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Developing a Strategic Framework in Reducing Urban Heat Island Effect for Cooler High-density Communities: The Case of Sampaloc, Manila

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Abstract

As a tropical country, the Philippines experiences a micro-climate phenomenon that is referred to as the urban heat island effect. It is considered as an environmental risk felt particularly during the hot seasons and becoming worse in the succeeding years. In response to this issue, there is a need for alternative strategies appropriate for a local setting. This study aims to provide approaches that can help mitigate the urban heat island effect in high-density communities in the City of Manila. It formulated a framework serving as a model that can be applied to any high-density community in Metro Manila regarding the negative effects of the urban heat island and its reduction. It provides useful information for the residents, experts in the field of architecture and urban planning, and academicians in finding alternative ways of reducing the urban heat island applicable in the local setting. The study employed a mixed-method research approach by collecting both quantitative and qualitative data. The descriptive research method was used in choosing the site to describe its existing conditions and relate the factors and elements that influence the UHI effect in the area. It utilized ground-truthing that assessed GIS maps. Purposive sampling, key informant interviews, observations, and field visits extracted data from the residents directly affected by the urban heat. The analysis produced a framework in mitigating an increase in the UHI effect in the community. These are to control the climate and adapt green architectural strategies, to re-examine functions in zoning, and to develop a community small-scale initiative in green environment awareness.

Keywords: *urban heat island effect, heat stress, comfort zone, cool high-density community*

1. Introduction

The urban heat island phenomenon is an environmental risk experienced in an urban area, particularly during hot seasons. It observes a higher temperature evident in cities or urban locations compared with the surrounding areas (Tiangco, Lagmay & Argete, 2008). The urban heat island (UHI) phenomenon in major cities shows changes in land use and land cover that impose a great deal of load on the environment (Akinaru, 2002). According to Yang, Qian, Song, and Zheng, (2016), the UHI effect is widely recognized as a heat accumulation phenomenon, which is the most obvious characteristic of urban climate caused by urban construction and human activities. This study proposed to develop a strategic framework that can help mitigate or somehow reduce the urban heat island effect in high-density communities located in the City of Manila. Using Sampaloc, Manila, as the setting for investigation, the proposed framework shall serve as a guide for urban planners, architects, and other experts in this field to help mitigate, if not avoid, the effect of the UHI in an urban setting like Manila. The present situation of the district will be the sources of information on the factors contributing to it. The developed framework is also envisioned to provide guidelines in designing urban communities to minimize the urban heat island effect in the area. Moreover, congruent with the proposed strategic framework, it will create mitigating designs to alleviate the UHI effect in the chosen location of the study, which is the District of Sampaloc. It can also serve as a model that can be applied to other high-density communities in Metro Manila to help achieve a cooler community. Likewise, it can serve as a blueprint in developing a strategic framework for the reduction of the UHI effect appropriate in a tropical country such as the Philippines. The City of Manila is considered a highly dense community. Thus, the challenge that will be encountered is the diversity of the community in terms of building types, socio-economic status, transport-related function, and economic activities. This study shall be the map of the local government of Manila in its vision in mitigating the urban heat island effect, and it can promote urban greening ideas to achieve a cooler community, with its primary beneficiaries being the residents not only in Manila but also in the whole National Capital Region.

2. Objectives

The research aims to formulate a strategic framework for mitigating the urban heat island effect in the district of Sampaloc that can be applied to high-density communities in Metro Manila.

1) To identify the areas with high and low UHI using Sampaloc, Manila, as the study area.

2) To determine and assess the factors that directly and indirectly influence the urban heat island effect on the study area.

3) To determine the elements that affect the factors identified and relate their influence on the UHI effect.

4) To formulate a strategic framework aimed at mitigating and alleviating the impacts of the urban heat island to achieve a cooler high-density community in Sampaloc.

3. Material and methodology.

3.1 Location of Site

The City of Manila is divided into six (6) congressional districts as shown in Figure 1 with 100 barangay zones composed of 895 barangays. Sampaloc is the 4th congressional district of Manila, comprising 241 barangays, namely, barangays 395-636. District 4, with 17 zones, comprises Sampaloc alone (Table 1). It is a high-density mixed-use residential and commercial area known also as the "University Belt." The study used the Sampaloc district, which has a population of 375,119 as of population census on January 8, 2015, as the setting for investigation

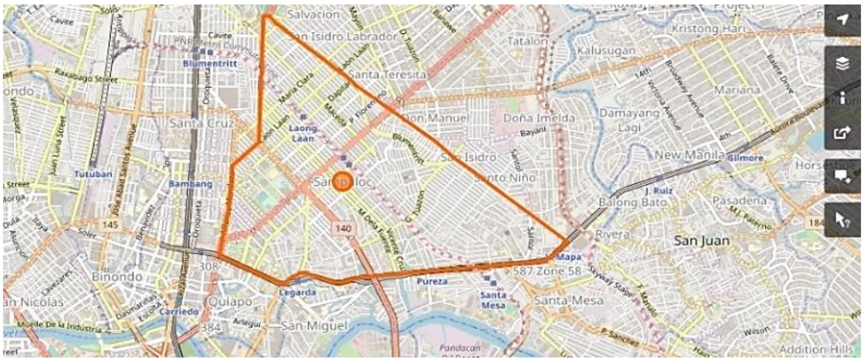


Figure 1 Boundary of Sampaloc district (https://www.openstreetmap.org)

Table 1 The political districts of Manila (Manila Comprehensive Land Use Plan and Zoning Ordinance 2005-2020)

Land area and zone per district of manila			
District	**Land Area (ha)**	**Zones Covered**	**Number of Zones**
I	624.11	1-16	16
II	375	17-24	8
III	613.67	25-40	16
IV	523.12	41-57	17
V	1125.38	68-89	32
VI	784.52	58-67, 90-100	11
Total	4045.8		100
Source	Computed	CEO, 2002	CEO, 2002

3.2. Method

The research employed a strategy of triangulation wherein a mix of qualitative and quantitative methodologies was used. It used a mixed-method approach to have a comprehensive understanding of the relationship of the UHI effect in the affected areas of the community. It also used a convergent parallel mixed method wherein the probability of converging and merging the collected data drawn from the quantitative and qualitative means provided an in-depth analysis of the research problem. A descriptive method in choosing the site was also adapted, which described its existing conditions and related the factors and its elements. Furthermore, ground-truthing was also utilized, which helped assess and verify the GIS or satellite image maps against what was physically seen in the ground.

3.2 Data Collection Procedure

The City Planning and Development Office of the Manila City Hall provided the District and barangay boundary maps for the study. To get the highest, medium, and lowest temperatures of the chosen area, the Sampaloc district was divided using the systematic sampling technique. The study used a random number generator via Microsoft Excel to select barangays in random at every fifth subject. The district was divided into seventeen (17) zones and 241 barangays, with the latter selected at random. The air temperature (AT), land surface temperature (LST), and humidity were measured in the selected barangays in the month of May and June 2019. The measurement was done for three consecutive weeks and three times a day for each month. The vicinity maps for the highest air temperatures were acquired in the specific barangays.

3.3 Instruments used for temperature measurement

The air temperature was determined by DBT (dry-bulb thermometer) as shown in Figure 2(a), which is the alcohol thermometer. Simultaneously, it used a digital Thermometer and a Hygrometer for the measurement of indoor and outdoor air temperatures and humidity, respectively. The land surface temperature was determined by the Infrared thermometer (IR) that was used at the same time as the alcohol thermometer. A downloaded GPS application on a mobile phone was used to note the latitude and longitude of each zone/barangay visited. Photographs of the area were also taken at every place where the temperatures were measured.

