FARU FACULTY OF ARCHITECTURE RESEARCH UNIT UNIVERSITY OF MORATUWA, SRI LANKA
FARU 2022 - 15TH INTERNATIONAL RESEARCH CONFERENCE
www.faru.uom.lk
Independence and Interdependence of Sustainable Spaces

EVALUATION OF THE IMPACT OF MULTIPLE FACTORS, ELEMENTS AND NEIGHBORHOOD PATTERNS ON THE SPREAD OF DENGUE AND COVID-19: SPECIAL REFERENCE TO COLOMBO 15.

RANASINGHE R. A. D. M.[1*] & RANASINGHE T. K. G. P.[2]
[1, 2]University of Moratuwa, Colombo, Sri Lanka
[1]172320l@uom.lk, [2]gayanip@uom.lk

Abstract: During past decades, the mass movement of people from rural areas towards urban areas made cities vulnerable to environmental hazards, inequality, poverty, and communicable diseases identified as a huge threat. The spread of the Covid-19 pandemic causing more than five million deaths highlighted urban planning to rethink and rebuild cities to mitigate the pandemic and to create livable neighborhoods during future pandemics. The emergence of Dengue seasonally and the high number of victims and death rate is also critical health issue identified in Sri Lanka. After the emergence of covid-19, the urban areas have been highly affected and the urban households, lifestyles of people, and the corruption of countries' economies caused an energy crisis, food crisis, unemployment, and increasing death rates that created a whole new chapter in urban planning to create comprehensive planning approaches to get back to normal while considering the risk factors. As Dengue fever is also more critical in the Sri Lankan context, the need for studies to identify the factors, and elements in urban areas including neighborhood patterns for the spread of Covid-19 and Dengue Fever is quite significant as a planner. The study focuses on the impact of urban elements, factors, and the different neighborhood patterns within the selected areas in Colombo-15 for the spread of covid-19 and dengue. The outputs indicate the vulnerability of different neighborhood patterns highlighting the measures that should be taken to mitigate the spread in the future. According to the study, the spread of dengue and covid-19 among people depends on the quality of housing and the characteristics of the neighbourhood and the comparatively high spread of diseases identified in horizontal neighborhoods with single-story housing and poor living condition.

Keywords: *Covid-19, Dengue, Neighborhood Patterns, Urban elements, Vulnerability*

1. Introduction

Urban planning has evolved throughout the decades, changing the paradigm from time to time. At present, the field has become more complex with modern variables and novel situations that the cities undergo. Urban designs depict a sense of imageability and legibility, as well as everything that happens in a city, has relations to its' surroundings, sequences of events drive it toward the form (Lynch, K. (1960). The Image of the City. Cambridge, MA MIT Press. - References - Scientific Research Publishing, n.d.). But Lynch's theories were subjected to mostly the perceptions and the behavioral patterns connected with the perceptions. Recently, researchers have considered the citizen's perspective on cities with the expansion of urban planning and cities with multiple elements and factors. The results indicated a huge dislike for urban sprawl, high population density, and interest showed towards smart growth concepts, and resilient city practices, ex: open spaces, vertical developments, integrated town centers, etc. (Ewing et al., 2016)

Urban planning and design are the major processes of designing the localities for people to live, gather and utilize the physical environment, which is connected, enhanced, enduring, vibrant, comfortable, safe, walkable, etc. (Urban Design Protocol, 2015). Therefore, it directly influences the economic status that indicates affordability, and availability of job opportunities, encouraging entrepreneurs and businesses with equal provision facilities and services. Furthermore, the physical scale, built form, and the space's ambiance influence the locality's community health and social-cultural aspects.

During past decades, the major paradigm that affected Urban Planning had been the mass movement of people from rural areas towards urban areas, making cities vulnerable to environmental hazards, inequality, poverty, and communicable diseases that mak e the urban lifestyle critical. According to UN-Habitat, about 4.2 billion people

*Corresponding author: Tel: +94 711245672 Email Address: 172320l@uom.lk
DOI: https://doi.org/10.31705/FARU.2022.1

which is half of the world's population live in urban areas which is estimated that by 2041, more than 6 billion people would choose to live in urban areas.

This rapid urbanization negatively impacts community health due to lack of nutrition, low-income levels, poor sanitation, low-quality housing (slums) that directly impact the spread of communicable diseases. Most of the developing, as well as developed countries, were affected by the spread of communicable diseases such as Influenza, Typhus, Tuberculosis, etc. that are associated with high crowding with poor living conditions. (D. Vlahov, S. Galea, 2002) Therefore, the impact of overcrowding and urbanization linking health status is a reliable character that shapes cities' urban landscape and urban planning.

Studies from around the world indicate that the dengue plague is highly correlated with socioeconomic and demographic factors. Built environment and overcrowding had consequences for the spread of the Dengue plague and Covid-19 pandemic in urbanized areas in Sri Lanka. To conduct the research an assumption is made that there is a strong correlation between urban elements, factors, and neighborhood patterns for the spread of plagues and pandemics like Dengue and Covid-19.

This study mainly focuses on using urban planning as a tool to mitigate the spread of plagues and pandemics in future cities which means creating disease-resilient cities that enhance the quality of life of people while upgrading the environment through the urban design characteristics as well as other multiple factors including urban morphological features, socioeconomic characteristics, environmental factors that are inevitable.

