocks the waterways. This also includes the in-city relocation of informal settlements along Manggahan Floodway. But like other projects, these are only part and parcel of the bigger project proposal.

With the administration under Rodrigo Duterte, the government's effort in nation-building is focused on infrastructure with its Build Build Build program. This includes the prioritization of Flood Control as one of the key projects. "The master plan proposed a set of measures to effectively manage major flood events, which include reducing flooding from river systems that run through the metropolis, by building a dam in the upper Marikina River catchment area in order to reduce the peak river flows entering Metro Manila during typhoons and other extreme rainfall events. Also included are the elimination of long-term flooding in the floodplain of Laguna de Bay, to protect the population living along the shore against high water in the lake; improvement of urban drainage, including modernization of Metro Manila's pumping stations; and improvement of flood forecasting, early warning systems, and community-based flood risk management (Finance, 2018). One of the biggest undertakings of this government is the continuation of the spillway project which has been undertaken by JICA in 2018 (JICA, 2018). However, this project is still on the boards.

E. Analysis

It can be noted that flood control strategies employed since the inception of the Bureau of Public Works (Department of Public Works and Highways) are focused on Risk Reduction with a few exceptions of Risk Avoidance strategies. The summary of these projects is shown in figure 18.

Major projects that employ risk avoidance strategies involve mostly relocation of vulnerable populations to less hazardous locations. The project which best represents this strategy is the relocation of San Juan town proper in Batangas. From then, flooding was never a problem in this town from Hispanic times until today. While major projects that employ risk reduction strategies create a false security scenario or risk transfer if left unfinished or poorly maintained. However, the two strategies need to be combined and a more innovative, efficient, cost effective and most of all, suitable for the local situation (local knowledge) must be employed.

Summary of Projects (Simplified Table)				
	Pre-Hispanic-Hispanic (1521-1898)	American (1898-1946)	WWII- Marcos (1946-1986)	Post-Marcos-Present (1986-2019)
Risk Avoidance	Relocation of town to higher ground; design of houses and buildings (primary considerations in locating cities)	Raising of driveways "well above high water", relocation of roads.	Eviction of informal settlers from waterways and dikes – Policy.	Relocation of informal settlements from esteros/waterways – Policy)
Risk Reduction	Irrigation canals used mainly to irrigate fields but also function as flood control. The use of plants for bank protection.	"Sausage", irrigation canals, riverbank erosion control (dikes, bamboo mats, walls, revetment), dams, dredging of rivers, channel diversion (pile hurdles, cut-off channels), channel improvement, flood canals, levees	Irrigation canals, riverbank, erosion control (dikes, walls, revetment), dams, dredging of rivers, channel diversion (cut-off channels), channel improvement, levees, flood canal, flood gates, flood reservoir, drainage, pumping stations, small water impounding management (SWIM), retarding lagoons	Irrigation canals, riverbank, erosion control (dikes, walls, revetment), dams, dredging of rivers, channel diversion (cut-off channels), channel improvement, levees, flood canal, flood gates, flood reservoir, drainage, pumping stations, small water impounding management (SWIM), retarding lagoons, mega dikes

Figure 15. Flood Control Strategies Summary Table.

V. Conclusion and Recommendation

Based on the records of flood control strategies from pre-Hispanic to the present, we can see that the focus since the creation of the bureau is mainly on risk reduction and not on risk avoidance as shown in figure 18. Most of the projects are engineering in nature and very few dealt with land use, thus neglecting the more important issues on housing, job creation, and others. Esteros and other natural drains are neglected and become breeding grounds of garbage, literally and figuratively. And even major engineering solutions such as the Manggahan Floodway just transferred the risk especially if the entirety of the proposal is not built. It is understandable that the application of available technology has been employed but the main reason for project implementation is the availability of funds and therefore very dependent on the priorities of the incumbent administration. The government has been trying to implement something that is not grounded in culture and local situations particularly in terms of economics. A number of proposals have been done but most projects have not been completely implemented thus providing false security and eventually neglected due to high maintenance cost as in the case of the failure of several pumping stations during Typhoon Ketsana (Ondoy). There are strategies that worked like the relocation of San Juan town proper to avoid flooding and the strategies employed by the Spaniards in selecting the location of the city. This only shows that the failure to consider land use planning in dealing with flooding brought the Philippines to the never-ending loop of flooding and recovery. The table below shows that there are very few risk avoidance strategies employed throughout history compared to the risk reduction strategies.

There must be some intervention. It is recommended that risk avoidance strategies should be given priority without losing the risk reduction strategies as both need to be working together. Risk reduction strategies should be combined with local or indigenous knowledge in order to be able to create strategies that are feasible and not very much dependent on borrowed engineering technologies. Figure 19 shows the illustration of the recommendation for a better way to build back better.

Further research must be done in order to make a more detailed analysis of the projects undertaken by the government in terms of their effectiveness.

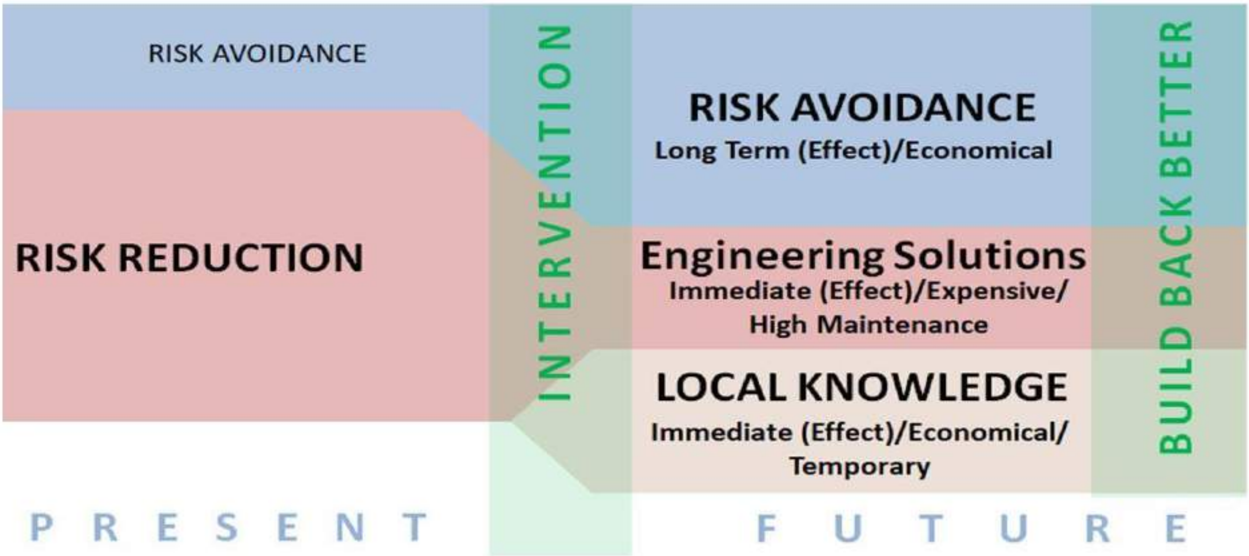


Figure 16. Recommendation.

References

Aduarte, F. D. (1640). History of the Dominican Province of the Holy Rosary. In *The Philippine Islands Vol. 30* (p. 162).

Balderama, O. D. (2014). Governance of Cagayan River Basin: characterization, institutional design and stakeholder participation toward development of integrated river basin masterplan. *International Conference on Ecohydrology* (pp. 340–347). Yogyakarta: Asia Pacific Centre for Ecohydrology - UNESCO and Research Center for Limnology - LIPI. http://katalog.limnologi.lipi.go.id/index.php?p=show_detail&id=797&keywords=

Bankoff, G. (2000). Constructing vulnerability: the historical, natural and social flooding generation in Metropolitan Manila. *Disasters*, 95–109. https://doi.org/10.1111/1467-7717.00230

Bankoff, G. (2007). Storms of history: water, hazard and society in the Philippines 1565–1930. In P. Boomgaard (Ed.), *A world of water: rain, rivers and seas in southeast asian histories* (pp. 153–183). Leiden: KITLV Press.

Bankoff, G. (2007). Storms of History: Water, hazard and society in the Philippines 1565-1930. In P. Boomgaard (Ed.), *A World of Water: Rain, Rivers and Seas in Southeast Asian Histories* (pp. 162–192). Leiden: KITLV Press.

Billington, M. (2009). George Shultz is still killing Filipinos. *IER News Service Inc.*, 33–34.

Bureau of Public Works. (1912, July 1). *Bureau of Public Works Quarterly Bulletin*, 12. Philippine Islands.

Bureau of Public Works. (1912, July 1). *Bureau of Public Works Quarterly Bulletin*, 9. Philippine Islands.

Bureau of Public Works. (1917, July 1). *Quarterly Bulletin of the Bureau of Public Works*, 19. Philippine Islands.

Bureau of Public Works. (1958). *Bureau of Public Works Annual Report*: *1957–58*, 4.

Chias, P., & Abad, T. (2012). Colonial urban planning and land structures in the Philippines, 1521–1898. *Journal of asian architecture and building engineering*, 9-16. https://doi.org/10.3130/jaabe.11.9

City government of Bacoor. (2017, February 1). *Lungsod ng Bacoor/Tourism/Historical Places*. Retrieved December 2, 2019, from Lungsod ng Bacoor: bacoor.gov.ph/tourism/prinza-dam/

EEA. (2013). *Adaptation in Europe - addressing risks and opportunities from climate change in the context of socio-economic developments* (EEA Report No. 3/2013). European Environmental Agency. https://www.eea.europa.eu/publications/adaptation-in-europe

EM-DAT. (2019). *EM-DAT: the emergency events database - Universite Catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.* CRED.

Escamilla, H. G. (2020, October 6). Personal interview. Office of Civil Defense Training Specialist.

Finance, D. O. (2018, January 9). *Department of Finance.* Retrieved January 18, 2019, from Department of Finance Website: http://www.dof.gov.ph?index.php/duterte-admin-targeting-january-start-of-500-m-metro-manila-flood-control-project/

Gilbuena, R. J. (2013). Gap analysis of the floor management system in Metro Manila, Philippines: a case study of the aftermath of Typhoon Ondoy. *Floods: From Risk to Opportunity*, 32-40. https://www.researchgate.net/profile/Akira-Kawamura-2/publication/283820205_Gap_analysis_of_the_flood_management_system_in_Metro_Manila_Philippines_A_case_study_of_the_aftermath_of_Typhoon_Ondoy/links/577c5ad508aec3b743367202/Gap-analysis-of-the-flood-management-system-in-Metro-Manila-Philippines-A-case-study-of-the-aftermath-of-Typhoon-Ondoy.pdf

JICA. (2018). *Data collection survey on Paranaque spillway in Metro Manila in the Republic of the Philippines.* https://openjicareport.jica.go.jp/pdf/12308284_01.pdf

Ocampo, R. B. (1992). Planning and development of prewar Manila: historial glimpses of Philippine city planning. *Philippine Journal of Public Administration*, 305–327. https://pssc.org.ph/wp-content/pssc-archives/Philippine%20Journal%20of%20Public%20Administration/1992/Num%204/07_Planning%20and%20Development%20of%20Prewar%20Manila.pdf

Palafox, F. J. (2017, June 15). Reviving the Parañaque spillway project. *The Manila Times*. https://www.pressreader.com/philippines/manila-times/20170615/281603830452084

Pante, M., & Loh, K. S. (2015). *Controlling nature: disciplining human nature floods in Singapore and Metro Manila, 1945–1980's*. Berghahn Books.