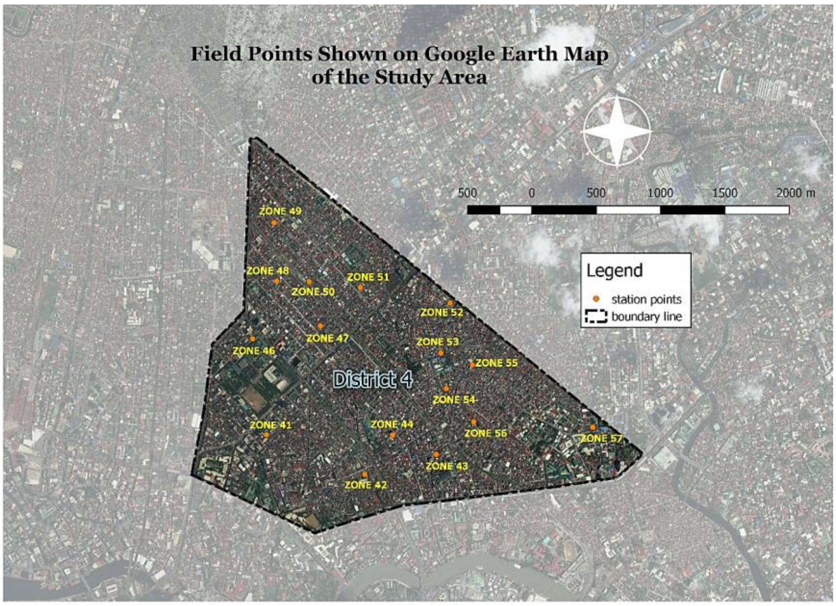


Figure 2 The field investigation points shown in the Google Earth image

3.4 Measurement of land surface temperature (LST), air temperature (AT), and humidity (HU)

The basic data, particularly the district map and its different zones, were collected from relevant sources such as the City Planning and Development Office of Manila City Hall. Aside from this, an open street and satellite map from QGIS was used to create and develop a shapefile of the study area shown in Figure 2. Temperature measurements were simultaneously taken by riding a tricycle and stopping at designated barangay as station points It was done for three (3) hours with specific times in the morning, noon, and evening during the month of May and June 2019, each for three consecutive weeks.

3.5 Field Data Investigation

In documenting the building and site configurations on the selected barangays relative to the urban heat, the study identifies the physical elements to determine how the urban heat island contributes to the physical features and spatial organization of the district. It utilized the land use type based on the official zoning map of Manila to categorize the area. Site layout helped describe the area, the type of building, and how it functions whether it is used as residential, commercial, or both. The materials and colors used in a building can ascertain its heat absorption and emissivity. Openings found in structures served as a source of ventilation, which determined the thermal comfort of occupants. Property setbacks were viewed in their relationship to building arrangement and the number of openings affecting ventilation.

4. Results and Discussion

4.1 Areas with high and low land surface temperatures (LST)

For the dry season (May) and wet season (June), the measurement of land surface temperature (LST) between 11.00 a.m. to 2.00 p.m. was chosen. LST is the radiative temperature of the ground surface that depends on the albedo, vegetation cover, impervious surfaces, and soil moisture. It is generally a mixture of surface temperatures of both vegetation and bare soil (Kumar, Bhaskar & Kumari, 2017). The study was similarly done in India, which used field investigation and measurement such as IR thermometer during the daytime from 11.00 a.m. to 2.00 p.m. local time. Thus, Zone 52 (highest), Zone 44 (medium), and Zone 52 (lowest) were the identified locations for May while Zone 52 (highest), Zone 56 (medium), and Zone 43 (lowest) were the identified locations for June, as shown in Figure 3.

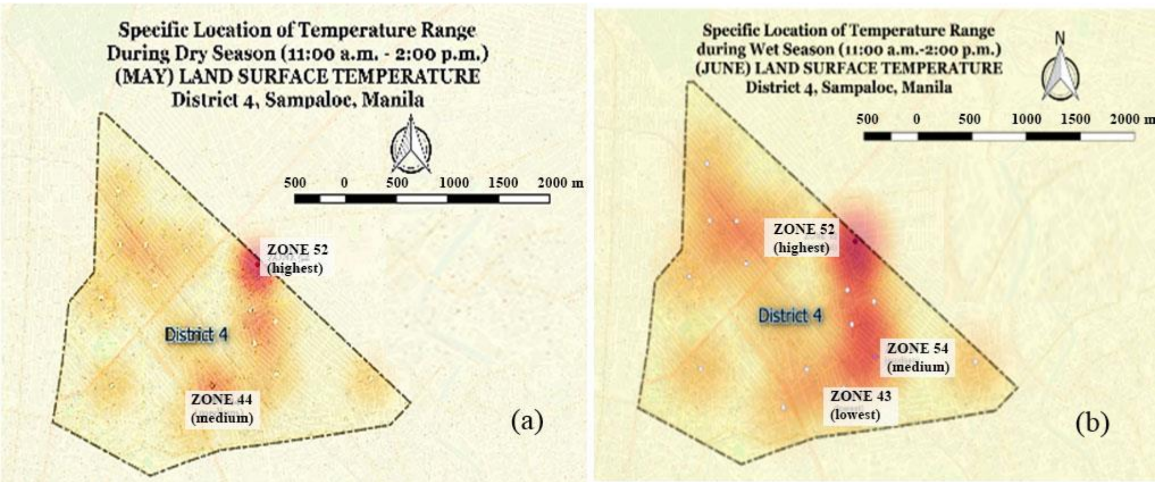


Figure 3 Areas with high and low land surface temperatures (LST) during the daytime from 11.00 to 2.00 p.m. on (a) May 2019 (b) June 2019

4.2 Areas with high and low air temperatures (AT)

The air temperature during the period between 11.00 a.m. to 2.00 p.m. was again considered for the wet and dry seasons. Its purpose was to ascertain the residents' response to the urban heat experienced compared with the nighttime air temperature. Figure 4 shows the identified location for the highest air temperature for May, which was revealed to be located at Zone 52, while the medium and the lowest values were recorded on different days at Zone 44 and Zone 52, respectively. For June, Zone 56 had the highest recorded air temperature, with Zone 41 being the medium air temperature, and the lowest air temperature was located at Zone 43.

Furthermore, Figure 5 shows the measurement of the highest and lowest air temperatures done during the nighttime from 9.00 p.m. to 12.00 a.m. It shows that Zone 42 (highest), Zone 47 (medium), and Zone 57 (lowest) were the identified locations of the barangays for May for air temperature. For June, Zone 47 (highest), Zone 43 (medium), and Zone 56 (lowest) were the identified barangays.

4.3 Areas with high and low humidity (HU)

During the nighttime from 9.00 p.m. to 12.00 a.m. for May, Zone 56 & 44 (highest), Zone 56 (medium), and Zone 48 (lowest) were the identified locations of barangays where humidity was measured. For June, Zone 56 (highest), Zone 53 (medium), and Zone 55 (lowest) were the identified locations of barangay as shown in Figure 3. As shown in Figure 4, for May, Zone 47 (highest), Zone 45 (medium), and Zone 47 (lowest) compromised the humidity values measured from 11.00 a.m. to 2.00 p.m. while during June, Zone 43 (highest), Zone 50 (medium), and Zone 56 were the identified locations.

