ISSN 2286-976X / Online: ISSN 2539-5513

RANGSIT JOURNAL OF SOCIAL SCIENCES AND HUMANITIES

Available online at https://rjsh.rsu.ac.th

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

Sheila V. Elardo

School of Architecture, Industrial Design, and the Built Environment Mapua University, Manila, Philippines
E-mail: svelardo@mapua.edu.ph

Received March 4, 2021 / Revised March 23, 2021/ Accepted April 5, 2021/ Publish Online May 20, 2021

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 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 urban heat island (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.

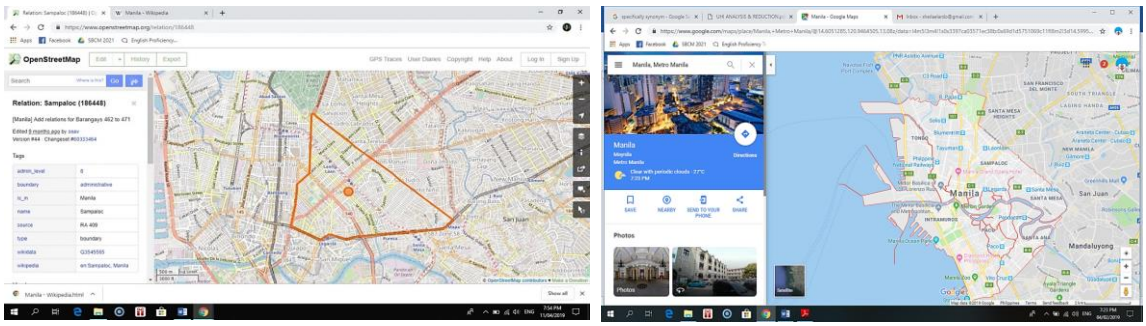
4) To formulate a strategic framework aimed at mitigating and alleviating the impacts of the urban heat island to achieve a cooler high-density community in Sampaloc.

3. Significance of the Study

The urban residents of the barangay and other barangays outside Metro Manila are the primary beneficiaries of this study. It is likewise beneficial to developers, urban planners, designers, and even academicians involved in research on environmental studies, particularly on the urban heat island (UHI) effect on a high-density community. It can help every urban household, neighborhood, and whole community becomes aware of the negative impact of the urban heat island effect in the area. This study shall serve as a reference map by the local government of Manila in its vision to mitigate the urban heat island effect. Likewise, it can promote urban greening ideas to achieve a cooler community. The UHI effect can be alleviated as the proposed study contributes to the awareness of the residents and the local officials. It can also add insights and knowledge to the residents in starting simple strategies aimed at gradually progressing to more difficult practices to mitigate this environmental risk, thus improving their quality of life as well as the environment.

4. 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. 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



(A) (b)

Figure 1 (a) Boundary of Sampaloc district (https://www.openstreetmap.org)
(b) Map of City of Manila (Google Map, 2019)

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

5. Materials and Methods

5.1. 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.

5.2 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.

5.3 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 similarly used at the PAGASA weather station, Science Garden in Quezon City. Simultaneously, it also used a digital Thermometer and Hygrometer that measure the indoor and outdoor air temperatures as well as humidity. 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.

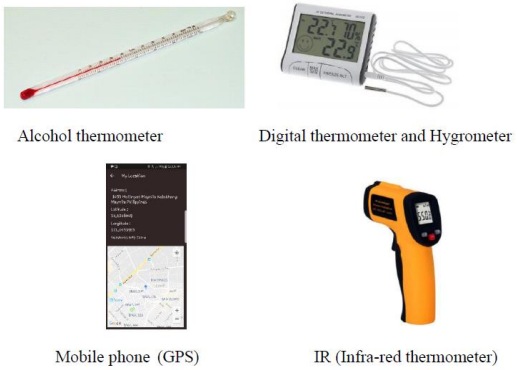


Figure 2(a) Equipment used in the field of temperature measurement

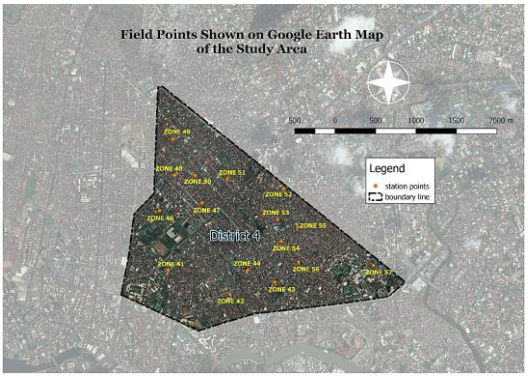


Figure 2(b) The field investigation points shown in the Google Earth image

5.4 Method of measuring 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(b). Temperature measurements were simultaneously taken by riding a tricycle and stopping at designated barangay as station points as shown in Figure 3. 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.

5.5 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.

(1) 7:42 a.m. Honradez street. (2) P. Florentino St. 8:30 a.m. (3) 11:42 a.m. P. Noval st (4) Mindoro street 9:44 p.m.

(5) Dapitan St. at 8:45 a.m. (6) Prudencio St. at 11:48 a.m. (7) Simoun st at 10:38 p.m. (8) P. Noval St. at 9:09 p.m.

Measuring at different barangays in the month of May and June

(1) 6:57 a.m. (2) 11:13 a.m. (3) 9:27 p.m.

Measurements are taken on May 29, 2019, at UST Quadrangle

Figure 3 Measuring land with IR thermometer and simultaneously with a digital thermometer and hygrometer for humidity.