Rinaldi, S.M. (2001, December). Identifying, understanding, and analyzing critical infrastructure interdependencies. *IEEE Control Systems Magazine*, 11–25. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.89.2276&rep=rep1&type=pdf

Saguin, K. (2017). Producing an urban hazardscape beyond the city. *Environment and Planning A: Economy and Space, 49*(9). https://doi.org/10.1177/0308518X17718373

Tesoro, G. B. (2017). Flooding and occupation in a late-nineteenth-century Philippine town. In C. D. Beaule (Ed.), *Frontiers and colonialism.* Florida Scholarship Online. https://doi.org/10.5744/florida/9780813054346.003.0006

Vernon, C. (2011). Daniel Burnham's Philippines: the landscape dimension and its Australian import. *Espasyo: Journal of Philippine Architecture and Allied Arts*, *3*, 2–19.

Warren, J. F. (2013, October 21). A tale of two decades: typhoon and floods, Manila and the provinces, and the Marcos years. *The Asia-Pacific Journal*, *11*(43). https://researchrepository.murdoch.edu.au/id/eprint/50335/1/typhoons%20and%20floods.pdf

Zaide, P. (2018). *Floodscape urbanism: Architectural design strategies for Manila at risk* [Doctoral dissertation, United Royal College of Art]. Royal College of Art. https://researchonline.rca.ac.uk/3457/

The Spatial Expression of Informal Livelihoods: An Examination of Charcoal Production in Tondo, Manila and Resettlement

Olivia Alma G. Sicam [1]
ogsicam@up.edu.ph

Abstract

Access and provisions for livelihood are mandated by policies in housing resettlement. However, while the design and planning of housing developments typically focus on the particulars of housing units, little attention is given to the spatial details of livelihood reconstruction. The study addresses this issue by examining Ulingan, an informal settlement engaged in the communal production of charcoal, clarifying its spatial organization, and comparing it with St. Martha Estate Housing, the resettlement site. By examining charcoal-making in Ulingan and its spatial characteristics, the research sheds light on the organization of space in communal livelihoods within informal human settlements and highlights how it compares with socialized housing templates. ***The study suggests that, although spatial organization influences the cultivation of systems of cooperation in livelihoods, it is also important to consider the broader context in which informal livelihoods thrive. Future studies should examine the impact of spatial organization in different types of resettlement sites (e.g., in-city, off-city, slum upgrading) across various types of informal economies to inform planning for livelihood reconstruction.***

Keywords: informal economy, informal settlements, livelihood reconstruction, resettlement, socialized housing

I. Introduction

Livelihood is widely acknowledged as essential in the successful relocation of informal settlements to formal housing sites. In the Philippines, the *Urban Development and Housing Act of 1992* (UDHA) identifies affordable housing, basic services, and access to livelihood as requisites in the upliftment of the living conditions of the urban poor (*RA 7279*, 1992). Typical socio-economic spaces such as neighborhood multipurpose buildings, shopping centers, and transportation terminals are mandatory in socialized housing design (HLURB, 2008). However, little attention is given to the spatial requirements for livelihood reconstruction that restores and improves existing socio-economic systems in informal settlement relocation and the lives of resettlers.

To explore this issue, the study examines the role that existing livelihoods can play in informing its restoration at resettlement sites. Specifically, it scrutinizes the spaces in an informal charcoal production settlement in Tondo, Manila (Ulingan) and juxtaposes it against the off-site socialized housing development where the community was relocated (St. Martha Estate Homes). By examining charcoal-making in Ulingan and its spatial characteristics, the research sheds light on the organization of space in communal livelihoods within informal settlements and highlights how it compares with socialized housing templates. While the study recognizes the poor living conditions at the site brought about by charcoal production, it does not make any assessment on environmental quality and is limited to characterizing spatial organization. Data from field observation, key informant interviews, satellite imagery, and archival records are coded and analyzed to inform the research.

A. Background of the Study

The study focuses on an informal settlement engaged in the production of charcoal in the Tondo Manila Bay Area. The community was known as "*Ulingan*," derived from the word "*uling*" or charcoal, and was located at the northwestern edge of the Vitas Reclamation Project owned by the National Housing Authority (NHA). From 2013 to 2014, houses and charcoal stations were incrementally demolished, and residents were relocated in phases to St.

The author has undergraduate and graduate degrees in architecture. She is currently taking doctorate studies in the Designed and Built Environment with a focus on informal settlements in the waste economy. She is also an assistant professor at the University of the Philippines, College of Architecture.

Martha, a rowhouse development in a peri-urban site in Bocaue, Bulacan, approximately 33 kilometers away from the Tondo Manila Bay Area (Figure 1).

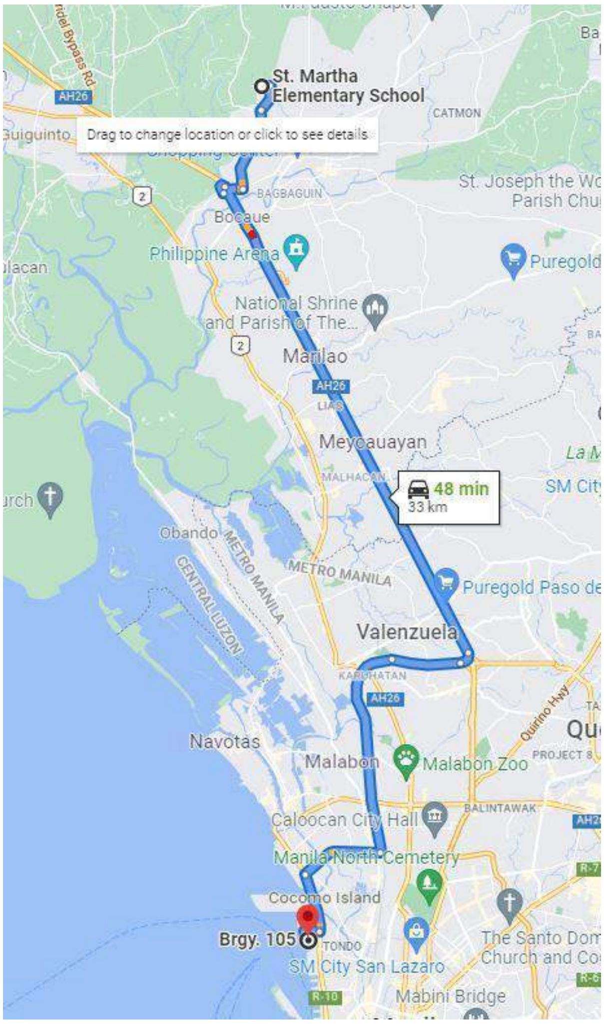


Figure 1. Directions from St. Martha Estate Housing to Ulingan, Tondo Manila. *Source: Google Maps, 2021.*

Informal charcoal production, an unregulated and illegal practice, has negative impacts on the environment and is associated with a number of occupational hazards. However, charcoal-making was a source of low-skill employment and income for the community and, apart from providing affordable energy to nearby low-income households, Ulingan also supplied charcoal to markets in other parts of Metro Manila.

Prior to eviction and relocation, Ulingan had more than a hundred self-built proprietary charcoal stations clustered at the center of its community surrounded by makeshift housing structures that were occupied by 330 recorded informal settlement families (NHA, 2013). It was part of a larger amalgamation of informal settlements along the bay. What set Ulingan apart from the other communities was its distinct and unique character defined by the production of charcoal—thick, smoky air, blackened structures, and the pervading odor of burnt wood. The "ulingan" was not only central to the community's economy but was also its identity. Aside from the lack of basic services, environmental quality was poor and charcoal-makers were not equipped with personal protective equipment (Figure 3).

In contrast, St. Martha Estate Homes in Batia, Bocaue, Bulacan is a rowhouse development that is typical of socialized housing units provided by the NHA, that included primary amenities such as power and water (Figure 3).

Figure 2. Charcoal production in Ulingan, Tondo, Manila. *Source: Olivia Alma G. Sicam, 2013.*

Figure 3. St. Martha Estate Housing, Bocaue Bulacan. *Source: Olivia Alma G. Sicam, 2016.*

B. Problem and Objectives

Access to livelihood is a primary consideration in the provision of shelter for the urban poor. However, unlike housing units, it is not expressed in detailed spatial or architectural terms and little attention is given to livelihood reconstruction during the design process. Current research and industry practice in socialized housing design and construction traditionally focus on the delivery of housing units. As a result, ways to meaningfully restore livelihoods in resettlement sites from a design and planning perspective are understudied.

To address this issue, the study aims to emphasize the role of space in the livelihoods of informal settlements by comparing the spatial organization of an evicted community and its relocation site. Consequently, the study has the following objectives: first, describe the existing livelihood system at Ulingan; next clarify its spatial organization and the spatial organization of St. Martha Estate Homes, the typical housing development where the community was relocated; and finally, compare the spatial qualities of both sites.

This study, by closely investigating the urban form of a livelihood-based informal settlement and its relocation site, can provide a more nuanced understanding of a community's existing socio-economic life that may inform the spatial terms of livelihood reconstruction in the design and planning of socialized housing prior to resettlement.

C. Review of Related Literature

Legislators recognize that socialized housing is rejected by a large percentage of beneficiaries due to the off-city location of resettlement sites, which tend to be far from income sources (*SBN-690*, 2019). As a result, the lack of economic opportunities is cited as one of the main justifications for amendments made to existing housing laws (*SBN-690*, 2019; *SBN-1216*, 2016; *HBN-236*, n.d.). But while livelihood and economic opportunities are widely acknowledged as essential components in socialized housing development, unlike housing units and basic services, they are not explicitly described in spatial or physical terms under the law or in guidelines set by government agencies aside from references to proximity, land area, and density.