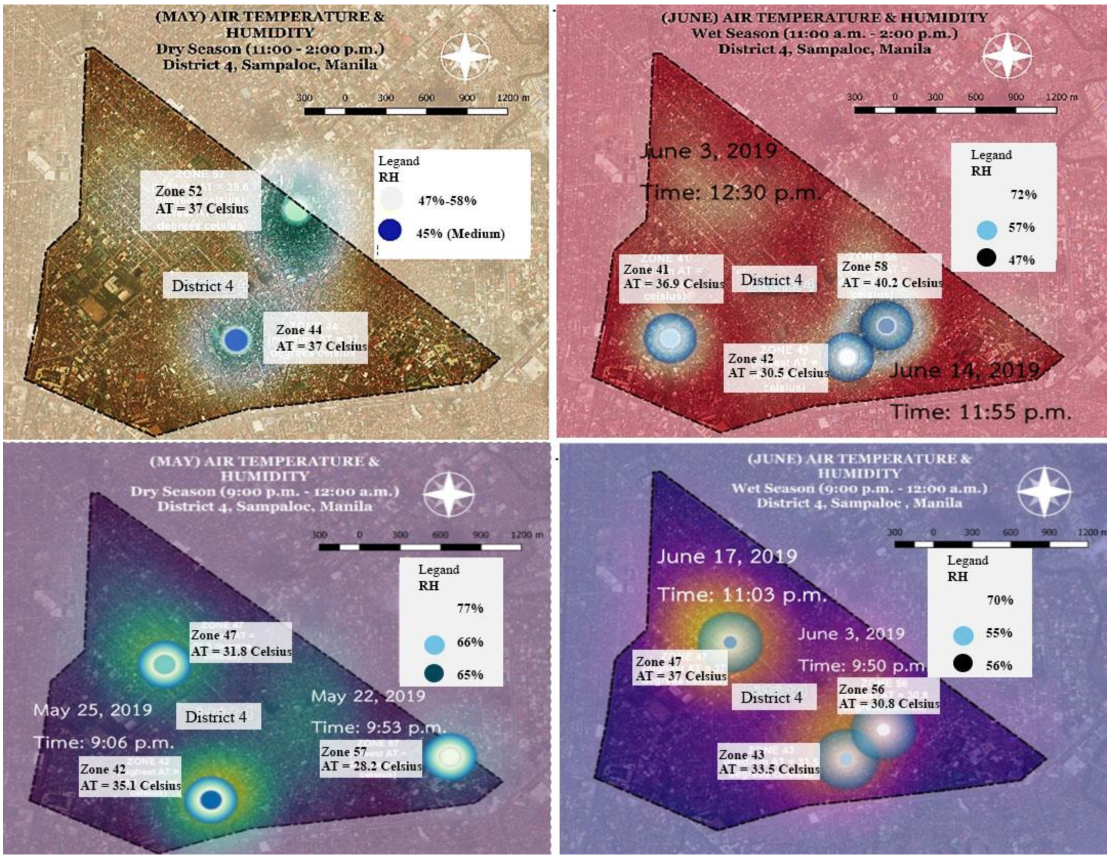


Figure 4 Profile of the highest, medium, and lowest temperature and humidity values during 11.00 p.m. -12.00 p.m. (wet & dry season) May & June 2019.

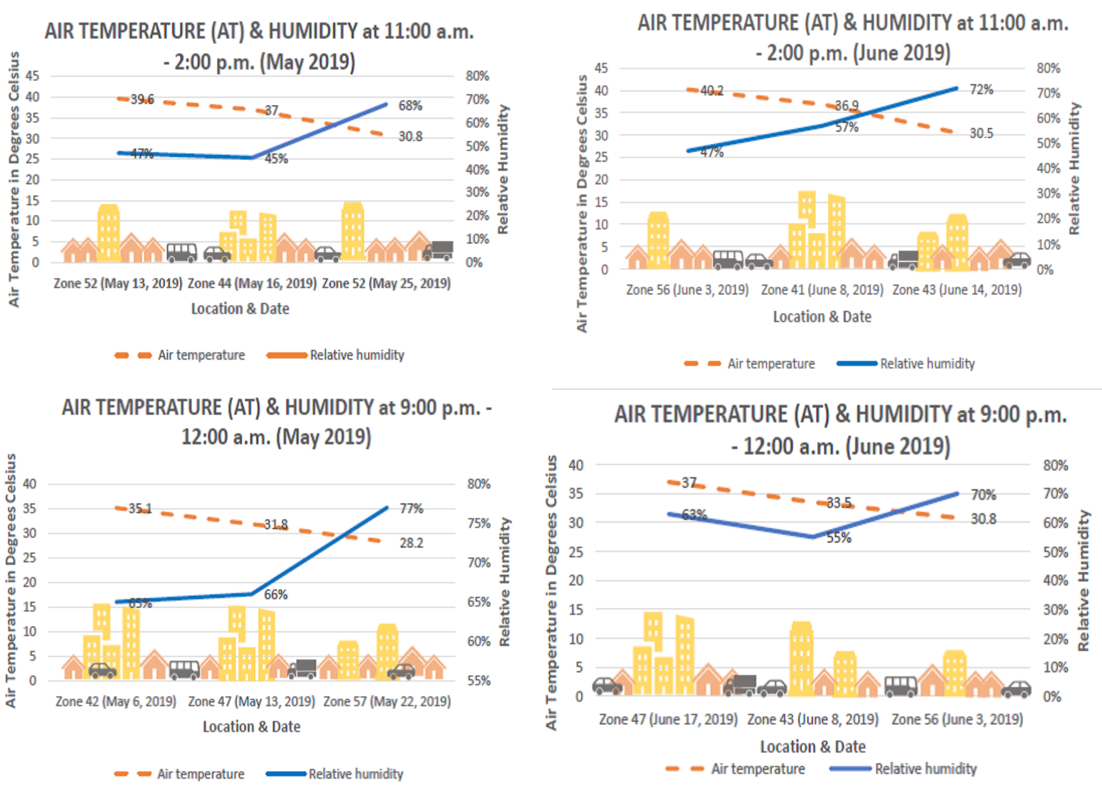


Figure 5 Profile of the highest, medium, and lowest temperature and humidity values during 9.00 p.m. 12.00 a.m. (wet & dry season) (a) May 2019, and (b) June 2019.

4.4 Factors that influence UHI effect in the study area and the elements affecting the factors identified in relation to its influence on the UHI effect

Factors that directly contribute to the "urban heat island" effect in these areas involved the incidence of solar radiation and its actual contact with the urban canopy layer, which were the albedo of building materials, the minimal amount of vegetation, lack of open spaces, and anthropogenic sources. Based on the survey conducted, the indirect factors are related to the repercussions of the identified direct factors, which consisted of the increased use of air conditioners, heterogeneity of structures, the density of the area, and the obstruction of wind flow. The identified elements are the age of the structures concerning its construction, economic status represented on the quality of materials and cooling appliances used, number of openings that served as ventilation, floor area with regards to the number of household members, conversion or expansion of spaces, burning of waste, heat that comes from cooking, road repairs, street parking, traffic due to increase of vehicles, and the heterogeneity of land use. Figure 6 shows the relationship of the direct and indirect factors as well as the identified elements that influence these factors to help increase the urban heat island effect.

4.5 The factors and elements that affect UHI increase and distinguished the barangays with the highest, medium, and lowest temperatures

Based on the data collected and observation through the time of measurements and field visits along the area, the similarity of the district's physical features for each zone are diverse, dense, and mixed-used in functions. However, there is still a distinctive quality that impacts an increase in the UHI in the study area. The data analyzed showed that the district's similarity with regards to physical features contributed to the increase in the urban heat that every urbanized community or city experiences. Its distinctive quality was the density and heterogeneity of the area wherein its function is mixed-used ranging from low, medium, to high-rise structures, whether residential or commercial in function, and maximized lots (conversion or expansion) that resulted in cramped spaces and inadequate ventilation. Moreover, its diverse functions comprised the different zones with the number of barangays within these, which provided different activities in a single location. It can have areas that are depopulated during the night such as institutions while the opposite is evident in nearby areas like residential and commercial areas. The areas that recorded the highest temperature were highly populated, composed of man-made materials with a high albedo, and lacked green spaces. The areas that have lower temperatures were influenced by the weather condition at the time it was recorded since the district exhibited similar physical features. As observed, the day and time temperatures recorded in these different barangays remain the same yet vary because of the factors identified in addition to wind velocity. A spatial and temporal variation can appropriately describe this case because some factors were changing from one time to another but remain constant across space (White, Ernest, Adler, Hurlbert & Lyons, 2010).