6. Results and Discussion

6.1 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 the month of May while Zone 52 (highest), Zone 56 (medium), and Zone 43 (lowest) were the identified locations for the month of June, as shown in Figure 4.

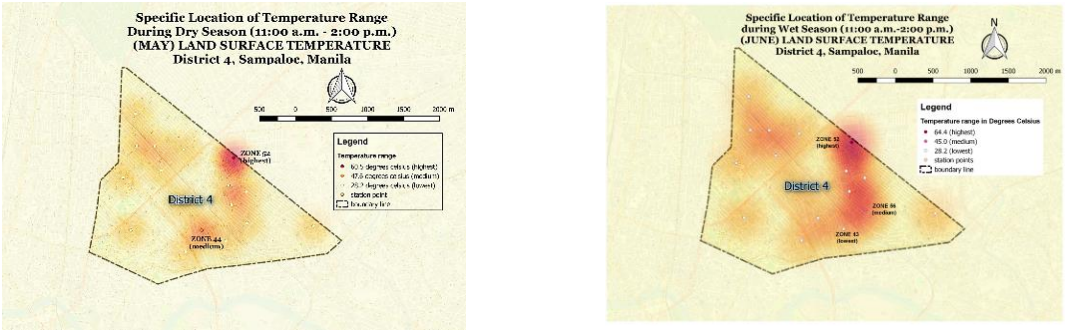


Figure 4 Areas with high and low land surface temperatures (LST) during the daytime on May & June from 11:00 to 2:00 p.m.

6.2 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 6 shows the identified location for the highest air temperature for the month of 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 the month of 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 the month of May for air temperature. For the month of June, Zone 47 (highest), Zone 43 (medium), and Zone 56 (lowest) were the identified barangays.

6.3 Areas with high and low humidity (HU)

As shown in Figure 6, for the month of 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 the month of June, Zone 43 (highest), Zone 50 (medium), and Zone 56 were the identified locations. During the nighttime from 9:00 p.m. to 12:00 a.m. for the month of May, Zone 56 & 44 (highest), Zone 56 (medium), and Zone 48 (lowest) were the identified locations of barangays where humidity was measured. For the month of June, Zone 56 (highest), Zone 53 (medium), and Zone 55 (lowest) were the identified locations of barangay as shown in Figure 5.

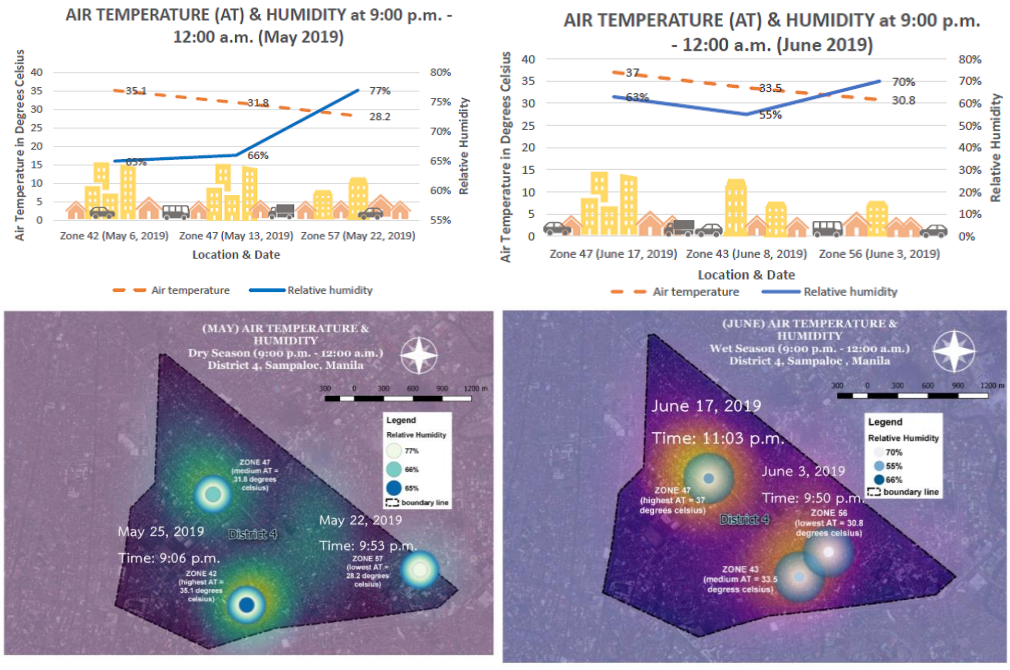


Figure 5 Profile of the highest, medium, and lowest temperature and humidity values during 9:00 p.m. 12:00 a.m. (wet & dry season) May & June 2019.