Spatial provisions for livelihoods under the three (3) Philippine housing agencies—the Urban Development Coordinating Council (HUDCC), the National Housing Authority (NHA), and the Housing and Land Use Regulatory Board (HLURB)—are vague and inadequately represented. To illustrate:

1. The National Informal Settlements Upgrading Strategy (NISUS) of the Philippines, a report prepared by the HUDCC in 2014, envisions all informal settlement families (ISFs) to live in resilient, vibrant, and connected communities with transportation and telecommunication links to employment and other sources of livelihood (HUDCC, 2014). It references the UDHA, which aims to uplift the living conditions of the homeless by providing affordable housing, basic services, and access to livelihood through different national and local government agencies. In the UDHA's Implementing Rules and Regulations (IRR), livelihood is a part of post-resettlement procedures and is provided through skills training, livelihood programs, and loans (*RA 7279*, 1992).
2. The NHA is charged with developing and implementing housing programs in the Philippines, which includes housing development and resettlement, financing schemes, and private-public partnerships. Its mission is to build affordable, livable, and inclusive communities that have access to utilities, social services, and livelihood opportunities (NHA, n.d.). In line with its goals of providing technical assistance in housing development and planning, the agency recently published design and training manuals for housing units (NHA, 2017). The manuals cover the drawing details and specifications for residential units but do not provide any guidelines or recommendations for the design and construction of livelihood spaces in socialized housing developments. Furthermore, in the different phases identified in the NHA's process of providing shelter (pre-implementation, implementation, and post-implementation), livelihood is considered during implementation, which is already at the phase of infrastructure construction and the provision of basic services and community facilities (NHA, 2015). That is, it is phased after site planning and architectural and engineering design.
3. The HLURB has the authority to prescribe standards and technical requirements for socialized housing. Its Implementing Rules and Regulations (IRR) of 2008 provides the basis and objectives for the minimum design standards and prescribes technical and building design guidelines. In it, the different parameters in the formulation of design standards are identified, including the basic needs of human settlements, identified as water, movement and circulation, storm drainage, solid and liquid waste disposal, park/ playground, and power. The IRR also includes minimum standards in the provision of livelihood spaces. The mandatory allocation for community facilities, such as neighborhood multi-purpose centers, convenience/ retail centers, schools, and tricycle terminals, is described as a function of gross land area, or the number of saleable lots and dwelling units of the housing development, and as a function of density, or the number of lots or dwelling areas per hectare. These spaces are recommended to be located strategically within the development with a preference toward adjacency to the park or playground. (HLURB, 2008)

Current socialized housing development policies in the Philippines are replete with design and construction guidelines for housing units while livelihood provisions are relegated to post-resettlement procedures that focus on facilitating assets and developing skills. Although it is acknowledged that resettlement provides improved housing conditions, most displaced families still experience negative impacts on their livelihood circumstances (Nikuze et al., 2019). Because the exclusion of livelihood reconstruction in the planning and development of resettlement projects can intensify generational poverty and heighten impoverishment risks. Thus, development studies advocate for the inclusion of livelihood reconstruction in planning processes (Cernea, 2008; Cherunya et al., 2021; Koenig, 2014; Nikuze et al., 2019), which includes involving affected communities in discussions during preparatory stages (Nikuze et al., 2019). However, there is a tendency for the participatory approach in slum upgrading to be narrowly interpreted and fail to respond to the livelihood reconstruction needs of communities. Traditional approaches to sustainable livelihoods focus on the facilitation of assets and do not address the adaptive strategies that emerge in precarious circumstances to secure livelihoods (Cherunya et al., 2021). Furthermore, urban resettlement deals with a range of complex issues, including the diversity of livelihood strategies and incomes among the urban poor (Koenig, 2014). This underscores the inadequacy of current standardized solutions for restoring and improving the socio-economic capacities of displaced communities.

The role of space is emphasized in mapping the precariousness of day-to-day activities to fulfill the livelihood needs of the urban poor. In a study on the challenges of reconstructing livelihoods in the context of informal settlement upgrading, Cherunya et al. (2021) found that domestic spaces in improved housing disregard the dynamic circumstances of beneficiaries and prevent them from accessing alternative livelihoods, which may result in the deterioration of housing facilities. Their research suggests that a lack of understanding of livelihood reconstruction can degrade spatial quality, worsen living conditions, and contribute to further impoverishment. This study builds on the examination of space as a primary component in livelihood reconstruction by utilizing urban design language to characterize spatial organization.

D. Methodology

The study explores ways informal livelihoods can be characterized by examining the spatial organization of charcoal production in an evicted informal settlement and by comparing it with a typical resettlement site. It aims to systematically describe and compare the order of spaces in informal and formal housing with a particular focus on livelihoods. The study draws on two (2) sets of data: qualitative primary and secondary data collected from 2013 to 2014, during the relocation period; and data gathered in 2016 and 2021 after resettlement.

A case study is used to compare pre- and post-resettlement livelihood spaces. Data are examined and collected on the informal settlement, Ulingan, and the relocation site, St. Martha Estate Housing, through field observations and interviews. These are then reviewed, coded, and mapped. Spatial patterns and themes in both sites are identified and examined using spatial principles of urban design (Schenk, 2013). These principles clarify the organization of space by categorizing urban forms according to typology (Table 1). Diagrammatic maps are coded on satellite images extracted from Google Earth Pro.

Table 1. Organizational Principles (adapted from: Schenk, 2013)

URBAN DESIGN ORGANIZATION PRINCIPLES			
SPATIAL PRINCIPLE	TYPES	DESCRIPTION	
General Organization	Non-Geometric	Biomorphic/ Organic	Curved layout; shaped by natural forces; evolved, vibrant, dynamic, or fluid character.
		Free, Artistic Composition, Collage	Loose arrangement of buildings in a park; detached; free; soft and fluid; planned; requires an explanation from authors.
	Geometric	Orthogonal Grid	Efficient division of land; common organizing principle; lots are arranged in an orthogonal grid.
		Circular	Radial streets.
		Hexagonal, Star, Honeycomb	Non-hierarchical hexagonal grid; hexagonal city blocks.
Spatial Relationships	Additive	Pre-defined parts; the sum of assembled parts; can be applied in different scales; can either be augmented, changed, and extended or fixed; not confined to a grid.	
	Divisional	Pre-defined overall form; parts are generated by dividing the whole.	
	Superimposition	Superimposing two or more ordering systems; enriches the spatial experience.	
	Single Entity/ Grad Form	Individual parts merge into an overall form; can be non-geometric or geometric; enclave.	

Primary data were collected through systematic observations and semi-structured interviews during field visits from 2013 to 2014, covering the last year of charcoal production, the demolition of Ulingan's structures, and the eviction of the community, and in 2016 in St. Martha Estate Housing, documenting the resettlement site. Panoramic photographs from Google Street Views are also used. Most field visits to Ulingan were conducted with the assistance of a local guide from the Tondo Manila Bay Area, while other visits were NHA-assisted inspections during incremental clearing and relocation operations. Observation, documentation, and interviews at Ulingan, recorded through field notes, photo documentation, and video recordings, aimed to distill information on the charcoal production process, networks, and their spatial outcomes. The interviews in St. Martha Estate Housing in 2016, on the other hand, aimed at gathering data on the spatial character and livelihood opportunities at the relocation site. To this end, interviews with former Ulingan residents who continued to work in Manila despite resettlement were also conducted in the vicinity of the former site, Barangay Aroma, in the Tondo Manila Bay Area in 2016 and in 2021. Participants in interviews before and after resettlement were composed of convenience samples of charcoal producers and their networks. Among the participants, two (2)—Respondent 1 (R1) and Respondent 2 (R2)—were interviewed in the pre- and post-resettlement phases in 2013, 2014, and 2016. R1 was also interviewed in 2021 with other respondents. These interviews provided insights into the progression of experiences of the same individuals and their families over time. NHA employees, barangay officials, and community leaders were also interviewed for additional context. Archival records to verify geographic and demographic data were collected from the City of Manila, the Department of Social Welfare and Development (DSWD), and the NHA.

The study recognizes a number of limitations. First, the analysis only considers the internal spatial elements in both sites and does not look into external variables such as geographic and socio-economic characteristics that may also have a significant impact on livelihood development. Second, the informal economy is a complex network that involves an immense variety of goods, services, and markets. Ulingan's very specific focus on charcoal production limits the study's generalizability. Third, the interviews were not exhaustive and are not representative of the entire community. Resettlers have different resources and capacities and will, therefore, have varying experiences. To address these issues, further research can also include an examination of extraneous variables that can influence livelihood reconstruction across different informal typologies and geographies (e.g., in-city/off-city resettlement) that includes a larger sample size or a more diverse profile of interview participants.

II. Data and Findings

The study focuses on the spatial outcome of the socio-economic activities in Ulingan, an informal collective involved in the production of charcoal, and compares it with the spatial qualities of St. Martha Estate Housing, the off-city resettlement site where the community was relocated. By comparing and contrasting the two (2) urban forms, the research provides insights into the role of space of informal livelihoods in the restoration of existing socio-economic systems in socialized housing developments.

The findings of the study are presented chronologically. First, charcoal production in Ulingan is described to establish the existing livelihood system of the community. Next, Ulingan is characterized to clarify its spatial organization prior to demolition, followed by the characterization of St. Martha Estate Housing where the community was incrementally resettled after eviction. Ulingan was an informal settlement located in the port area of Tondo, the most populated district in Manila with 628,363 people (PSA, 2015). In contrast, St. Martha Estate Housing is located in Bocaue, Bulacan, a peri-urban site with a population of 119,675 (PSA, 2017).

A. Ulingan Livelihood Systems

Ulingan was accessed through R-10 by entering the NHA right of way that was also the main access road to Pier 18, which served as a temporary dumpsite for Manila's wastes. A dirt road leading to the community through Sitio Damayan, a larger informal settlement, could be traversed on foot or in different types of land vehicles—from small pedicabs to large dump trucks. The site was bounded to the north and west by the bay, to the south by a privately leased area, and to the east by Sitio Damayan. There were no connections to basic services such as power and water.

Charcoal production involved different sets of people: the community leader, charcoal producers (proprietors and laborers), raw material suppliers (junk shops, dump trucks, scrap wood collectors or *mangangahoy*), and buyers (wholesale and retail). The community leader assigned plots to proprietors for charcoal stations. The proprietors could perform multiple roles: from collecting their own scrap wood for raw materials, providing their own labor in the making of charcoal, and selling their own products directly to end-users. There were four (4) key stages: (1) delivery and stockpiling of raw materials; (2) production; (3) packaging; and (4) trading/distribution (Figure 4).

Delivery and stockpiling of raw materials.

The raw materials used in the production of charcoal were used and discarded wood, sourced from nearby port facilities and construction and demolition sites all over Metro Manila. Wood raw materials were brought to designated stockpiling areas or *tambakan* inside Ulingan that were easily accessible to charcoal producers. These were delivered directly to Ulingan or through middlemen, such as the junk shops and the *mangangahoy* in the Tondo Manila Bay Area. Some Ulingan charcoal station proprietors were also involved in collecting their own scrap wood. Drop-off areas for stockpiling raw materials were located along R-10 and in designated tambakan areas in Ulingan. The scrap wood was delivered in large quantities by dump truck or in smaller quantities by pedicab, sidecar, or *kuliglig* (modified motorized pedicab) or other such light vehicles.

Production

The production process of charcoal involved sorting, stacking, carbonization, and cooling. This was accomplished in designated, independently-owned charcoal stations or kilns. While charcoal-making was a communal industry, each kiln or station had its own production schedule depending on the resources and skills of each proprietor. Based on interviews, the number of charcoal stations ranged from one hundred (100) to one hundred forty (140), with production capacities that ranged from fifteen (15) to one hundred (100) sacks per cycle depending on the size of the charcoal kiln. Each sack of charcoal produced could be divided into fifty (50) smaller packages that were sold for individual household use. On average, each charcoal station had a production rate of two cycles per week.

Stacks of scrap wood were brought to individual charcoal stations by light vehicles or on foot. Preparation for a batch of charcoal took half a day. Solid wood pieces were neatly stacked inside the stations, enclosed from bottom to top in scrap galvanized iron sheets, and topped with soil. The stack was then lit up with fire for the three-day carbonization process of wood. After carbonization, the kiln was cooled by sprinkling water brought in small buckets and the metal enclosure was then removed for re-use in the next cycle.

Packaging

The finished charcoal was sorted and packaged by sack or by smaller plastic bag units. The charcoal was packaged and sold in two (2) ways—in PVC sacks to be sold wholesale on-site or delivered to markets, and in smaller plastic bags to be delivered and sold retail to the nearby communities. Each piece of carbonized wood was inspected for nails, screws, and other attached recyclable materials during the packaging stage. Recovered objects were collected and sold to the junk shops along R-10.