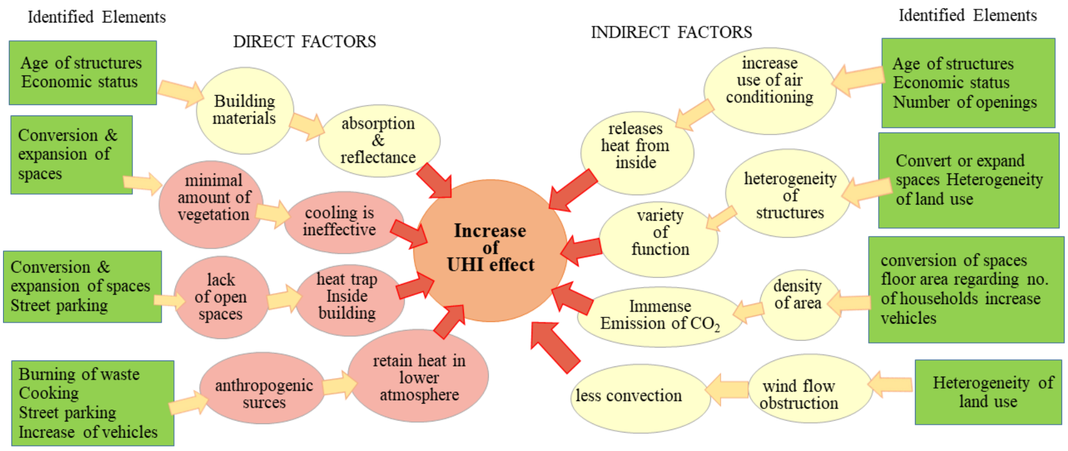


Figure 6 The influence of the identified elements on the factors influencing the UHI effect in the study area.

4.6 Correlating Physical and Social impacts that generate UHI effect in the development of an initial framework

The barangay with the highest daytime and nighttime air temperatures was given the questionnaires, and the highest response was selected from the residents. Table 2 shows the responses that revealed the influence of the physical features on the UHI effect, which led to the architectural design solutions and initial framework in mitigating the UHI effect. Likewise, the responses of the residents, as shown in Table 3 regarding heat stress, indicated the social impact influencing the UHI effect in the selected areas associated with the heat index or human discomfort index and thermal comfort zone.

4.7 Heat Index relation to heat stress

The air temperatures from May and June were calculated using the heat index calculator from calculator.net. It estimated the temperature felt by the body as a result of air temperature and relative humidity. The data collected used the nighttime temperature from 9.00 p.m. to 12.00 a.m. due to the more pronounced UHI effect at that time. To further enrich the gathered data, it also used the daytime temperature from 11.00 a.m. to 2.00 p.m. to know the response of the residents at this time of the day. It used the highest air temperature with its equivalent humidity value on a specific day. Under the description of the heat discomfort index, the resulting temperatures posed danger due to the increased likelihood of heat cramps, heat exhaustion, and heatstroke if the activity is continued, as shown in Figure 7. From the data collected, mitigation strategies were extracted and led to the formulation of a framework to achieve a cool high-density community.

Table 2 The physical impacts that influence the UHI effect in the area

Physical impacts				**Architectural means**
Respondents - Barangays that have the highest temperature (highest response)		*Indication*		*Consideration*
Myriad structures – apartments – function – renting – highest number – Barangay 575		Houses converted to commercial purposes (renting)		Configuration of building
3- to 4 storeys – Barangay 527 3 to 5 household members		Middle-income earners		Affordable & cost-efficient
Shortest lease – 19 years (Barangay 527) Longest - 39 years (Barangay 575)		Numerous old residential & commercial structures		Retain and adapt old structures
(Present) Spaces	Characteristics (Ventilation system)	Features (Description / Perception)	Indication	Consideration
Barangay 411 (Zone 42)				
living room, dining room, kitchen, toilet and bath and bedroom, office and roof deck	inadequate	Sufficient to crammed	Owned houses large space than rented space Convert and expand spaces	Multi-purpose use of spaces
Barangay 472 (Zone 47)				
living room, dining room, kitchen, toilet and bath, bedroom and a few have porch or verandah, carport and sari-sari store	Ample	Spacious to crowded	Larger areas for owned houses	Flexibility of spaces
Barangay 527 (Zone 52)				
living and dining room, kitchen, toilet and bath and bedroom	Inadequate	Sufficient to crammed	Rented spaces are smaller than owned houses	Multi-function of spaces
Barangay 575 (Zone 56)				
living and dining room, kitchen, study room, toilet and bath, bedroom, a porch and terrace, garage and rental spaces	Appropriate to inadequate	Sufficient to crammed	Conversion and expansion on structures	Flexibility of spaces

Table 3 The social impact that influences the UHI effect in the area

Social impacts (Heat stress) *Considered the highest response*							
	Barangay 411	*Consideration (Strategic framework)*	*Barangay 472*	*Consideration (Strategic framework)*	*Barangay 527*	*Consideration (Strategic framework)*	*Barangay 575*
Heat experience	Much worse		Can be manage		A little worse		tolerable
The main contribution of heat stress	Use of air conditioner Lack of open space		Increase of motor vehicles Increase of resident's population		Household cooking & heating Lack of open & green spaces		Burning of waste Increase of resident's population
The extent of heat affecting residents	Very much affected		Affected a little		Very much affected		Very much affected
Ways in which residents were affected by heat	Excessive sweating Dizziness Intense thirst		Feel tired Headache		Excessive sweating headaches		Doing less outdoor activities High blood pressure
Transport vehicles generate heat	Yes		Yes		Half (yes)		Yes
	Consideration (Strategic framework)						
Reasons why transport vehicle cause heat	Street parking (double parking) Fixing auto-mechanic parts		Street parking (double parking)		Fixing auto-mechanic parts		Location of tricycle terminals Fixing auto-mechanic parts
	Consideration (Strategic framework)						
Prohibited ownership of the vehicle if no parking	Yes		No		Yes		Yes
	Consideration (Strategic framework)						
Commercial establishment cause heat			Yes		No		Yes
	Consideration (Strategic framework)						

Social impacts (Heat stress) *Considered the highest response*							
	Barangay 411	*Consideration (Strategic framework)*	*Barangay 472*	*Consideration (Strategic framework)*	*Barangay 527*	*Consideration (Strategic framework)*	*Barangay 575*
Ways commercial activities cause heat	Change/convert for parking Use sidewalk for commercial activities		Change/convert for parking		Remove green space		Change/convert for parking Remove green space
	Consideration (Strategic framework)						
Prohibition of commercial activities by local government (sidewalk & road)	Strongly agree		Neutral		Neutral		Strongly agree
	Consideration (Strategic framework)						
Poor infra-structure & increase of vehicle ownership cause heat	Traffic & congestion		Increase of air pollution		Increase heat		Increase heat
	Consideration (Strategic framework)						
Construction of greenery (planting ornamental & vegetable plants)	Strongly agree		Strongly agree		Neutral		Strongly agree
	Consideration (Strategic framework)						
Promote greening concepts by local government	Strongly agree		Agree		Neutral		Strongly agree
	Consideration (Strategic framework)						
Residents do to lessen heat	Turn on cooling appliances Turn off lights Use hand-held fans (pamaypay)		Minimize use of electrical appliances		Turn on cooling appliances		Turn on cooling appliances Turn off lights Use hand-held fans (pamaypay)
	Consideration (Strategic framework)						

Legend:		
Consideration	Strategy 1: Understand the process of climate	
	Strategy 2: Re-examine zoning	
	Strategy 3: Community participation	