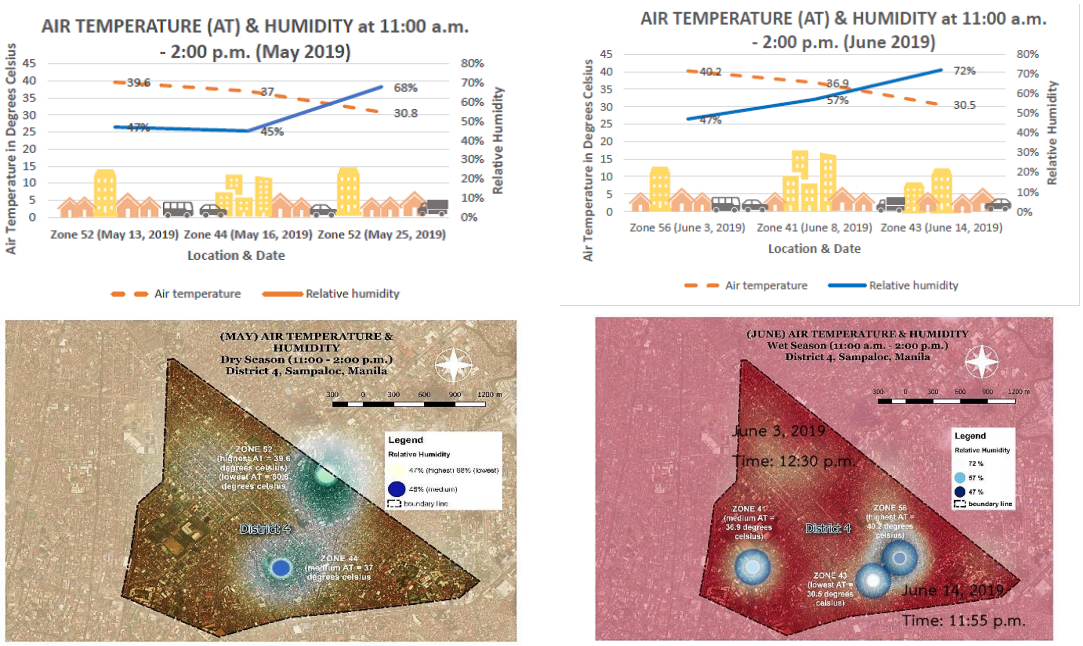


Figure 6. Profile of the highest, medium, and lowest temperature and humidity values during 11:00 p.m. -12:00 p.m. (wet & dry season) May & June 2019.

6.4 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 7 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.

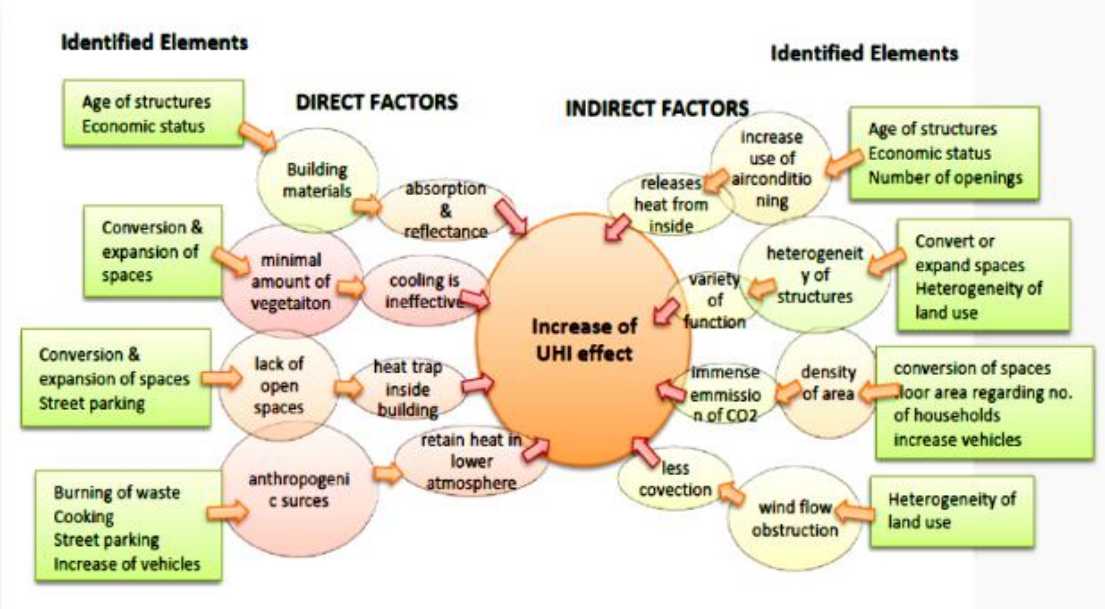


Figure 7 The influence of the identified elements on the factors influencing the UHI effect in the study area.

6.5 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.

6.6 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.

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

Physical impacts *Respondents - Barangays that have the highest temperature (highest response)*		*Indication*		**Architectural means** *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
Barangay 411 (AT recorded at 9:00 to 12:00 p.m.)				
(Present) Spaces	Characteristics (Ventilation system)	Features (Description / Perception)	Indication	Consideration
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 (AT recorded at 9:00 to 12:00 p.m.)				
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 (AT recorded at 11:00 a.m. to 2:00 p.m.)				
living and dining room, kitchen, toilet and bath and bedroom	Inadequate	Sufficient to crammed	Rented spaces are smaller to owned houses	Multi-function of spaces
Barangay 575 (AT recorded at 11:00 a.m. to 2:00 p.m.)				
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
Recommended Strategic Framework			 	

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
Main	Use of air		Increase of		Household		Burning

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*
contribution of heat stress	conditioner Lack of open space		motor vehicles Increase of resident's population		d cooking & heating Lack of open & green spaces		of waste Increase of resident's population
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
Affected residents by heat stress	Highest – female 21-35 years ---36-55 years --- 56-65 years ---65 years & above						
Transport vehicles generate heat	Yes *Consideration (Strategic framework)*		Yes 		Half (yes) 		Yes
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 vehicle if no parking	Yes *Consideration (Strategic framework)*		No 		Yes 		Yes
Commercial establishment cause heat	Yes *Consideration (Strategic framework)*		Yes 		No 		Yes

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 infrastructure & 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)

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*
Consideration (Strategic framework)						

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

6.7 Heat Index relation to heat stress

The air temperatures from the month of 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 8. From the data collected, mitigation strategies were extracted and led to the formulation of a framework to achieve a cool high-density community.