Trading and Distribution

Charcoal proprietors either sold their products to wholesale buyers, who purchased the charcoal on-site and distributed them off-site, or they engaged in off-site wholesale and retail delivery themselves. The markets for Ulingan-produced charcoal included five (5) informal settlements in Tondo with the highest population in Manila—Baseco, Parola, Aroma, Vitas Katuparan, and Smokey Mountain; major markets in Manila—Divisoria and Pritil; and major markets in nearby areas outside of Manila—Navotas and Malabon.

The relocation process and incremental demolition of housing structures began in 2013. By 2014, housing structures were completely demolished while the proprietors of the remaining charcoal stations completed their last batches of charcoal. In interviews, the last proprietors on-site expressed feelings of apprehension and uncertainty toward the future at the loss of their main source of livelihood.

Housing conditions were significantly improved at the resettlement site, in comparison to the makeshift housing structures in Ulingan. This was observed during a field visit and interviews in 2016. However, some of the resettlers complained of lowered incomes and difficulties in sourcing alternative livelihoods. Others maintained ties with Tondo, Manila. Two (2) respondents from 2013 and 2014, R1 and R2, were interviewed at St. Martha Estate Housing. R1 secured quarters at Barangay Aroma, an informal settlement in Tondo, Manila near the former Ulingan, and opened a market stall while maintaining her housing unit at St. Martha. Her husband engaged in other sources of income, such as pig farming. R2 continued to produce charcoal in a different town in Bulacan, which she sold at a public market in Tondo, Manila. Both indicated that they were additionally burdened by the longer commutes.

Resettlers who engaged in livelihoods in Barangay Aroma, including R1, were interviewed in 2021. R1 continued to maintain both her market stall in Tondo and her housing unit in Bulacan. She related that most of her neighbors at St. Martha already sold their housing units and moved back to Tondo. However, there were others, like her, who kept their houses in Bulacan and periodically commuted back and forth to Manila for work.

Figure 4. Charcoal production process. *Source: Olivia Alma G. Sicam, 2013.*

B. Spatial Organization

Ulingan

Two (2) major zones defined the community—the charcoal production cluster (Figure 5), composed of charcoal stations, and the residential perimeter of self-built houses (Figure 6). It had a biomorphic form with paths that curved in and around the site. Informally defined unpaved roads that could accommodate large trucks extended into networks of narrow paths for smaller vehicles and pedestrians, with several points for stockpiling raw materials and end products evenly distributed throughout the production cluster.

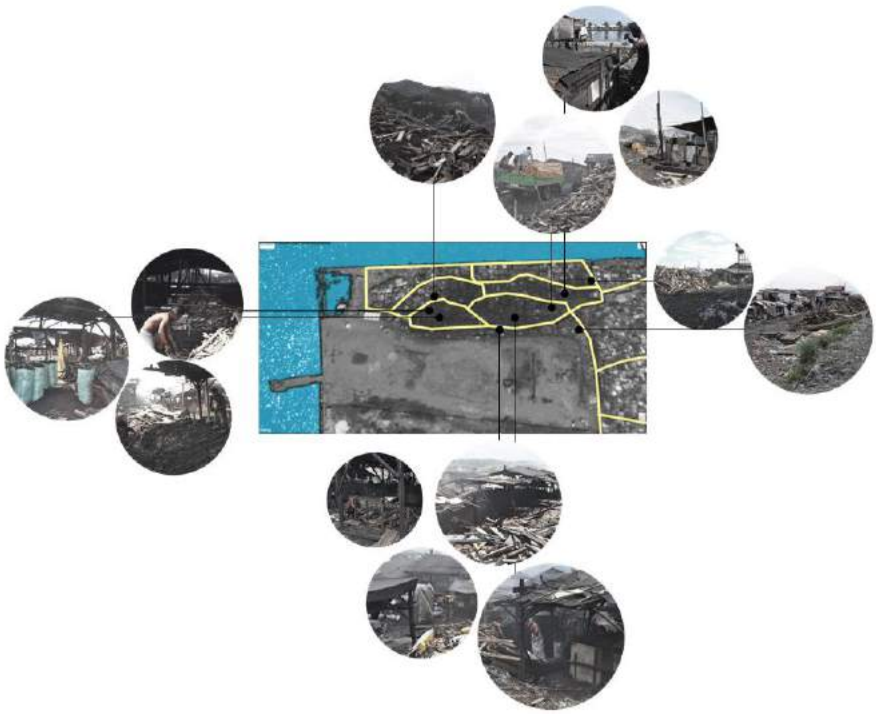


Figure 5. Mapping of the charcoal production cluster. *Source: Olivia Alma G. Sicam, 2013; Base map: Google Earth Pro.*

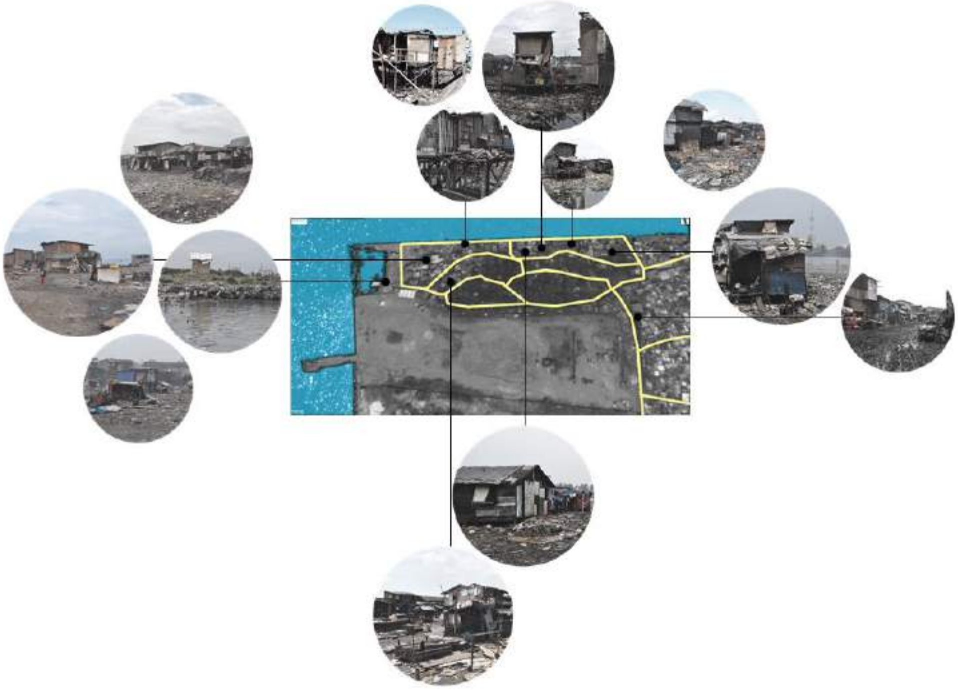


Figure 6. Mapping of the residential perimeter. *Source: Olivia Alma G. Sicam, 2013; Base map: Google Earth Pro.*

The residential perimeter was a high-density area with single and two-storey structures mostly made of light-weight materials. Houses along the break water to the north and the west were raised on stilts. Most houses observed did not have fenestrations except for the main entrance door. The production cluster was a high intensity zone with closely spaced charcoal stations. Stations had two (2) basic configurations: (1) tent and kiln or (2) kiln only. The tent was made of a light framing system of wood vertical posts attached to a batter board on the ground that had a pvc fabric tarpaulin roof and was open on all sides. The kiln was built from wood stakes supporting used plywood or galvanized iron sidings or shoring that enclosed the stacks of wood that were later carbonized into charcoal.

Fumes from the charcoal kilns blackened building surfaces and covered the site in a thick fog of smoke. Ulingan's built forms merged into a charcoal production enclave for its residents. The individual charcoal stations clustered into a single grand form with biomorphic exterior edges and served as an open central area that was enclosed by the residential perimeter (Figure 7).

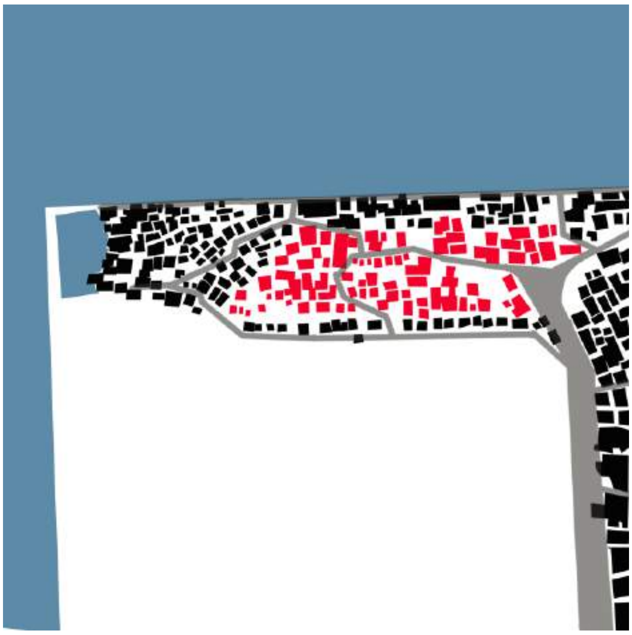


Figure 7. Spatial organization of Ulingan, Tondo, Manila. *Base map: Google Earth Pro.*

St. Martha Estate Housing

The resettlement site was organized by a geometric orthogonal grid. It had a formally defined perimeter of row houses and was surrounded by large tracts of land. Building blocks were composed of single-storey row houses. The units had a generous interior vertical space that could be converted into a loft. Row houses were made of reinforced concrete columns and beams with concrete masonry walls, reinforced concrete slab-on-fill, and galvanized steel roof (NHA, 2017). An elementary school was located at the center of the community with buildings that partially enclosed a front open space. Other open spaces were composed of undeveloped lots. The development had provisions for electricity and running water.

Branching from the main road, the resettlement site was an assemblage of predefined and repetitive units. It was augmented to the north by a second housing development phase. The row house blocks allowed for future expansion (Figure 8).

Figure 8. Spatial organization of St. Martha, Bocaue, Bulacan. *Base map: Google Earth Pro.*

III. Discussion

It is widely acknowledged that livelihood is an essential part of housing resettlement. Apart from the mandatory allocation for community facilities, livelihood provisions in resettlement sites also involve skills training, capacity building, and the facilitation of capital. However, socialized housing development typically focuses on the design of housing units while spatial considerations for livelihood reconstruction remain understudied. As a result, there is a limited understanding of how the allocation of space in housing developments impacts capacities to restore and improve livelihoods. To address this, the study characterizes livelihood space in an informal charcoal production community and a socialized housing resettlement site and compares the two (2) sites by articulating spatial organization through urban design principles.

Table 2. Spatial Organization Comparison

SPATIAL ORGANIZATION		
PRINCIPLE	ULINGAN, Tondo, Manila	ST. MARTHA ESTATE HOUSING, Bocaue, Bulacan
GENERAL ORGANIZATION	Non-geometric; biomorphic.	Geometric, orthogonal gird.
RELATIONSHIP OF PARTS TO WHOLE	Grand form; unplanned enclave.	Additive; planned rowhouse development.

The data suggests that, while the housing resettlement site at St. Martha Estate Housing improved living conditions, it did not address the spatial requirements of livelihood needs that the resettlers from Ulingan were accustomed to. The two (2) sites had contrasting spatial organizations and different assemblage patterns (Table 2). Ulingan's spaces were organized to cultivate a common business among neighbors, whereas the row houses at St. Martha focused on individual housing units. What was lost at St. Martha were the spatial qualities in Ulingan that allowed the community to share resources, foster socio-economic networks, and self-organize.