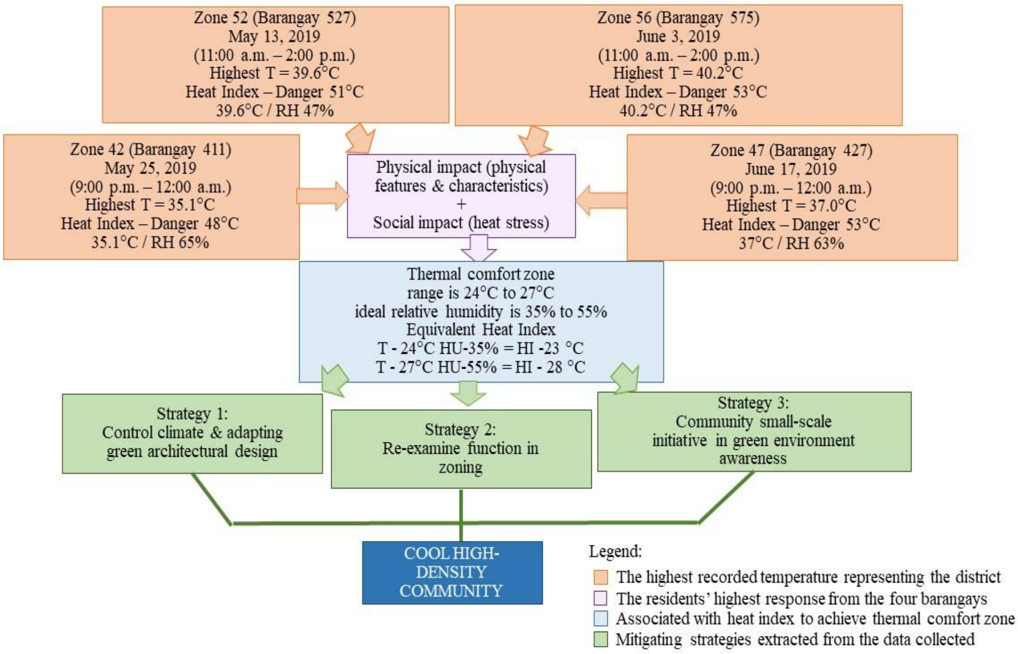


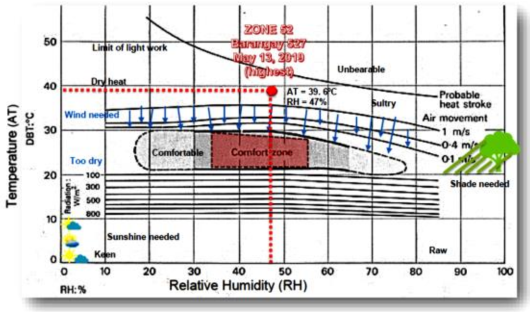
Figure 7 Heat index relationship to the thermal comfort zone

4.8 Correlation of results and the comfort zone in determining design solutions for the framework Temperature, Humidity, and Heat index in relation to Comfort Zone

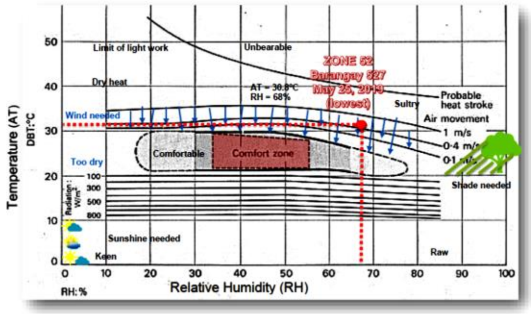
From the collected data, the highest temperature with the low relative humidity during the day (11.00 a.m. to 2.00 p.m.) needed an appropriate airspeed to offset the temperature and restore the feeling of comfort. Since the area is a large body of land, the wind brings dry air (National Geographic, 2011). Passive designs such as natural and cross ventilation, solar shading, and other green concepts are useful tools that can be applied to a highly urbanized area. At night (9.00 p.m. to 12.00 a.m.), the low temperature with a high relative humidity needed a faster airspeed. An increasing humidity further reduces airspeed, making it heavy and dragged downward, thus, it needs faster air circulation to lower the relative humidity. With air movement, the rate of evaporation is increased; with the mixing of air, the temperature and humidity differences tend to even out (Dotson, 2018).

The highest air temperature on May 13, 2019, from 11.00 a.m. to 2.00 p.m. was located at Zone 52, Barangay 527 (see Figure 8a) where the plotted point falls outside the comfort zone. It means that corrective measures are needed. If the point is higher than the upper perimeter of the comfort zone, winds are needed. With a temperature of 39.6 ºC and relative humidity of 47%, it needed a wind velocity of 4.0 m/s or 14.4 km/h to restore the feeling of comfort and offset the high temperature. The lowest air temperature on May 25, 2019, was also located at Zone 52, Barangay 527 (see Figure 8b) with a value of 30.8 ºC and relative humidity of 68%. The plotted point also falls in the upper perimeter of the comfort zone. Thus, it needed a wind velocity of 3.56 m/s or 12.81 km/hour. Since it is near the lower perimeter of the comfort zone, shading is needed.

On June 3, 2019, the highest air temperature recorded was 40.2 ºC with a relative humidity of 47% at Zone 56, Barangay 575, and at the same period as the records in May (see Figure 9a). The plotted line falls higher than the upper perimeter of the comfort zone; therefore, it needed a wind velocity of 4.0 m/s or 14.4 km/hour. Figure 9b shows that the lowest air temperature of 30.5 ºC and relative humidity of 72% was recorded on June 14, 2019, at Zone 43, Barangay 421. The plotted line falls in the upper perimeter of the comfort zone, which needed a 4.0 m/s or 14.4 km/hour wind velocity. Similarly, it is near the lower perimeter of the comfort zone; therefore, shading is needed.

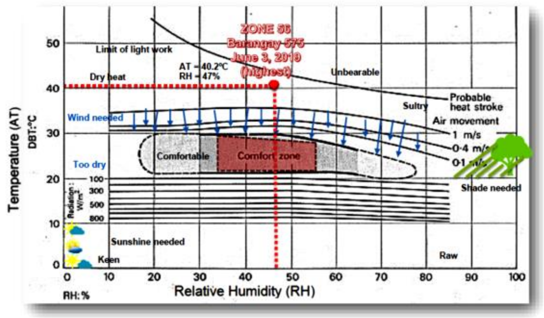


Rule of Thumb for Philippine
Setting Air Temperature – 39.6 ºC (low) RH 47%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind: speed 12km/hr or 3.33m/s
Wind speed needed: Moderate breeze
Direction (ESE) 112.5º 3.56m/s or 12.81 km/hr
(a)

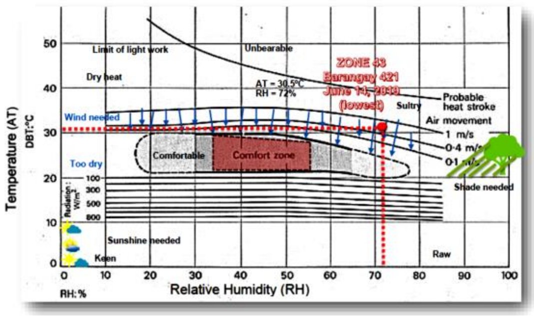


Rule of Thumb for Philippine
Setting Air Temperature – 30.8 ºC (low) RH 68%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind: speed 12km/hr or 3.33m/s
Wind speed needed: Moderate breeze
Direction (ESE) 112.5º 3.56m/s or 12.81 km/hr
(b)

Figure 8 (a) The highest air temperature in May 2019 (11.00 a.m. to 2.00 p.m.) in relation to comfort zone. (b) The lowest air temperature in May 2019 (11.00 a.m. to 2.00 p.m.) in relation to the comfort zone.



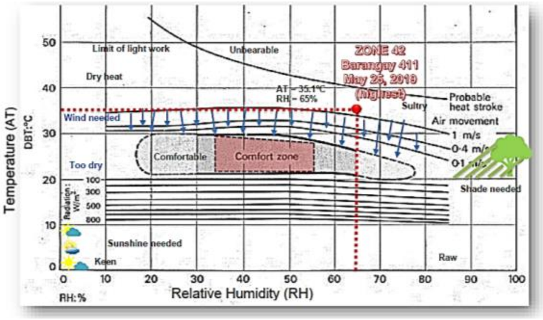
Rule of Thumb for Philippine
Setting Air Temperature – 40.2 ºC (high) RH 47%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind: speed speed 10 km/hr or 2.77 m/s
Wind speed needed: Moderate breeze
Direction (ESE) 112.5º 4.0 m/s or 14.4 km/hr
(a)



Rule of Thumb for Philippine
Setting Air Temperature – 30.5 ºC (low) RH 72%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind speed 23 km/hr
Wind speed needed: Moderate breeze
Direction (WSW) 247.5º 4.0 m/s or 14.4 km/hr
(b)

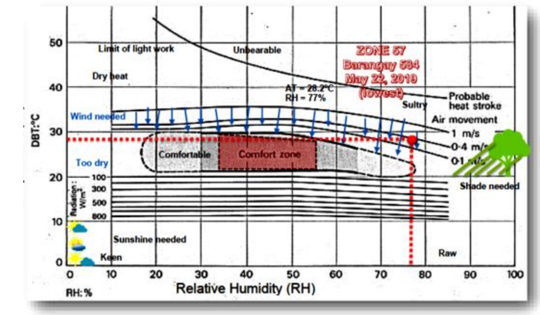
Figure 9 The highest air temperature June 2019 (11.00 a.m. to 2.00 p.m.) in relation to the comfort zone. (b) The lowest air temperature June 2019 (11.00 a.m. to 2.00 p.m.in relation to the comfort zone

Figure 10a shows the highest temperature recorded at night (9.00 p.m. to 12.00 a.m.), which was at 35.1 ºC with a relative humidity of 65% on May 25, 2019, at Zone 42, Barangay 411. The plotted line falls higher than the upper perimeter of the comfort zone, making it humid; therefore, it needed a 5.0 m/s or 18 km/hour wind velocity. Figure 11b shows that the lowest air temperature on May 22, 2019, was recorded at 28.2 ºC with a relative humidity of 77% at Zone 57, Barangay 584. The plotted line falls on the upper perimeter of the comfort zone wherein it needed a 2.54 m/s or 9.14 km/hour wind velocity.