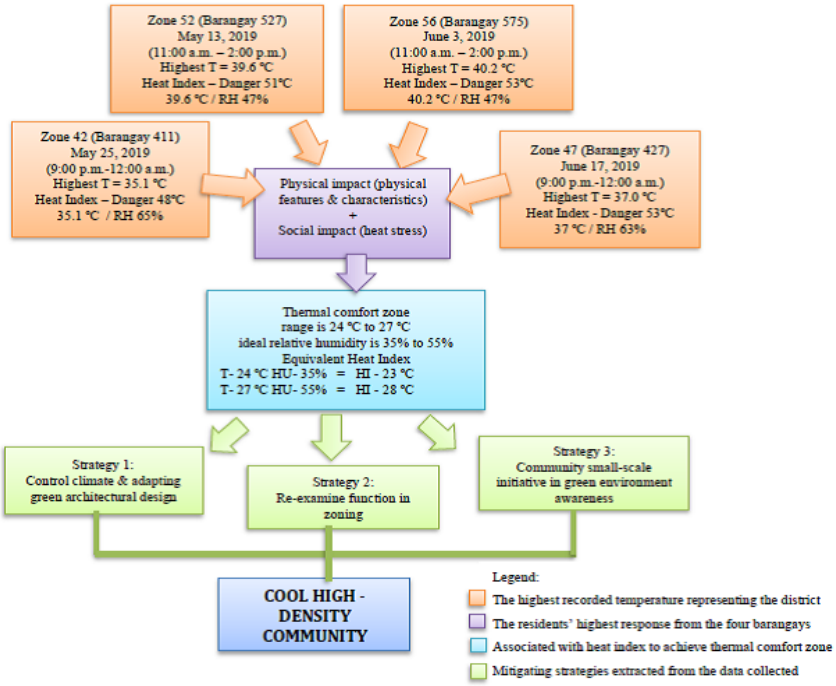


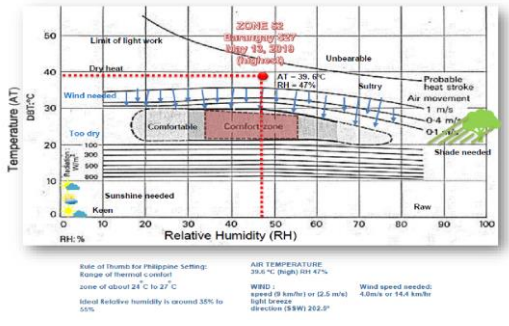
Figure 8 Heat index relationship to the thermal comfort zone

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

To relate the temperature, humidity, and heat index to the comfort zone, the study used the bioclimatic chart that considered the air temperature, relative humidity, and air velocity. Any climatic condition determined by its dry-bub temperature and relative humidity can be plotted on the chart. A bioclimatic chart shows the comfort zone and the relationships of the climatic elements to each as shown in Figures 9 and 10. It was constructed with the dry-bulb temperature as the ordinate (y-coordinate) and relative humidity as the abscissa (x-coordinate).

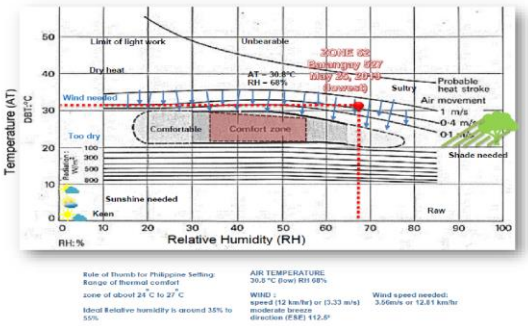
From the data, the highest temperature with the low relative humidity during the day (11:00 a.m. to 2:00 p.m.) needed an appropriate airspeed to offset the temperature and restore the feeling of comfort. Since the area is a large body of land, the wind brings dry air (National Geographic, 2011). Passive 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 9a) 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 9b) 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.



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)



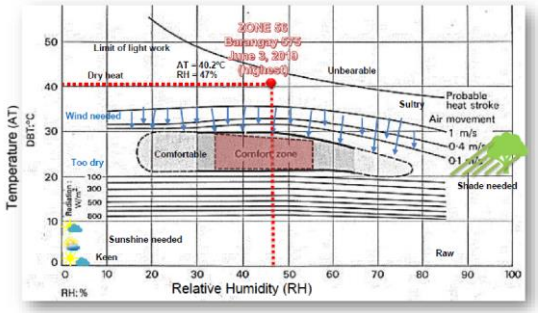
Rule of Thumb for Philippine Setting Air Temperature – 30.8 ºC (low) RH 68%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind: speed (12km/hr)or (3.33m/s) Wind speed needed:
Moderate breeze Direction (ESE) 112.5º 3.56m/s or 12.81 km/hr

(b)

Figure 9 (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.