Shared resources

The clustering of charcoal stations at the community core of Ulingan provided equal access to livelihood spaces, which was convenient to the charcoal producers. While charcoal stations were individually managed, the communal production cluster also allowed for the sharing of space and resources that was essential to the business of making charcoal. Common spaces included circulation and stockpiling areas where suppliers and buyers from outside the community intermingled with charcoal producers. In contrast, St. Martha had linear, structured residential blocks that did not orient toward community spaces.

Fostering networks

Resource-sharing enabled the community to form a medium-scale industry in the production of charcoal. Ulingan was a hub for the supply of charcoal in the Tondo Manila Bay Area and was supported by a network of backward and forward linkages. The eviction of the community disconnected the complex socio-economic links in Tondo that fostered the lively informal charcoal production economy.

Capacity to organize

Informal settlement formation is associated with organic spatial morphologies. While it is the general perception that informality is unplanned, Ulingan was, to a certain extent, internally planned. The site was overseen by a community leader who designated plots for charcoal stations that were individually managed. This resulted in the centralization of production spaces for charcoal-making that strengthened the community's capacity to organize and work toward common interests. A lack of shared spaces and central axis, typical of resettlement housing, reduces interactions among neighbors and inhibits social cohesion.

The results build on the evidence that a more nuanced understanding of how the urban poor communities navigate socio-economic spaces in addressing the precariousness of everyday life can inform livelihood reconstruction (Cherunya et al., 2021). The typical rigid and linear spaces at row housing resettlement sites do not respond to the dynamic circumstances of resettlers and limit access to communal livelihoods. This can lead to the worsening of living conditions and impoverishment of relocated communities. By examining the spatial patterns that emerge from the lived experiences of beneficiaries prior to relocation, ways in which livelihoods are restored at resettlement sites can be better understood.

However, it should be noted that external factors, such as geography and local economy, play an important role in determining access to livelihood opportunities. The Tondo Manila Bay Area is the most densely populated district in Manila and constitutes a large market for the informal economy. The success of charcoal production at Ulingan can be attributed to the high demand for charcoal as the main source of affordable energy in the urban poor communities of Tondo. St. Martha Estate Housing, on the other hand, is a peri-urban site with a much smaller population. In addition, the informal economy covers a broad range of goods and services that have their own spatial characteristics. Generalizability is limited by characteristics that are very specific to charcoal production. Future research is needed to establish the interrelationships between location, the informal economy, livelihoods, and spatial organization.

IV. Conclusion

While livelihood is recognized as essential to housing for displaced informal settlers, the role of space in informal settlement livelihoods as a means to inform reconstruction at resettlement sites remains understudied. By investigating communal charcoal production in an informal settlement in Tondo, Manila, clarifying its spatial organization, and comparing it with that of the resettlement site in Bocaue, Bulacan, the study establishes the value of space in supporting community livelihoods. However, this does not take into account other variables such as location and type of goods or services in the informal economy that also have an impact on accessibility and marketability of livelihoods at resettlement sites.

This suggests that, although spatial organization influences the cultivation of systems of cooperation in livelihoods, it is also important to consider the broader context in which informal livelihoods thrive. Future studies should examine the impact of spatial organization on different types of resettlement sites (e.g., in-city, off-city, slum upgrading) across various types of informal economies to inform livelihood reconstruction.

References

Cernea, M. M. (2008). IRR: An operational risks reduction model for population resettlement. *Hydro Nepal: Journal of Water, Energy and Environment*, *1*, 35–39. https://doi.org/10.3126/hn.v1i0.883

Cherunya, P. C., Truffer, B., Samuel, E. M., & Lüthi, C. (2021). The challenges of livelihoods reconstruction in the context of informal settlement upgrading. *Environment and Planning A*, *53*(1), 168–190. https://doi.org/10.1177/0308518X20926514

Housing and Land Use Regulatory Board. (2008). *Revised Implementing Rules and Regulations for B.P. No. 220 (with Amendments)*. Housing and Land Use Regulatory Board. https://hlurb.gov.ph/wp-content/uploads/laws-and-issuances/Revised_IRR_BP220_2008.pdf

Housing and Urban Development Coordinating Council. (2014, July). *Developing a National Informal Settlements Upgrading Strategy for the Philippines*, 1–251. https://hudcc.gov.ph/sites/default/files/styles/large/public/document/NISUS%20Final%20Report_July2014.pdf

Housing and Urban Development, HB08248, 18th Congress. (2019). https://www.congress.gov.ph/members/search.php?id=belmonte-jc&pg=commem.

Koenig, D. (2014). Reconstruction and improving livelihoods among the urban displaced: Lessons from Mumbai, India. In J. Perera (Ed.), *Lose to gain: Is involuntary resettlement a development opportunity?* (126-150). Asian Development Bank. https://www.adb.org/sites/default/files/publication/41780/lose-gain-involuntary-resettlement.pdf

National Housing Authority. (n.d.). *About*. Retrieved March 19, 2018, from nha.gov.ph/about/

National Housing Authority. (2015). *National Housing Authority Quality Manual*. Office of the President, National Housing Authority. https://doi.org/10.1243/pime_proc_1985_199_061_02

National Housing Authority. (2017). *National Housing Authority Standard Housing Models Design Manual Guidelines on One-Storey Dwelling Unit*. Housing Technology Development Office, National Housing Authority. https://nha.gov.ph/wp-content/uploads/2020/02/Design-Manual-Guidelines-on-one-storey-dwelling-unit.pdf

Near City Resettlement Act, Senate Bill No. 690, 18th Congress. (2019). http://legacy.senate.gov.ph/lisdata/3106727965!.pdf

Nikuze, A., Sliuzas, R., Flacke, J., & van Maarseveen, M. (2019). Livelihood impacts of displacement and resettlement on informal households - A case study from Kigali, Rwanda. *Habitat International*, *86* (September 2018), 38–47. https://doi.org/10.1016/j.habitatint.2019.02.006

On-site, In-city, or Near City Resettlement Act of 2016, Senate Bill No. 1216, 17th Congress. (2016). https://legacy.senate.gov.ph/lisdata/2504321578!.pdf

Philippine Statistics Authority. (2015). *Philippine Statistics Authority, 2015 Census of Population Report No. 1 - A NATIONAL CAPITAL REGION (NCR) Population by Province, City, Municipality, and Barangay*. https://doi.org/ISSN 0117-1453

Philippine Statistics Authority. (2017). *2015 Census of Population Demographic and Socioeconomic Characteristics Bulacan*. Republic of the Philippines, Philippine Statistics Authority. https://psa.gov.ph/sites/default/files/03_Bulacan.pdf

Schenk, L. (2013). *Designing cities* – basics, principles, projects. Birkhauser.

Urban Development and Housing Act of 1992, Republic Act 7279, 5th Regular Session of the Philippine Congress, (1992). https://urbanlex.unhabitat.org/sites/default/files/philippines_republic_act_7279.pdf

Investigating Traffic Noise Levels Using FWHA Traffic Prediction Model In the Streets of Quezon[1]

Cherry Amor Ailes del Barrio [1]
archeamor@gmail.com

Florencio Romario Ty Sebastian III [2]
arkitect_sebs@yahoo.com

Mark Abraham Sangueza Goduco [3]
markgoduco@gmail.com

Luis Maria Tiansay Bo-ot [4]
lt.boot@up.edu.ph

Abstract

The potential of the Traffic Noise Model version 2.5 (TFNv2.5) in simulating and predicting traffic noise pollution levels on major streets of Quezon City is explored. The TFNv2.5, supported by a scientifically founded and experimentally calibrated acoustic computation methodology, was applied to three (3) sites within Quezon City, chosen due to their key locations and different urban environments, namely: educational, hospital and residential. To identify the traffic noise impact, traffic volume count at these selected sites of the city were obtained from pertinent government data and the results are compared against World Health Organization standards. The study further explores mitigation of unacceptable noise level results through the incorporation of reasonable and feasible measures available in the same software, such as attenuation over/through rows of buildings or dense vegetation, or noise barrier design vis-à-vis realistic possibilities in each case study's unique context.

Keywords: Traffic, Noise, Prediction, Software, FHWA, Quezon City

1 Cherry Amor A. del Barrio is a practicing Architect and an Instructor at the Department of Architecture in the Technological Institute of the Philippines. She is currently a graduate student at the College of Architecture, University of the Philippines, Diliman where she is taking Master of Architecture – Building Science.

2 Florencio Romario T. Sebastian III is a practicing Architect and a partner in a construction company. He is an active member of the United Architects of the Philippines, a singing alumnus of the Philippine Madrigal Singers, and a Kendo practitioner.

3 Mark Abraham S. Goduco is an Architect at the Office of Design and Planning Initiatives in University of the Philippines. He is currently a graduate student at the College of Architecture, University of the Philippines Diliman where he is taking Master of Architecture.

4 Luis Ma. T. Bo-ot is an Associate Professor and Architecture Graduate Studies Director of the College of Architecture in University of the Philippines Diliman.

I. Introduction

Two of the current trends affecting the design and construction development in the Philippines are climate change awareness and disaster preparedness; various steps are taken to address air, water and land pollution and alternative material innovations are now focused on strength, resiliency and cost efficiency. However, there has been little effort to address the compelling need to mitigate noise pollution in terms of building construction and design. And as our cities develop an uncontrolled growth through urbanization and in-migration, our problem with noise will only continue to aggravate.

According to World Health Organization Guidelines, annual average night exposure should not exceed forty (40dB) decibels. People exposed to higher levels over the year can suffer mild health effects, such as sleep

1 This article was originally submitted as a class requirement for Arch 255-Environmental Technology under Prof. Luis Ma. Bo-ot, PhD.

disturbance and insomnia. Long-term average exposure to levels above 55dB can trigger elevated blood pressure, stroke and heart attacks. Studies show that for every 10dB of added noise on a person exposed from 42dB up to 84dB, there is a 12% increase in the risk of having a heart attack. It has been medically proven that prolonged exposure to noise levels around 80dB can cause permanent hearing loss. Thus, the dangers posed by noise pollution must not be ignored.[1]

The national standards for a residential area is 60dB during the day and 50dB at night. However, many residential areas in Metro Manila averages at 80dB from six in the morning up to seven in the evening, and 65dB from ten in the evening up to four in the morning. One of the main noise contributors according to a study conducted by Asian Development Bank are the two and three-wheeled vehicles that produces as high as 97dB up to 110dB for areas densely populated by tricycles.[2]

Section 5 of the Philippine Environment Code (PD 1152) promulgated in 1977 states that, with regard to community noise standards,—appropriate standards for community noise levels shall be established considering, among others, location, zoning and land use classification.

Stress-related health problems such as stroke and heart disease are today being linked to traffic noise. On a research conducted by Michelle Brandt of Stanford Medicine in June 2012, that is been tracked for an average of 10 years starting 1993; It is determined that for every 10dB of added traffic noise on persons exposed from anywhere from 42dB of traffic noise—considered ambient noise—to 84dB, there's a 12 percent increase in heart attack risk.[3]

Another research titled The Effect of Road Traffic Noise at Hospitals in Baghdad City by Zeena T. Jaleel from the University of Technology Building & Construction Eng. Department, states that the noise impact to mental and physical health affects sleep, conversation, perception of annoyance, hearing loss and cardiovascular problems as well as task performance.[4]

A multi-year survey of 5,075 people living in and around Stockholm conducted at the Institute of Environmental Medicine in Sweden showed that traffic noise exposed all surveyed participants to diabetes risk factors.[5]

FWHA Software

The Federal Highway Administration (FHWA) has developed the FHWA Traffic Noise Model (FHWA TNM), a state-of-the-art computer program for predicting noise levels in the vicinity of highways.[6]

The FHWA TNM calculates sound levels for locations with and without noise barriers. The FHWA TNM allows for analyses of noise from constant-flow and interrupted-flow traffic and determines the effects on noise levels of different pavement types, graded roadways, rows of buildings, dense vegetation, and parallel noise barriers.