Rule of Thumb for Philippine
Setting Air Temperature – 35.1 ºC (high) RH 65%
Range of thermal comfort zone of about 2 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind: speed (8 km/hr) or (2.2 m/s)
Wind speed needed: light breeze
Direction (SW) 225º 5.0 m/s or 18 km/hr

(a)

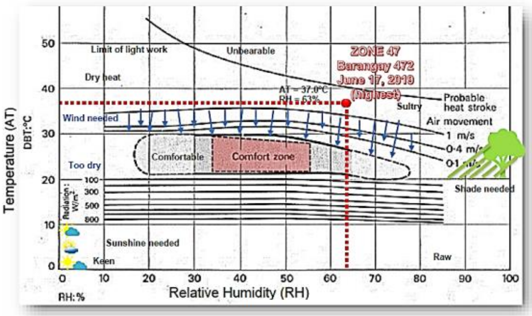


Rule of Thumb for Philippine
Setting Air Temperature – 28.2 ºC (low) RH 77%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind speed (23 km/hr
Wind speed needed: light breeze
Direction (SW) 225º 2.54 m/s or 9.14 km/hr

(b)

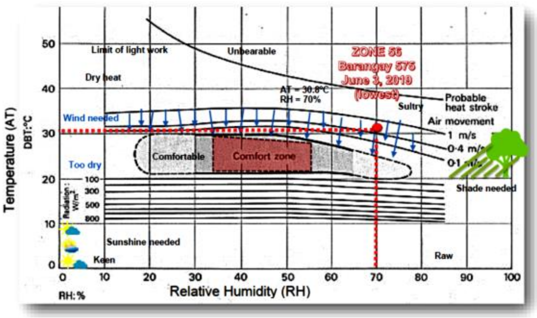
Figure 10 The highest air temperature in May 2019 (9.00 p.m. to 12.00 a.m.) in relation to the comfort zone. (b) The lowest air temperature in May 2019 (9.00 p.m. to 12.00 a.m.) in relation to the comfort zone.

On June 17, 2019, the highest air temperature recorded was at 37.0 ºC with a relative humidity of 63% at Zone 47, Barangay 472 (see Figure 12a). The plotted line also falls higher on the upper perimeter of the comfort zone, which makes it humid and needs a 5.0 m/s or 18 km/hour wind velocity. Aside from this, the lowest air temperature recorded was on June 3, 2019, at 30.8 ºC and relative humidity of 70% at Zone 56, Barangay 575 (see Figure 12b). The plotted line falls on the upper perimeter of the comfort zone where it needed a wind velocity of 2.54 m/s or 9.14 km/hour.



Rule of Thumb for Philippine
Setting Air Temperature – 37.0 ºC (high) RH 63%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind speed 23 km/hr
Wind speed needed: light breeze
Direction (SW) 225º 2.54 m/s or 9.14 km/hr

(a)



Rule of Thumb for Philippine
Setting Air Temperature – 30.8 ºC (low) RH 70%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind speed 23 km/hr
Wind speed needed: light breeze
Direction (SW) 225º 2.54 m/s or 9.14 km/hr

(b)

Figure 12 The highest air temperature June 2019 (9.00 p.m. to 12.00 a.m) in relation to the comfort zone. (b) The lowest air temperature June 2019 (9.00 p.m. to 12.00 a.m.) in relation to the comfort zone.

According to Koenigsberger (1975), the comfort zone is defined in terms of dry bulb temperature (DBT) and relative humidity (RH), but eventually, it is shown by additional lines how this comfort zone is pushed up by the presence of air movements and how it is reduced by radiation. Since the air temperature was recorded only three times a day, the rule of thumb for the Philippine setting on the range of thermal comfort zone is about 24 to 27 ºC, and the ideal relative humidity is around 35 to 55%. The thermal comfort zone is the range of temperature that most people feel comfortable given a set of environmental conditions.

It helped understand the comfort zone of the area where most people feel comfortable to provide a solution in the mitigation of urban heat.

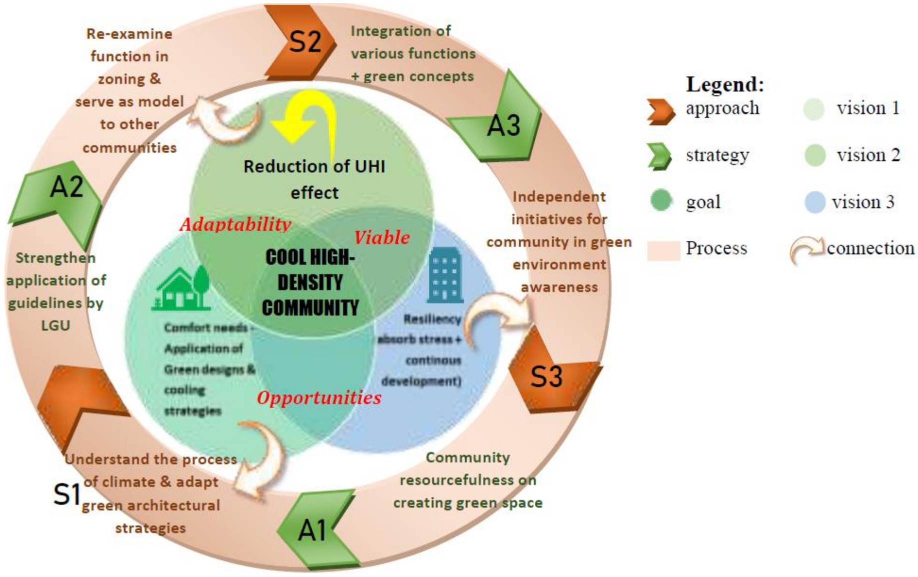


Figure 13 The strategic framework in mitigating urban heat island effect for a cooler high-density community.

4.9 The strategic framework in mitigating UHI effect for a cooler high-density community

Based on the result of the study, the framework for mitigating UHI effect that serve as a guide to achieve a cooler high-density community was formulated (see Figure 13). It created approaches and strategies where urban community must be designed (a) to understand the process of climate and adapt green architectural designs by providing directions for passive design and cooling techniques to achieve comfort needs, (b) as a scheme in re-examining zoning types and serve as a model to other urban communities, and (c) as an independent initiative for the community to be involved in green environment awareness to reduce the UHI effect.

4.10 Mitigation of UHIs in specific areas in Sampaloc District based on the framework as a design solution

As a rule of thumb for the Philippine Setting, the range of comfort zone is about 24 to 27 ºC and the ideal relative humidity is around 35 to 55%. Table 5 shows the air temperature recorded at 11.00 a.m. to 2.00 p.m. while Table 6 shows the air temperature from 9.00 p.m. to 12.00 a.m. during the month of May and June. These data, in correlation to the bioclimatic chart of the barangays, were used to better understand the comfort zone and, in turn, identify the problems and provide possible design solutions. Based on the data, the highest and the lowest air temperatures during the daytime (11.00 a.m. to 2.00 p.m.) on dry and wet seasons had a slight difference, which was similar to the difference between the highest and lowest air temperatures during the nighttime (9.00 p.m. to 12.00 a.m.) on dry and wet seasons that is also negligible. Therefore, the application of the framework is particularly the same for both instances.