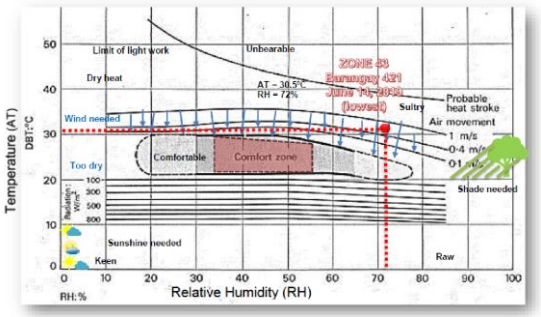
On June 3, 2019, the highest air temperature recorded was 40.2 ºC with a relative humidity of 47% at Zone 56, Barangay 575, and at the same period as the records in May (see Figure 10a). The plotted line falls higher than the upper perimeter of the comfort zone; therefore, it needed a wind velocity of 4.0 m/s or 14.4 km/hour. Figure 10b 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 – 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)

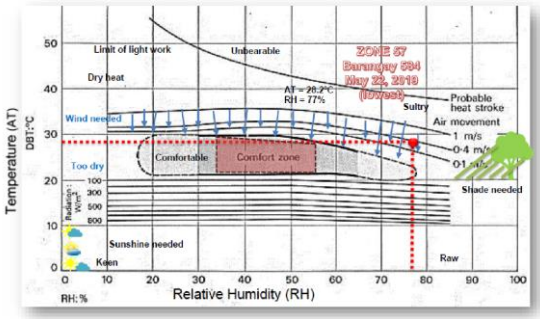


Rule of Thumb for Philippine Setting Air Temperature – 30.5 ºC (low) RH 72%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind speed (23 km/hr Wind speed needed:
Moderate breeze Direction (WSW) 247.5º 4.0 m/s or 14.4 km/hr

(b)

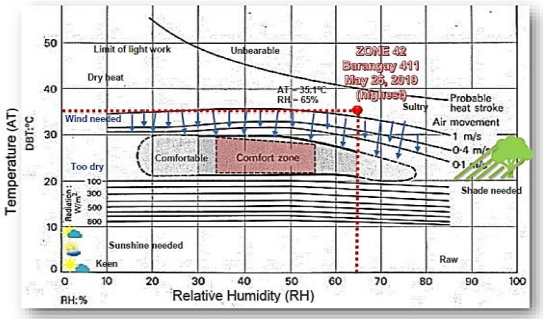
Figure 10 The highest air temperature June 2019 (11:00 a.m. to 2:00 p.m.) in relation to the comfort zone.
(b) The lowest air temperature June 2019 (11:00 a.m. to 2:00 p.m.in relation to the comfort zone

Figure 11a 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 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)



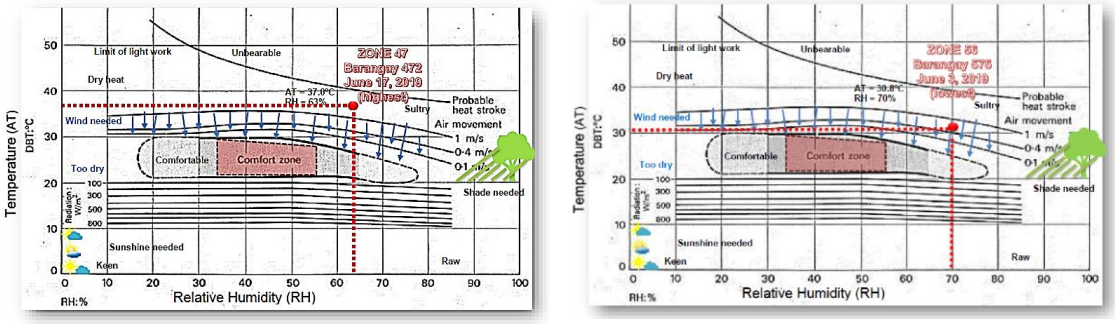
Rule of Thumb for Philippine Setting Air Temperature – 28.2 ºC (low) RH 77%
Range of thermal comfort zone of about 24 ºC to 27 ºC
Ideal Relative humidity is around 35% to 55%
Wind speed (23 km/hr Wind speed needed:
light breeze Direction (SW) 225º 2.54 m/s or 9.14 km/hr

(b)

Figure 11 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 light breeze Direction (SW) 225º
Wind speed needed: 2.54 m/s or 9.14 km/hr

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 light breeze Direction (SW) 225º
Wind speed needed: 2.54 m/s or 9.14 km/hr

(a) (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.

7. Conclusion and Recommendations

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

Based on the results of the study, a framework is proposed as shown in Figure 13 for mitigating the urban heat island (UHI) as a guide in designing a cooler high-density urban community. The framework was drawn out from the measured temperature data as well as the physical and social impact information gathered after determining the location of the highest range of temperature in the study area and linked to the equivalent heat index with regards to the comfort zone. The zones that recorded the highest temperature in the study area represented similar physical features where it needed an approach to understand the process of climate and adapt architectural design such as passive cooling techniques to achieve the comfort needs of the residents. Furthermore, the data extracted from the responses and views of the residents helped strengthen the claim that the formulated framework will be successful in its application and implementation for the district as well as other urban communities.