This software will be used to investigate the traffic noise levels on the streets of Quezon City.

II. Methodology

a. A Google Map image was used as a basis to create a scaled AutoCAD file projecting building boundaries, streets, open areas, and landscape of three different locations, having a 250-meter radius each in Quezon City. The chosen locations were specific to residential, health, and institutional areas. For a higher degree of accuracy, actual measurements were taken on site such as road and sidewalk widths, building frontage, and the like.

b. The generated map was used in the TNM v2.5 software and was then subjected to five standard vehicle types, including automobiles, medium trucks, heavy trucks, buses, and motorcycles, as well as user-defined vehicles on constant-flow and interrupted-flow of traffic using the most current field measured data base from DPWH

c. Multiple target receivers were strategically placed in locations with varying height and distance from the road to predict the traffic noise exposure sound levels and attenuation over/through rows of buildings and dense vegetation based on a one-third octave-band data base and algorithms.

d. TNM v2.5 features such as multiple diffraction analysis, parallel noise design barrier analysis, contour analysis, including sound level contours, barrier insertion loss contours, and sound level difference contours were optimized to come up with recommendations to mitigate or at least reduce the documented traffic noise pollution.

III. Case Studies

A. Residential: New Manila

For Manila's upper- and middle-class families during the American colonial period in the Philippines, particularly during the 1920's-1930's, the country's capital city Manila was experiencing unprecedented progress and commercial expansion which brought out much stress that they consider moving to Manila's outskirts or suburbs instead. Part of this development became what was known as New Manila, a vast area of lush greenery with elevated topography and a hilly terrain. However, in recent years, a new wave of development has begun in New Manila as property developers scrambled anew in developing the district, with a number of them putting up condominiums or residential high-rises standing out in this once-quaint district, not to mention the rise of low-level developments like townhouses. With all these changes, the district has nonetheless maintained its residential image.

Eulogio A. Rodriguez Sr. Avenue (popularly called E-Rod today) is one of the major thoroughfares bordering New Manila's residential zone. Over the years, it has become highly commercialized with restaurants, mini-malls, groceries, and shops sprouting along its length, not to mention high density places such as high-rise condominiums, schools, and sports clubs. The jeepney and tricycle are the main mode of public transportation, along with private vehicles and trucks, make E-Rod a very busy road, hence, the focus of this study.[7]

B. Health: The Lung Center of the Philippines

The Lung Center of the Philippines (LCP) is a government owned and controlled corporation established to provide the Filipino people state-of-the-art specialized care for lung and other chest diseases. It is located along Manuel L. Quezon Avenue (popularly called Q-Av) where a few other hospitals are located such as the National Kidney and Transplant Institute (within the LCP compound) and the Philippine Children's Medical Center (PCMC). [9]

Quezon Avenue is different from other roadways in Quezon City in that it is heavily tree-lined on both sides including the center island, not to mention the 22.7-hectare Ninoy Aquino Parks and Wildlife right across which becomes a botanical and zoological barrier to air and noise pollution.

C. Educational: University of the Philippines, Diliman Campus

The University of the Philippines Diliman (UPD) is the biggest campus and the physical seat of the UP System (UPS) Administration. Every year, thousands of people from across the nation and around the world visit the 493-hectare UP Diliman Campus, which prides itself on several sites of interest and other cultural sites such as museums and performance spaces, 63 hectares of which encompasses parks, open spaces, and protected forest areas. As of April 2016, the university has enrolled 23,757 students and has an active faculty of 1526 teachers.[8]

The main entrance to the University of the Philippines at Diliman, therefore the busiest, is University Avenue—about 800 meters long of two four-car lanes—which is the focus of the study. It admits private vehicles, delivery vans, and the quintessential jeepney which becomes the preferred public utility transport in and out of the university other than the tricycle.

III. Gathered Data

A. Traffic Data Summary

The Department of Public Works and Highways (DPWH) has generated a report in its 2012 Atlas the Annual Average Daily Traffic which reveals the total number of vehicles per vehicle type *(Table 1)*. All three case studies fall under the Quezon City 2nd District Engineering Office. [10] However, TNM v2.5 groups vehicles into five (5) major types which requires the DPWH vehicle types to be reclassified to match.

Table 1. Traffic Data Summary from DPWH 2012 Atlas reclassified for TNM v2.5

Case Study	University Avenue	Quezon Avenue	E. Rod Avenue
Motorcycle	128	89	168
Automotive	48,009	119,332	35,468
Large Bus	95	2,727	257
Medium Truck	6,616	4,261	673
Heavy Truck	700	406	32

Moreover, the software only needs an hourly vehicle count *(Table 2)* which only requires simple mathematics to get. The study assumes that there are no peak hours.

Table 2. Hourly Vehicle Count for TNM v2.5

Case Study	University Avenue	Quezon Avenue	E. Rod Avenue
Motorcycle	5	4	7
Automotive	2,000	4,972	1,478
Large Bus	4	114	11
Medium Truck	276	178	28
Heavy Truck	29	17	1

B. Input Data Summary

E. Rodriguez, Sr. Avenue. The area of focus for purposes of this study is the residential zone within a 200-meter radius from the intersection of E. Rodriguez Avenue and Victoria Avenue where a cluster of townhouses are on one side of Victoria Avenue and large residential lots with dense landscaping occupy the other side *(Fig. 1)*. Victoria Avenue divides the two types of residential clusters.

The westward lane E. Rodriguez Sr. Avenue heads towards the city of Manila, while the eastward lane goes further into Quezon City.

The baseline readings (Receivers 9-10 and 13-15) are those along the avenue itself which is fronted by low-rise commercial buildings around 7 meters in height.

The western side of Victoria Avenue plays host to several subdivisions of townhouses, namely Alpha Victoria (Receivers 1-2) and Galleria New Manila (Receivers 8 and 16) among others. The eastern side remains the original New Manila residential models characterized by large lots of at least 1000 square meters and heavily landscaped (Receivers 3-5). *(Fig. 1)*

Lung Center of the Philippines, Quezon Avenue. The area of focus for this paper's study is within the 250-meter radius from the main entrance point of the Lung Center of the Philippines. Ten (10) receivers were laid out: two (2) along the roadways, two (2) along building rows, and three (3) at tree zones *(Fig. 2)*.

The two roads plotted represent Quezon Avenue's east and westbound directions. Roadway 2 is eastbound while Roadway 3 is westbound.

The two buildings plotted represent the Lung Center of the Philippines, designated as building row 1, and the Kidney Institute of the Philippines, designated as building row 2.

The first tree zone represents the greeneries around the wildlife park area, the second tree zone represents the island or the greeneries in the middle of the highway, and lastly, the third zone represents the greeneries around the vicinity of the Lung Center of the Philippines and Kidney Institute of the Philippines. *(Fig. 2)*

University Avenue, University of the Philippines Diliman Campus. The area of focus is the whole stretch of University Avenue from its entry from Commonwealth Avenue up to its termination fronting Quezon Hall, the university's central administration building *(Fig. 3)*.

University Avenue consists of the eastward lane (Receivers 38-42 and 45-46) heading into the campus, and the westward lane (Receivers 20-24 and 51-53) heading outward into Commonwealth Avenue.

The nearest buildings on the northern part of the avenue, those likely to be affected by the traffic noise along University Avenue are the National College of Public Administration, UP Institute for Small-scale Studies (Receivers 30 and 64), UP College of Social Work and Community, and the UP Film Institute Media Center (Receivers 65 and 69). Within the southern part is the Commission on Higher Education (Receivers 76-78). At the end of the avenue is Quezon Hall (Receivers 71-74), the node wherein vehicles enter and exit.

All other receivers are spread across the trees and wide fields between the avenue and the nearest buildings from it. *(Fig. 3)*

IV. Simulation Results

A. Summary of Relevant Receiver Data

For brevity, this paper selected only the 10 relevant of the many receiver data calculated by the software.

E. Rodriguez, Sr. Avenue

Among the 16 receivers spread across the test area, 10 of which represent the relevant data for the study *(Table 3)*. These are those closest to E. Rodriguez, Sr. Avenue and those which fall within the property of both the townhouses and the private single-detached residences.

Table 3. Relevant Receiver Data for E. Rodriguez Avenue (with and without mitigation)

Receiver Number	Relevant Receiver Locations	dB	dB (w/ Mit)
9	E. Rodriguez, Sr. Commercial	66.8	NA
10	E. Rodriguez, Sr. Commercial	66.0	NA
13	E. Rodriguez, Sr. Commercial	65.6	NA
14	E. Rodriguez, Sr. Commercial	66.1	NA
2	Alpha Victoria (75 meters from road)	57.0	45
1	Galleria New Manila (25 meters from road)	61.0	45
8	Galleria New Manila (80 meters from road)	56.1	45
4	Private Residential Property (30 meters from road)	62.5	45
5	Private Residential Property (50 meters from road)	60.9	45
3	Private Residential Property (60 meters from the road)	57.8	45

Lung Center of the Philippines, Quezon Avenue

The 10 receivers listed below *(Table 5)* represent the most relevant receivers fronting the Lung Center of the Philippines and those areas adjacent to it such as the National Kidney Institute and the Ninoy Aquino Parks and Wildlife. Refer to Figure # for the actual data results.

Table 4. Relevant Receiver Data for Quezon Avenue (without mitigation)

Receiver Number	Relevant Receiver Locations	dB
1	Roundabout	65.3
2	Lung Center, ground floor	59.9
3	Lung Center, second floor	57.8
4	Lung Center, third floor	58.3
5	Lung Center, rear	47.3
6	National Kidney Institute, ground floor	47.3
7	National Kidney Institute, second floor	47.1
8	Parking Area	52.2
9	Wildlife Park (10 meters from the road)	67.7
10	Wildlife Park (30 meters from the road)	56.7

University Avenue, University of the Philippines Diliman Campus

Among the 78 receivers spread across the test area, 10 of which represent the relevant data for the study *(Table 4)*. Of great importance are those receivers that are located at colleges and offices, namely Receivers 91, 92, 30, and 64 (National College of Public Administration), Receivers 65 and 69 (UP Institute for Small-scale Industries), Receivers 80 and 81 (UP School of Urban and Regional Planning), and Receivers 66 and 67 (College of Mass Communication).

The uniformity of the receiver data is owed to the fact that all subject buildings are equidistant from University Avenue and that the density of foliage are, more or less, equal as well.

Table 5. Relevant Receiver Data for University Avenue (with and without mitigation)

Receiver Number	Relevant Receiver Locations	dB	dB (w/ Mit)
30	National College of Public Administration	66	40
64	National College of Public Administration	66	40
90	National College of Public Administration	66	40
91	National College of Public Administration	66	40
65	UP Institute of Small-scale Studies	66	40
69	UP Institute of Small-scale Studies	66	40
80	UP School of Urban and Regional Planning	66	40
81	UP School of Urban and Regional Planning	66	40
60	College of Mass Communication	66	40
67	College of Mass Communication	66	40

B. Mitigation

TNM v2.5 allows for some noise pollution mitigating measures through noise barrier design such as walls or buildings, or landscape features such as trees or berms. Each case study, however, requires a different realistic approach depending on the location, present condition, city ordinance, and other circumstances.