4.11 Applicability of the framework to Sampaloc district.

Table 7 shows how the approaches and strategies provide a direction in designing and planning for the reduction of the UHI effect in the district, which is also applicable to any urban district in Manila. They were based on the data generated, in particular, the result of the survey as well as the field visits, observations, and unstructured interviews from the residents. It should be considered that the district is physically evolving and subsisting by continuously adapting economic purposes, resulting in conversion and expansion of spaces. The heterogeneity of the district results in the different functions and should be integrated with green designs/ideas while considering continuous development to be viable. The approaches and strategies are a continuous process where its implementation should be strengthened with the help of the local government. Therefore, the formulated framework, in providing direction by establishing guidelines in design and planning, corresponds to the prevailing condition of the district.

4.12 Graphical representation of the applicability of the framework to Sampaloc district

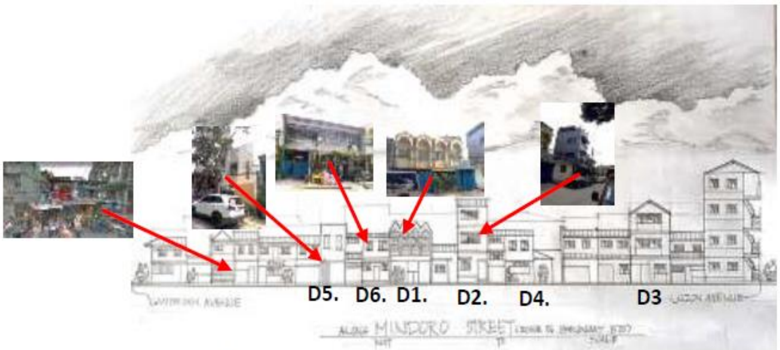
A conceptual elevation of the houses along Mindoro street located in Barangay 575, Zone 56, as shown in Figure 13(a) illustrates the congruency of the strategies to the current condition of the district. Each applies to every structure. Figure 13(b) shows the architectural design strategies of the framework that can be applied. The principles of passive design and recommendation of adapting green concepts consist of the first approach that helps reduce the UHI effect in the area.

Table 5 The relationship of air temperature and humidity with regards to the comfort zone (11.00-2.00 p.m.).

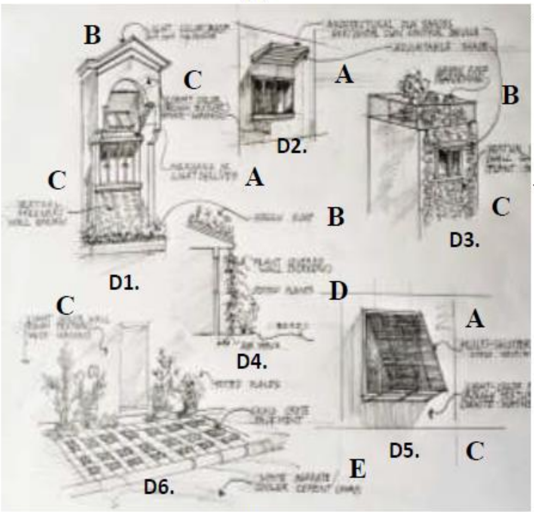
Air Temperature (11.00 a.m. -2.00 p.m.)	**(Highest) (MAY)**	**(Highest) (JUNE)**	**(Lowest) (MAY)**	**(Lowest) (JUNE)**
Location/ Date temperature measured	Zone 52, Barangay 527 May 13, 2019	one 56, arangay 575 ıne 3, 2019	Zone 52, Barangay 527 May 25, 2019	Zone 43, Barangay 421 June 14, 2019
Temperature	40.2 ºC	0.8 ºC	30.5 ºC	30.5 ºC
Humidity	47%	8%	72%	72%
Heat index temperature	53 ºC (Danger)	6 ºC Extreme Caution)	37 ºC (Extreme Caution)	37 ºC (Extreme Caution)
Criteria	**Identifying problems regarding comfort zone (For the Highest AT)**		**Identifying problems regarding comfort zone (For the Lowest AT)**	
Condition	Temperature is way above comfort zone and humidity high		Temperature is above comfort zone and humidity is moderate	
Necessary rectification	Thermal capture and thermal storage must be reduced, humidity must be reduced by facilitated air movement Shading is needed		Thermal capture and thermal storage must be reduced, wind ventilation is needed. Shading is needed	
Possible solution	Sun baffles, insulation, and mechanized ventilation or cooling		Sun baffles, insulation and buoyancy, and cross ventilation are needed.	

Table 6 The relationship of air temperature and humidity with regards to the comfort zone (9.00-12.00 p.m.)

Air Temperature (9.00 – 12.00 p.m.)	**(Highest) (MAY)**	**(Highest) (JUNE)**	**(Lowest) (MAY)**	**(Lowest) (JUNE)**
Location/ Date temperature measured	Zone 42, Barangay 411 *May 6, 2019*	Zone 42, Barangay 427 *June 17, 2019*	Zone 57, Barangay 584 *May 22, 2019*	Zone 56, Barangay 575 *June 3, 2019*
Temperature	35.1 ºC	37 ºC	28.2 ºC	30.8 ºC
Humidity	65%	63%	77%	70%
Heat index temperature	48 ºC (Danger)	53 ºC (Danger)	32 ºC (Caution)	35 ºC (Extreme Caution)
Criteria	**Identifying problems regarding comfort zone (For the Highest AT)**		**Identifying problems regarding comfort zone (For the Lowest AT)**	
Condition	Temperature is way above comfort zone and humidity high		Temperature is above comfort zone and humidity is moderate	
Necessary rectification	Thermal capture and thermal storage must be reduced, humidity must be reduced by facilitated air movement Shading is needed		Thermal capture and thermal storage must be reduced, wind ventilation is needed. Shading is needed	
Possible solution	Sun baffles, insulation, and mechanized ventilation or cooling		Sun baffles, insulation and buoyancy, and cross ventilation are needed.	



(a)



(b)

A Shading	Adjustable shade (wood, aluminum)
	Movable curtains for window
	Multi-shutters (deter heat absorption but allow cross ventilation)
	Incorporate overhangs on light shelves
	Trellised roof
	Plant covered walls
B Roof	Light color but not reflective
	Green roof/solar roof (if can be afforded)
C Wall	Plant screen
	Vertical wall garden
	Light color paint; rough texture; white washed (avoid glare)
D Sidewalk	Put potted plants
	Vertical plant screens
	Light color paint; rough texture; white washed (avoid glare)
E Roads	White aggregate, cooler cement

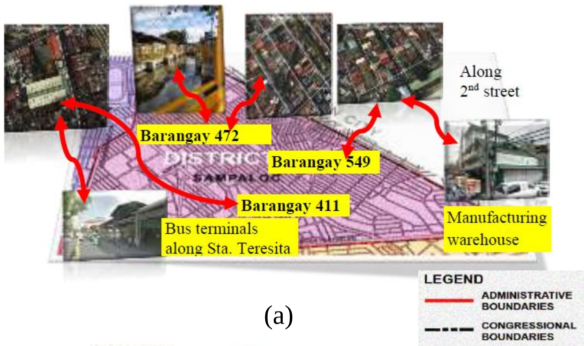
Figure 13 (a) Elevation of identified houses where strategies can be applied to the area (b) Architectural design strategies as the first approach of the framework.

A variety of functions or mixed-use types existed in the district that resulted in inappropriate zoning types. As mentioned, integration of various functions and adapting green concepts affected by anthropogenic sources in the area while allowing continuous development is a strategy for the second approach. Figure 14 (a & b) shows the strategies that can be applied in the district.