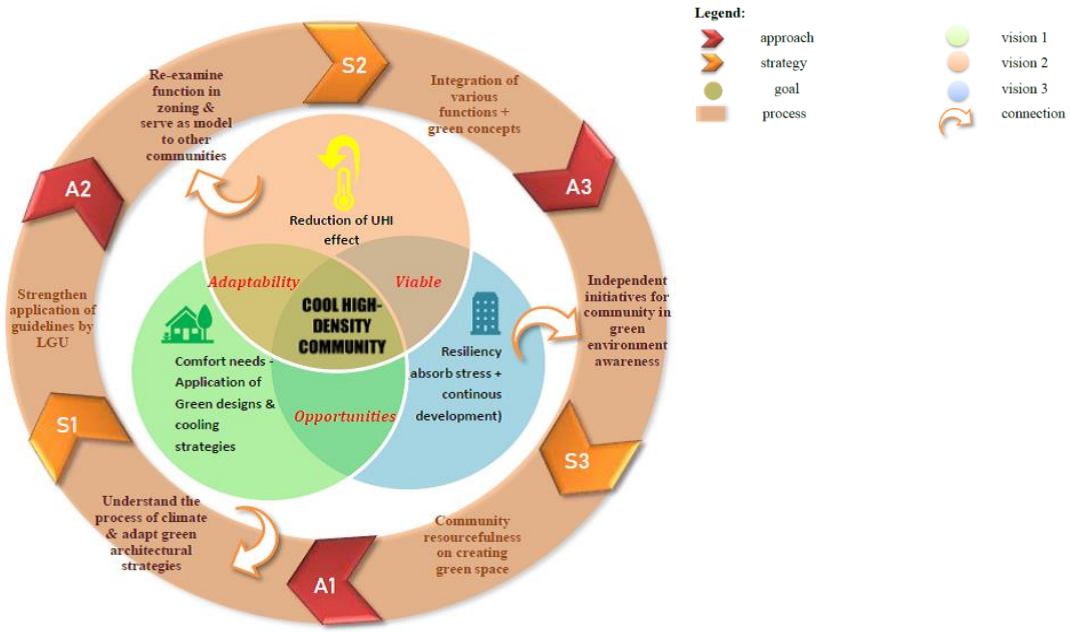
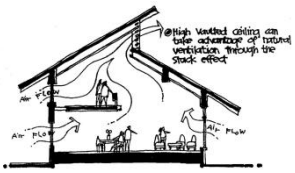
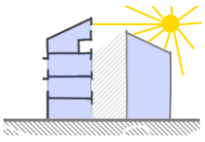
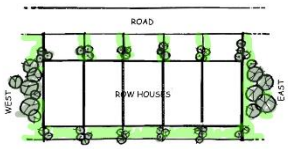


Figure 13 Strategic framework in mitigating the UHI effect for a cooler high-density community

7.2 Describing the UHI effect mitigation approach and strategy

The framework highlighted the intentions of the visions and its process to achieve the aim of the study, that is, a cooler high-density community. It created approaches and strategies as shown in Table 4 as a continuous process drawn out from the physical and social impact information gathered after determining the highest range of temperature in the study area. An 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. These approaches follow the three vital components, namely, environment, people, and economic aspects, which were considered in the recommendations.

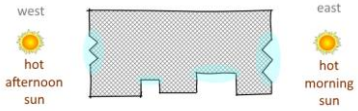
Table 4 The framework description on its UHI effect approach and strategy (Note. Reprinted from *Lectures on Tropical Architecture*, by Ar. M.C.G)

Principles of Passive design • **Avoid heat gain** • **Building orientation & form**
Design Approach
Provide high ceiling options when possible 
Elongate building along east- west axis 
Orient windows to prevailing winds & to prevent direct sunlight from hitting it 
Take advantage of protection given by adjacent structures (when available) or vegetation  

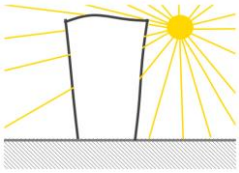
Use lattice-works and sunscreens as additional building form feature

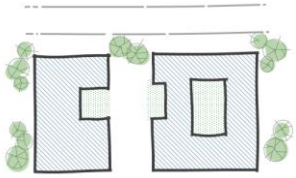
Create multi-level courtyards to create several shaded areas

Avoid walls that will be perpendicular to intense sunlight



Create shadow courts





- **Building materials selection**

Design Approach

Use of lightweight construction materials with low thermal mass particularly on walls exposed to sun

Recommended properties of materials:

- Low Conductivity
- Low Admittance (small Y-Value)
- Low Transmittance (small U-Value)
- Low Heat Capacity (small time lag)
- High Resistance
- High Reflectance (light color)
- Low Absorptance (light color)

Source: Sustainable Building Design

Re-examining zoning types

For the community	*Principle*	*For newly design and constructed communities*
Strict implementation of the type of use where residential area should be located and not any other type of use	  Source: Google photos	Provide future land use plan for urban farming in the communities and not just a temporary or conditional use for commercial or suburban expansion
A high intensity mixed use residential or commercial zone is useful in integrating a single function for the district; however, transport terminals and warehouses for manufacturing and the like is a different type of use.	 Source: Google photos	Clustering residential, commercial and institutions as well as transport terminals should not be within but adjacent to each other. Urban communities should preserve open spaces and incorporate community agriculture, connecting these types all at a walking distance.

Implement pedestrianization on secondary roads and discourage parking vehicles on street.
Vehicle terminals and other types not considered residential, commercial or institutional should not be within a residential community.
Support a green and walkable urban community by connecting open spaces and parks to any type of use.

21st Century Street Design Competition
(Source: Lecture on Tropical Design)

A well-planned community should have a street for pedestrian, row of green elements such as shrubs and trees, a bicycle path to minimize use of transportation vehicle, rows of trees and road for vehicles which is similar to the other side connecting to community gardens, residentials, and institutions.