E. Rodriguez Sr. Avenue

The entire length of E. Rodriguez Sr. Avenue accommodates offices, institutional, and commercial. In recent years, the site of the case study has gone increasingly commercial, yet the city government has not made improvements on infrastructure. The 1.50-meter sidewalk runs adjacent to the street on one side and immediately the property line of the commercial buildings on the other where vehicular parking also begins. There are no provisions for green strips, nor could there ever be, unless the landowners provide it themselves. The most realistic mitigating measure for this case study is a noise barrier such as a building. In fact, more and more high-rise condominiums have been towering along E. Rodriguez, Sr. Avenue these past years.

While high-rise residential condominiums along E. Rodriguez, Sr. Avenue have reached heights of 100 meters, a row of at least 40-meter high (medium-rise) buildings, side by side, along the avenue should be able to uniformly reduce the noise levels down to 45 dB one block in, which is an acceptable daytime noise level *(Table 3)*. Additional trees within the single-detached private properties, should the property allow it, can still reduce noise levels down to another decibel or two.

Lung Center of the Philippines, Quezon Avenue

The stretch of Quezon Avenue where the Lung Center of the Philippines is located is heavily-tree-lined on both sides and the center island. The compound of the Lung Center is in itself lush with landscaping. One possible solution to mitigate the high noise levels assessed by the software is the use of barriers. The graph below *(Fig. 4)* shows that the decrease in noise levels is dependent on the increase in the height of the barrier.

The testing for this specific case study has been, in terms of mitigation, interestingly difficult—requiring several tests as to barrier design, specifically, wall height. Receivers one (1), two (2) and eight (8) in the simulation, having a 1.5-meter barrier, seemed to have decreased 3 to 4 dB from its original noise levels of 62.5dB, 54.6dB and 51.3dB, respectively. While the 3m-barrier decreased the noise levels of Receivers 1, 2, 3, 5, and 8 by 4dB to 10dB. The pattern shows that there is an average decrease of 2dB to 4db at every 3m increase on the barrier's height. However, upon reaching the height of 15m, the average decrease in noise level at every 3m increase on the barrier went down to 1dB.

For the results to be in accordance with the recommendations of WHO, having noise levels of no more than 35 dBA in rooms where persons are treated and observed, and no more than 30dBA in ward rooms, the needed height of the barrier that will be effective for receivers 2,3,4, 6,7 should be 24 meters which is not possible along Quezon Avenue.

University Avenue, University of the Philippines, Diliman Campus

The University of the Philippines has always maintained University Avenue and its immediate environs to be an expansive park which makes the travel into the campus most impressive, not to mention the center island lined with sunflowers that become the main attraction every summer. Buildings are set back far from the avenue which emphasizes the large open space. Therefore, the best mitigating measure for this case study is the addition of landscape features such as trees, shrubbery, and berms.

The mitigation test that yielded successful results *(Table 4)* is that which used architectural treatment on the buildings with a Noise Reduction Coefficient (NRC) between 0.28 and 0.45. This means that the material facing University Avenue should be at least 45% reflective to achieve ambient noise acceptable to educational standards. The addition of trees and other greenery could not lower the noise to those acceptable levels.

IV. Conclusion

University Avenue, University of the Philippines, Diliman Campus

High levels of traffic noise are registered at roadside along the whole stretch of University Avenue, averaging at 71.4dB, which is unacceptable for educational zones. However, since the buildings are at least 100 meters from the avenue, traffic noise is greatly diminished, the highest of which is 55.2dB for colleges and 56.8dB for offices. The tree cluster that buffers noise to the building has proven to be effective by reducing noise by at least 6dB. In fact, even an open field has reduced levels by as much as 13.8dB on one receiver.

After experimenting on different landscaping options in front of buildings facing University Avenue, using materials with NRCs between 0.00 and 0.45 on the façades of buildings should create a suitable interior environment for educational or business (office) purposes. Moreover, the northern and southern fields flanking University Avenue are already tree-lined which, as the results present, noise reduction as an effect of additional trees would be minimal, if not negligible.

Lung Center of the Philippines, Quezon Avenue

One out of the two hospitals within the 250m radius from the entrance of the Lung Center of the Philippines did not meet the World Health Organization's (WHO) recommended noise levels of no more than 35dBA in rooms where patients are treated or observed and no more than 30dBA in ward rooms.

Receivers on higher locations seemed to be experiencing higher noise levels as compared to receivers situated on the lower floors. The 20m tree belt reduced the traffic noise sound level by 7dB. Building rows having 3-4 storeys that are approximately 40-60m in width greatly decreases the traffic noise sound level by 20-30dB.

Due to structural limitations and reasons of practicality, a 24-meter high barrier is neither advisable nor realistic. The effect of the barrier in mitigating the high noise levels, however, is expected to change depending on its thickness, design and material. But since the said considerations were restricted to the predetermined input by the software, these were no longer explored.

E. Rodriguez Sr. Avenue

The traffic noise emitted by vehicles traversing the length of E. Rodriguez Sr. Avenue registers an average of 66.1dB —slightly high based on international standards of 65dB - 70dB for commercial zones. The residential zone, which begins from within one block of the avenue, registers sound levels between 56.1dB up to 62.5dB—quite high for residential zones which should have a maximum sound level, according to internationally-accepted standards, of 55dB during the day and 40dB at night.

However, the experiment on a row of medium-rise buildings, as a realistic mitigating measure, was able to drop noise pollution to daytime levels of 45dB.

At this present condition, and considering that private vehicles and public utility vehicles and its passengers will continue to increase over the years, the sound levels will only continue to rise exponentially, making the living conditions inside New Manila more unbearable, at least one block in.

IV. Recommendations and Software Review

The software does not let its user define exactly the length and width of buildings making it hard for irregularly shaped buildings to be modeled; it also does not identify the building's openings and fenestrations, nor the type and specification of trees or the tree belt around it. Thus, the results from the simulation are not exact.

Software programs performing acoustic simulations and measurements on building interiors, such as CATT-Acoustic used in churches, are starting to emerge. However, software programs that focus on a larger scale of development are almost non-existent. These types of simulations will open up doors in and out the academe on the exploration of more innovative approaches and solutions that will help solve, or at least curb, noise pollution.

References

Aguilar, K. (2012, September 28). *The residences of New Manila.* The Urban Roamer.

http://www.theurbanroamer.com/residences-of-new-manila/

Bliss, L. (2015, May 26). *Exposure to traffic noise may raise your risk of obesity.* City Lab. https://www.citylab.com/transportation/015/05/exposure-to-traffic-noise-may-raise-your-risk-of-obesity/394103/

Brandt, M. (2012, June 21). *Stanford Medicine Study shows link between traffic noise and heart attack.* Stanford Medicine. http://scopeblog.stanford.edu/2012/06/21/study-shows-link-between-traffic-noise-heart-attack/

Department of Public Works and Highways. (2013). *CY 2012 Summary Traffic Data.* http://120.28.38.50/infrastructure/infra_stat/2012%20Atlas%20for%20viiewing/2012%20Atlas/ncr1.html/

Dulay, B. (2013, June 28). *DOTC, DENR should curb noise pollution.* Manila Times. http://www.manilatimes.net/dotc-denr-should-curb-noise-pollution/13924/

Federal Highway Administration Resource Center. *FHWA Traffic Noise Model Version 2.5.* https://fhwa.dot.gov/resourcecenter/teams/environ

Jaleel, Z. T. (2014, May). *The effect of road traffic noise at hospitals in Baghdad City. Journal of Engineering and Development, 18* (3). https://www.iasj.net/iasj/download/f0828af652c25959

Lung Center of the Philippines. (n.d.) *About Us.* http://lcp.gov.ph/

Nepomuceno, J. (2010, September 2). *When noise is too much.* Philippine Council for Health Research and Development. http://www.pchrd.dost.gov.ph/index.php/news/library-health-news/1819-when-noiseis-too-much

University of the Philippines Diliman. (n.d.) *Facts at a glance.* http://upd.edu.ph/about/facts-at-a-glance/

Figure 1. Receiver Layout along E. Rodriguez and Sr. Avenue

Source: TNM v2.5 Simulation Results

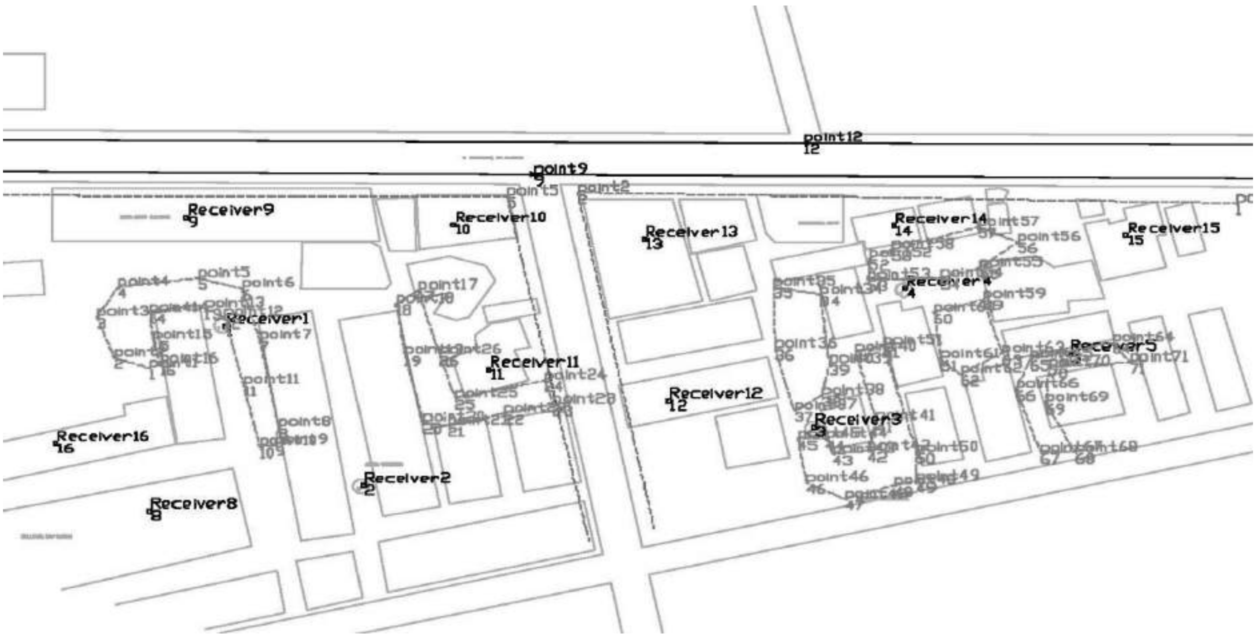


Figure 2. Receiver Layout along Quezon Avenue
Source: TNM v2.5 Simulation Results