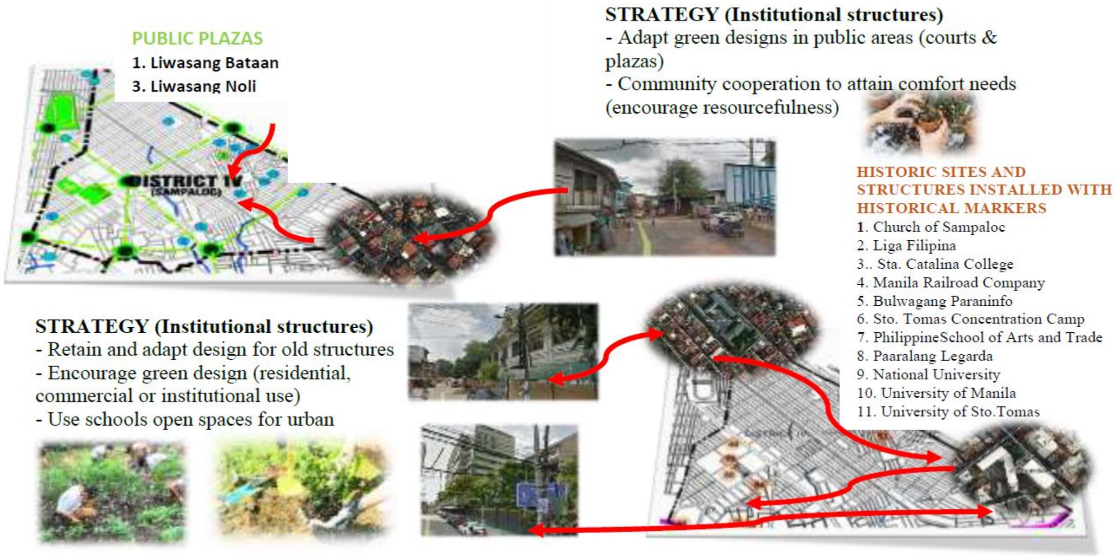
The recommendation of adapting green concepts on the structures and landscape in the area is more effective if the whole community will participate through its resourcefulness along with the strong implementation of the LGUs. Figure (15a) shows how the framework will help in the reduction of heat in the area. For potential landscapes, small-scale edible landscaping can be used. Figure 15(b) shows that a holistic approach is needed for this goal as the key to success with the support of the local government and the participation of various stakeholders including residents of the community. The strategies should help achieve comfort needs by reducing the urban heat island effect so a cooler high-density community may be realized in the future.

STRATEGY
(Barangay 472)
- Water from (creek) emits heat at night (redesign structure features through green concepts along bodies of water)
- Apply green designs/concepts for various functions

STRATEGY (Barangay 411)
- Function not appropriate to zoning (bus terminals within a high-residential type zone)
- Apply green designs/concepts for various functions

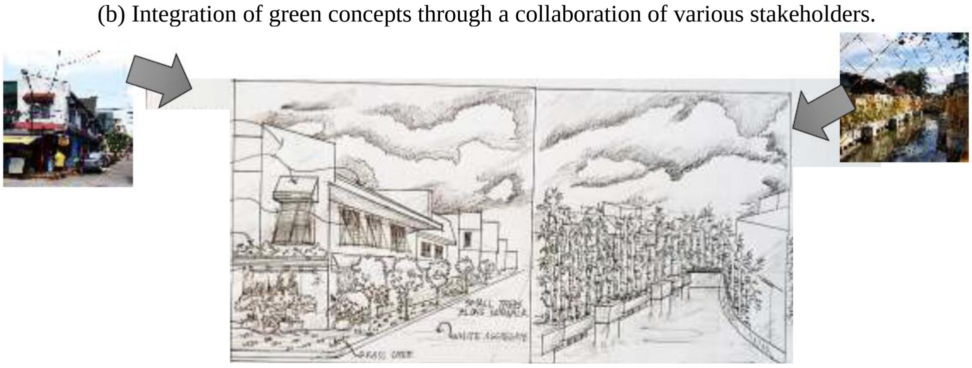


(a)

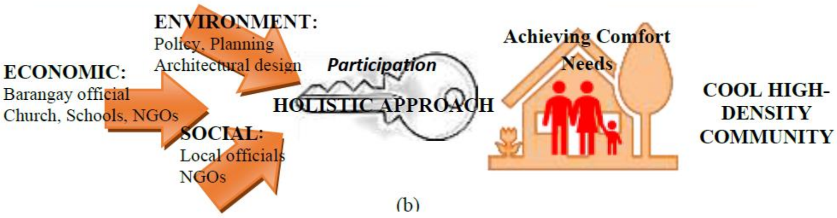


(b)

Figure 14 (a) Graphical representation to re-examine zoning in the district
(b) Integration of green concepts through a collaboration of various stakeholders.



(a)



(b)

Figure 15 (a) Recommendations of the framework on urban structures and landscape in the area
(b) A conceptual illustration of the recommendation.

Table 7 Applicability of the framework to the current condition of Sampaloc district.

Physical features/characteristics	**Barangay 527**	**Barangay 575**	**Barangay 411**	**Barangay 472**	**Indication**	**Strategic framework applicability**
Classification of buildings	Mixed-use (low to medium-rise)	Mixed-use (low to medium-rise)	Mixed-use (low to medium-rise)	Mixed-use (low to medium-rise)	Configuration of building	
Color of structures	Light color (reflect solar radiation)	Light color (reflect solar radiation)	Light and dark colored paint	Light and dark colored paint	Absorption and reflectivity	
Materials used	Concrete, wood, glass	Concrete, wood, glass, steel, bricks	Concrete, wood, glass, steel, bricks	Concrete, wood, glass, steel, bricks	Absorption and reflectivity	
Age of structures	59 to 69 yrs.	4 to 59 yrs.	20 to 40 yrs.	30 to 49 yrs.	Retain and adapt old structures	
Roofing materials	Light color paints (high reflectivity) Corrugated metal	Light color paints (high reflectivity) Corrugated metal	Light color paints (high reflectivity) & dark color paint Corrugated metal	Light color paints (high reflectivity) Corrugated metal	Absorption and reflectivity	
Lot area (sq.m.)	30 to 40 (owned) 20 to 25 (rented)	64 to 150 (owned) 20 to 123 (rented)	80 to 100 (owned) 22 to 27 (rented)	50 to 120 (owned)	Maximization of lots	
Roads	Wide road serve as major road others were narrow	Wide road others were narrow	Wide road serve as major road others were narrow	Wide road serve as major road others were narrow	Absorption and reflectivity	
materials texture greenery	Concrete & asphalt Smooth Minimal green spaces potted plants	Minimal green spaces, few trees, potted plants	Minimal green spaces, few trees potted plants	Minimal green spaces, few trees, potted plants	Lack of open space and required green areas	
Characteristics	Houses converted to commercial purposes (renting) Middle-income earners Numerous old residential & commercial structures Rented spaces are smaller to owned houses Conversion and expansion on structures Owned houses large space than rented space Convert and expand spaces Larger areas for owned houses				Density due to economic reasons result to con-conformity to building code	

Legend:		
Consid e ration	Strategy 1: Understand the process of climate	
	Strategy 2: Re-examine zoning	
	Strategy 3: Community participation	

5. Conclusion

The UHIs in the Sampaloc District area vary in one location at the same time frame but on a different day which is a function of land surface temperature, air temperature, and the factors that influenced these temperatures. Its limitation was a mobile manner of recording temperatures three times a day for three consecutive weeks in only two months at a single urban location. The temperature remains constant in one space but varies because of the different factors. Since the district has varied features and is continuously subsisting and evolving, the UHI effect is likewise in a similar course. Its limitation on the physical impact was that the temperatures recorded were based on the physical features of the area excluding indoor temperature while on the social impact, the residents' interviews were limited to 10% of the total structures or houses selected. For the framework to become feasible at the initial stage of structure, the design must be (a) an approach to understanding the process of climate and adapt green architectural designs; (b) a scheme in re-examining zoning types integrating various functions in connection with green concepts; and (c) an independent initiative for the community to be involved in green environment awareness in their resourcefulness. The effectiveness of the strategies and approaches of the framework to the old and existing district is realized by understanding the weather condition and the interaction of the identified factors that affect the UHI effect. Similar research should be undertaken to other districts located in any local urban city because of no available specific data focusing on an urban community that provided a mitigating strategy for the UHI effect. Future research related to this study will further guide local government administrators, planners, designers, architects, and others who wish to undertake planning and designing urban communities using the framework obtained from the study. A more sophisticated instruments should be utilized. A measuring instrument fixed in different locations may be applied to record temperatures simultaneously instead of in a mobile manner to determine if the results will be similar or not.

8. Acknowledgements

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