HEALTHY LIVING. The Iloilo Esplanade allows people to run, bike or just hang out by the river. Photo by Paulo Alcazaren

Community independent initiative to be involved in green environment awareness		
For the community	*Principle*	*For newly design and constructed communities*
Choose cool surfaces for maintenance or replacement of roofs, walls or parking lots and pavements	 Source: Google photos	Implementing at the first stage of design of the use of cool surfaces for maintenance and replacement.
Local government under barangay level should train local people to empower communities in green environment awareness	 (Image source: Paseo Verde at Real Facebook page)	High-rise buildings such as condominiums should take the lead in promoting green environment awareness by incorporating a part in the building urban gardening or farming involving their tenants
Advocate for local food production like organic farming for economic purposes. Local government, churches, NGOs, and residents can help sell the produce for their benefit	 	There should be a green environment association that will economically help the community as well as reducing urban heat

(http://ati.da.gov.ph)

Educate community on composting and plant waste since these are preferable than using chemical fertilizers.
Schools should promote urban gardening/farming

Barangay level should involve participation of the community with the support of the local government.

Composting

Vermicomposting
(https://philippinesgraphic.net)

Barangay chairman should take the lead in initiating and maintaining urban gardening/farming in their community

This should be supported by LGU and the residents to be successful

(http://ati.da.gov.ph)

Buy or replace a high-efficiency window air conditioner and shade the exposed part.
Use energy efficient cooking stoves and the right size cooking utensil for cooking.
Practice edible landscaping aside from ornamental plants commonly used in conventional landscaping. According to Tayobong, Sanchez, Balladares and Medina (2013) edible landscaping in the Philippines is an innovative concept of combining various principles of landscape design with existing technologies for small-crop production. It utilizes vegetables, herbs and fruit crops as major softscape and considers aesthetics and functionality of space in relation to production of safe and readily available crop products for the family and community.

7.3 Recommendations to mitigate 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.0 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.

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	Zone 56, Barangay 575 June 3, 2019	Zone 52, Barangay 527 May 25, 2019	Zone 43, Barangay 421 June 14, 2019
Temperature	40.2 ºC	30.8 ºC	30.5 ºC	30.5 ºC
Humidity	47%	68%	72%	72%
Heat index temperature	53 ºC (Danger)	36 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.

7.4 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.

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	Light color	Light color	Light and	Light and	Absorption	

Physical features/characteristics	Barangay 527	Barangay 575	Barangay 411	Barangay 472	Indication	Strategic framework applicability
structures	(reflect solar radiation)	(reflect solar radiation)	dark colored paint	dark colored paint	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:		
Consideration	Strategy 1: Understand the process of climate	
	Strategy 2: Re-examine zoning	
	Strategy 3: Community participation	

7.5 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 14(a) illustrates the congruency of the strategies to the current condition of the district. Each applies to every structure. Figure 14(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.

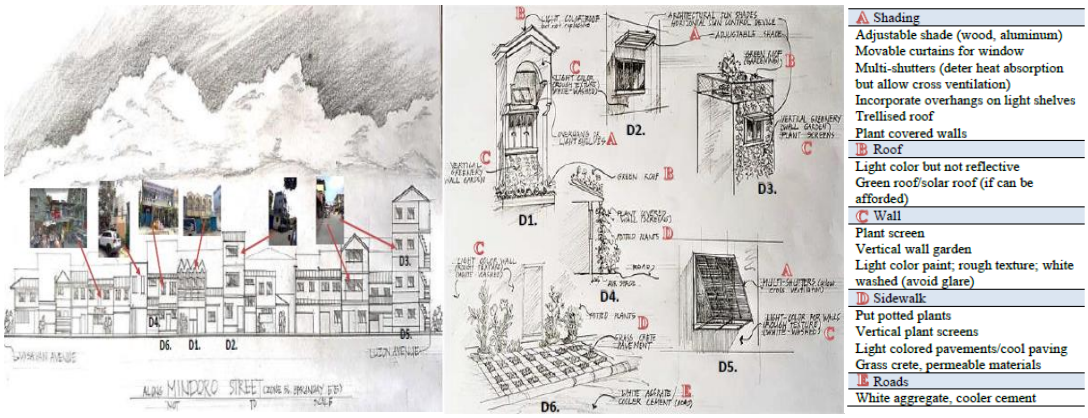
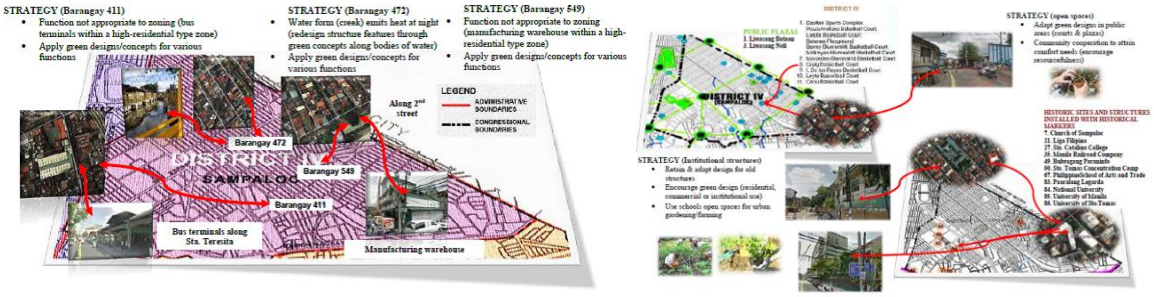


Figure 14 (a) Elevation of identified houses where strategies can be applied to the area
(b) Architectural design strategies as the first approach of the framework.