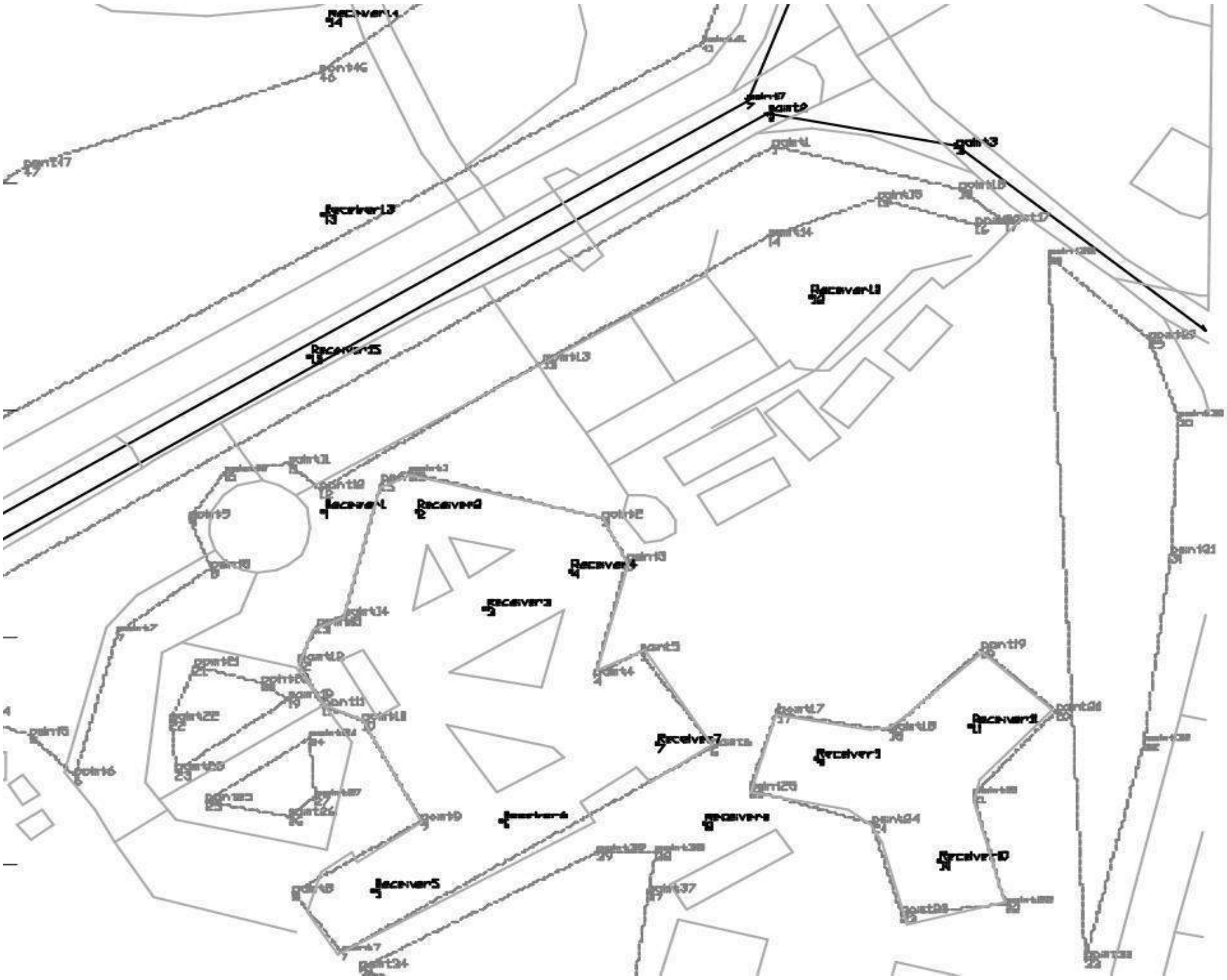
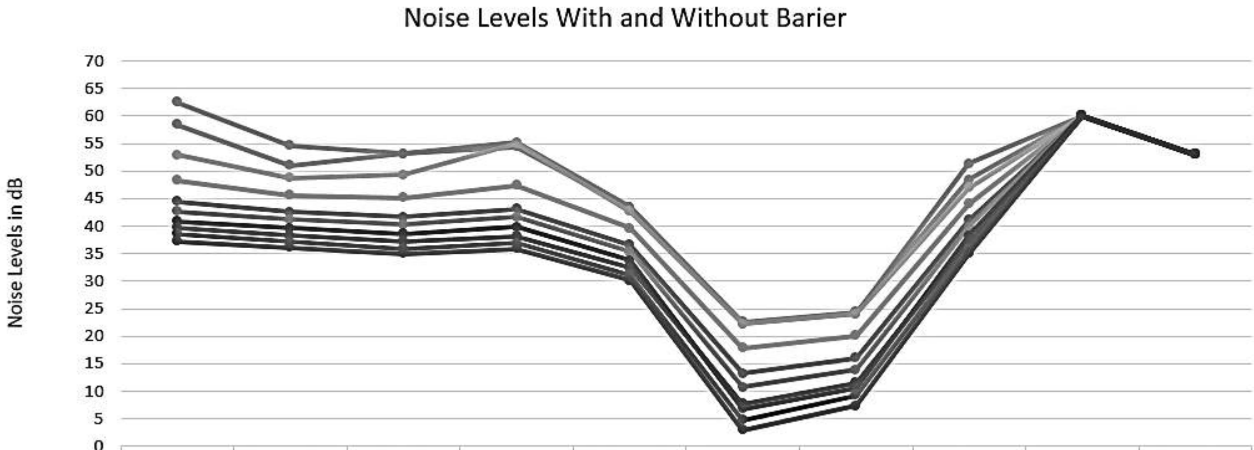


Figure 3. Receiver Layout along University Avenue
Source: TNM v2.5 Simulation Results

Figure 4. Effect of Barrier with Varying Height on Noise Level
Source: TNM v2.5 Simulation Results



	Receiver 1	Receiver 2	Receiver 3	Receiver 4	Receiver 5	Receiver 6	Receiver 7	Receiver 8	Receiver 9	Receiver 10
0.0 M	62.5	54.6	53.1	54.4	43.3	22.2	24.1	51.3	60	53
1.5 M	58.4	51	53.2	55.2	43.5	22.6	24.4	48.4	60	53
3.0 M	52.9	48.8	49.3	55	42.7	22.2	24.1	46.9	60	53
6.0 M	48.3	45.6	45.1	47.4	39.6	17.8	20.1	44	60	53
9.0 M	44.5	42.5	41.7	43.1	36.6	13.2	16	41.1	60	53
12.0 M	42.7	41.2	40.3	41.6	35.3	10.7	13.9	39.9	60	53
15.0 M	40.9	39.6	38.6	39.8	33.7	6.8	10.6	38.3	60	53
18.0 M	39.7	38.3	37.2	38.2	32.4	7.7	11.5	37	60	53
21.0 M	38.6	37.1	35.9	36.9	31.2	4.8	9.3	36	60	53
24.0 M	37.3	36.1	35	35.9	30.1	3	7.4	35	60	53

0.0 M, 1.5 M, 3.0 M, 6.0 M, 9.0 M, 12.0 M, 15.0 M, 18.0 M, 21.0 M, 24.0 M

MUHON Call for Papers

Format and Procedures

Interested authors are requested to prepare papers and essays with a maximum of 7000 words (excluding captions of tables, images or figures). The following are unacceptable for publishing: simultaneous submissions to other journals, previously published work, or work which is substantially similar to previous published work. Contact the Editorial Staff of MUHON (through email or visit to the Research Office of the UP College of Architecture) for any query regarding this requirement.

A submitted paper for possible publication will undergo double blind review process by international experts in the related topic or field of study. The template for the paper format can be downloaded from the UP College of Architecture website (**http://upca.upd.edu.ph/**). The Call for Papers is open all throughout the year. Authors may submit their abstracts and full papers or manuscripts (Word file) to **muhon@up.edu.ph** together with the accomplished and signed Copyright Agreement Form.

Review Process

Initial screening of papers is done by the members of the Editorial Board. After the first revision, the manuscripts are then subjected to a double blind peer review, which means that both the reviewer and author identities are concealed from each other throughout the entire process.

Reviewers from various local and international academic institutions are invited to be part of the Pool of International Reviewers of MUHON. All of the invited referees are experts in their respective fields of specialization. Papers are assigned to them for review according to their expertise and are given enough time to evaluate the manuscripts if they are publishable or need revisions.

Authors shall be notified of the comments of the reviewers on their manuscripts, as well as confirmation by the reviewers that the papers are deemed publishable to the journal.

References and Works Cited

Prepare a bibliography to contain key references for the article, plus the author's judgment of the most important reference sources on the topic. Follow the format of the American Psychological Association (APA), which emphasize on the date a work was created. Book citations in APA generally require author's name, publication year or last edited date, work title, publication city, and publisher. Arranged the references alphabetically (based on main author's surname or title of literature for references without author indicated).

Terms of Publication

Upon acceptance of the Title and Abstract, the authors must be committed to abide by the schedule provided by the MUHON Editorial Board. Also, the contributors shall be responsible for submitting pictures or images with a resolution of at least 300 dpi, clearly labeled (with required photo credits). Obtain permission, pay royalty fees, etc., as may be required for the reproduction of illustrations taken from other sources.

The contributor, in turn, waives any royalties for the publication of his/her article, as the UP College of Architecture (UPCA) is a non-profit organization. The copyright for the published work belongs to UPCA and its selected publisher (if any). Once submitted to the journal, the contributor is responsible in ensuring that the article will not appear in other publications.

The contributor guarantees that:

- the article does not infringe on the copyright or any proprietary right of any other person;
- the article contains no libelous or other unlawful matter; and
- the article makes no improper invasion of the privacy of any other person.

Acknowledgments

The eighth issue of MUHON
acknowledges the support
of the University of the Philippines Diliman
Office of the Vice Chancellor for Research and Development
for providing the
University of the Philippines College of Architecture
an online public access
to share the published works
included in the previous issues of the journal.

As a research university,
the U.P. College of Architecture
is responsible for disseminating
new body of knowledge.

Thus, MUHON is published
as a vehicle for reaching out
to other architectural schools,
building architects and landscape architects in the academe,
in the architecture and design professions
and to the public at large.

MUHON Editorial Team
Research Program
College of Architecture
University of the Philippines Diliman

UPCA Building 2
E. delos Santos Street, UP Diliman Campus
Quezon City 1101

(+632) 9818500 loc. 3138
muhon@up.edu.ph

University of the Philippines
College of Architecture

Integrated Graduate Program

GDipLS
Graduate Diploma in Landscape Studies

A one-year program that will enable the non-Bachelor in Landscape Architecture degree holders to proceed to the Master of Tropical Landscape Architecture and, thereafter, take the LA licensure exam.

MArch
Master of Architecture

An updated two-year program that is significantly reconfigured to incorporate new design and design policy-making practice, innovative design conceptualization processes, emergent industry needs.

MAAS
Master of Arts in Architecture Studies

A non-thesis two-year program designed for non-B.S. Architecture degree holders, who do not intend to take the Architecture licensure exam to enroll and immerse in spatial theories, concepts and strategies.

MTLA
Master of Tropical Landscape Architecture

A revitalized two-year program, that builds on the old MTLA program while bringing in the latest and emergent design concepts and approaches for outdoor environments in city and countryside settings.

PhDDBE
Doctor of Philosophy in the Designed and Built Environment

A four-year program with 2 tracks: Track A (39 units) for Architecture/ Landscape Architecture-related fields, Interior Design, Urban Planning, Civil Engineering; Track B (48 units) for all other fields, e.g. humanities, social science, natural science, arts and others.

For details, kindly scan this code or visit https://upca.upd.edu.ph/igp-admissions.html
For inquiries, please email us at upca.igp.upd@up.edu.ph.