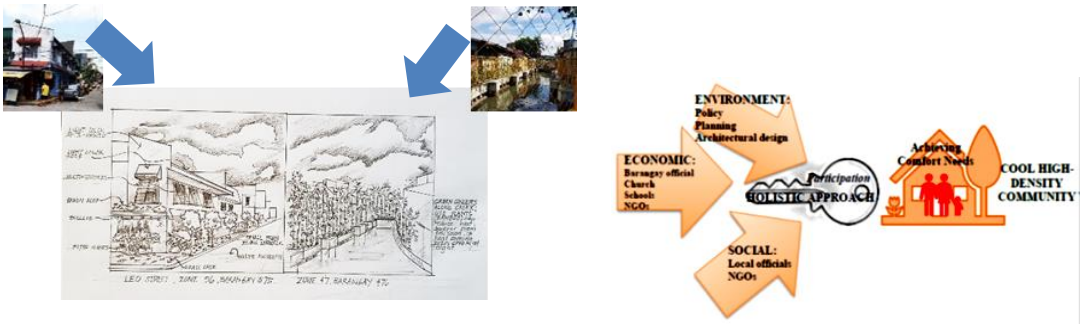
A variety of functions or mixed-use types existed in the district that resulted in inappropriate zoning types. As mentioned, integration of various functions and adapting green concepts affected by anthropogenic sources in the area while allowing continuous development is a strategy for the second approach. Figure 15(a & b) shows the strategies that can be applied in the district.



(a) (b)

Figure 15 (a) Graphical representation to re-examine zoning in the district
(b) Integration of green concepts through a collaboration of various stakeholders.

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 16(a) 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 16(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.



(a) (b)

Figure 16 (a) Recommendations of the framework on urban structures and landscape in the area (b) A conceptual illustration of the recommendation.

Based on the results generated from this study, it can be concluded that 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.

Furthermore, 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). To further elaborate, 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 by providing directions to implement passive cooling techniques that lead to achieving comfort needs wherein the application of guidelines must be strengthened by the local government; (b) a scheme in re-examining zoning types integrating various functions in connection with green concepts where it can serve as a model to other urban communities and be an effective tool in mitigating the increase in the UHI effect; and (c) an independent initiative for the community to be involved in green environment awareness in their resourcefulness to alleviate heat experienced in the area.

On the other hand, 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 which was stated in the first approach/strategy. The promotion of creating the residents' awareness of using green ideas should be instilled in their minds. Since the Sampaloc district evolved from simple to myriad forms consisting of mixed-used function, the examination of the zoning for this area, as the second approach/strategy has stated, is functional as green ideas/measures are applied. Moreover, this must be supported by the third approach/strategy wherein the local government should help strengthen this idea through community participation and resourcefulness for economic reasons. Residentials and commercials, whether existing for a long time, renovated or newly constructed, should bear in mind that this framework is appropriate and applicable in alleviating the UHI effect in this area. Therefore, to reduce the UHI effect in the area, the framework visions were linked to the process created, which are the approaches and strategies indicated in this study. These were interconnected and, likewise, assured the consideration and integration of environmental, economic, and social viability that can lead to a long-term solution for a cooler high-density community.

For future research, the possibility of undertaking similar research to other districts located in any local urban city poses a challenge. There are only a few studies regarding the UHI effect in Metro Manila as well as in rural cities. However, no available specific data is 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. Since a simple and inexpensive tool was used in measuring land surface and air temperature, it is recommended that more sophisticated instruments be utilized. Moreover, 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

My deep gratitude goes first to our Lord God who guided me despite difficulties and trials encountered through the way. My appreciation and gratitude extend to my adviser, Dr. Marcelino Siladan, to Mapua University, Dr. Reynaldo B. Vea, our University President, and my immediate supervisor, Dean Gloria B. Teodoro. I would also like to acknowledge the Commission on Higher Education (CHED) for the financial assistance given to me, in finishing this dissertation, under the CHED Dissertation Grant program.

9. References

Akinaru, I. H. (2002). *Towards Creating a Sustainable City*. Manila, Philippines: UP Press.

Dotson, J. D. (2018). *How Temperature and humidity are related.* Retrieved from https://sciencing.com/temperature-ampamp-humidity-related-7245642.html

White, E. P., Ernest, S. M., Adler, P. B., Hurlbert, A. H., & Lyons, S. K. (2010). Integrating spatial and temporal approaches to understanding species richness. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1558), 3633-3643.

Koenigsberger, O. H. (1975). *Manual of tropical housing & building*. Telangana, India: Orient Blackswan.

National Geographic (2011). *Air Mass.* Retrieved from https://www.nationalgeographic.org/encyclopedia/air-mass/

Kumar, K. S., Bhaskar, P. U., & Kumari, K. P. (2017). Assessment and mapping of urban heat island using field data in the new capital region of Andhra Pradesh, India. *Indian Journal of Science and Technology*, *10*(11), 1-8.

Tayobong, R. R. P., Sanchez, F. C., Balladares, M. C. E., & Medina, N. G. (2013). Edible landscaping in the Philippines: Maximizing the use of small spaces for aesthetics and crop production. *Journal of Developments in Sustainable Agriculture*, *8*(2), 91-99.

Tiangco, M., Lagmay, A. M. F., & Argete, J. (2008). ASTER-based study of the night-time urban heat island effect in Metro Manila. *International Journal of Remote Sensing*, *29*(10), 2799-2818.

Yang, L., Qian, F., Song, D. X., & Zheng, K. J. (2016). Research on urban heat-island effect. *Procedia Engineering*, *169*, 11-18.