When considering Sri Lankan cities, the spread of the Dengue plague and the death rate is at a significant level. According to the Epidemiology Unit of the Ministry of health statistics, the reported Dengue cases in 2019 is about 99,120 and about 15.9% of cases have been reported from the Western province. According to the Department of Census and Statistics of Sri Lanka, the population density of the Colombo Municipal Council is 20182 per km2. But the density of the entire district is 3,300 per km2. Therefore, uneven distribution of urban components, basic amenities should be focused on to create a resilient and inclusive urban design.

The spread of communicable diseases like Dengue and Covid-19 has been critically affected the daily routine of people and the short-term and long-term consequences can be identified through the vulnerable, marginalized communities in cities.

Through this study, the assumption that basic urban morphological characteristics, multiple factors, and the different neighborhood patterns in the vulnerable areas have a strong inter-relationship with the spread of Dengue plague and Covid-19 pandemic will be analyzed through the obtained data.

1.1 SIGNIFICANCE

In Sri Lanka, the highest GDP contribution to the national GDP is obtained from Western Province which is about 38% in 2020 according to the Central Bank of Sri Lanka. In 2020, out of 6,165,000 of the total population in Western Province about 2,455,000 lives in Colombo district which is highly populated with a population density of 3512/km2 within a 699km2 area (Census and Statistics Department, 2020).

Previously researchers have only focused on marginalized groups and low-income settlements in cases of spreading pandemics, but in the recent covid-19 pandemic situation and dengue plague almost all the community has affected in different levels making it significant to rethink planning behaviors in urban areas that are highly vulnerable for pandemics (M. Acuto, 2020). Therefore, the significance of conducting this research is to identify the factors, elements, and neighborhood patterns in urban areas that significantly impact the spread of plagues and pandemics to mitigate this situation through novel urban planning strategies.

1.2 LIMITATIONS

This study is conducted to identify the thriving factors, elements, and neighborhood patterns in urban areas for the spread of the critical diseases which are the Dengue plague and Covid-19 pandemic in Sri Lanka considering the Colombo-15 area. Although countless multiple factors can be taken under urban elements, for this study purpose the most significant urban morphological factors, socio-economic factors, and some other elements have been taken into consideration.

2. Literature Review

According to the literature, pandemics are nothing new to urban planning because even before the emergence of the corona pandemic, research articles were written related to pandemics and cities. (Matthew and Macdonald,2006).

Urban Planning and Public Health sound like two different fields but when considering the urban context, the purposes of both fields share common practices to enhance the quality of life of people, and well-being of the society, provide healthy lifestyles, take necessary actions for vulnerable groups in localities considering the demographic characteristics, etc. The research conducted by John Snow, a British Physician, 1800 using geographical mapping of a

Cholera outbreak to find the outbreak's source as the public water pump was a significant movement of using urban planning tools and techniques to mitigate the outbreak in the city (Kochtizky, 2006). Comprehensive city planning and neighbourhood planning are key factors in the physical and mental well-being of people. (Frederick, 2008). To mitigate the increasing health issues with contagious diseases the "Haussmann model" of zoning was introduced in Germany that focused on land use functionality and hierarchy to separate the residential areas from other land uses considering health and clinical measures as well. All these measures, models, and strategies identified by research, show the importance of considering public health as a major approach of urban planning that should be addressed when planning for cities in the future.

The impact of urban land use on sustainable city growth considering the dynamics of urban population density has been ignored throughout the urban planning paradigms from time to time. The research topic, "Impacts of changing urban land use structure on sustainable city growth in China" (X. Song, Q. Feng, J. Scheffran, 2021) provides a holistic framework considering the factors of urban population density (UPD) as well as the city growth and shrinkage under the research hypothesis. A land substitution model related to UPD dynamics has been introduced. When studying the impact of multiple factors and elements associated with urban planning and design the need for urban land use and the policies that have driven the urban form and human settlements into the existing form is important to analyze the difference between the residential clusters and factors for the spread of covid-19 and dengue. When changing the urban planning perspective towards new urbanism the physical environment of urban areas has been considered as developed areas with moderate temperature, floodwaters channelled properly, and diseases controlled with easy access to food and other resources (Pelling, 2003).

Due to poor housing conditions, lack of nutrition, poor sanitation the vulnerability to get affected by flooding, inequality, lack of opportunities, and increasing health issues has occurred (Clarke, 2008). Rapid urbanization caused the urban planning practitioners to fail to prioritize the basic needs of the population so that the negative aspects of urbanization keep growing with the increasing population (UNDP, 2004). Land ownership and tenure are key factors in urban planning which allows people to consider government regulations and policies when constructing houses. If people have the tenure for their lands and houses, they will automatically upgrade their living environments with security measures, good quality living to avoid government interference in destructing those housing units (Rhyner, 2002). A case study in Ghana, Accra demonstrated that the household level factors in different residential types such as poverty, underserved housing, unsanitary neighborhoods are affecting environmental quality that increases health-related issues (Sida, 2002).

The rapid transformation of the physical setting in the environment with the land-use changes with the exploitation of natural assets, environmental degradation in different levels in different urban settings and neighborhoods mainly contributes to the increasing health risk in urban areas (Hardoy et.al, 2001). Other than the urbanization and deforestation, the environmental degradation is occurred by inadequate infrastructure facilities causing improper waste disposal, blocking drainage systems and water canals in and around neighborhoods, different unsecure methods of domestic water supply (unprotected wells, storage tanks) that provide breeding places for mosquitos during the rainy season, improper stormwater and sewer management resulting deterioration of surrounding (Chardon, 2002).

Increasing rural-urban migration and the population growth rates make cities highly concentrated with people, buildings, infrastructure, social networks, etc. (Gavidia, 2004). During Pre-Industrial cities, the neighborhoods were considered as permanent family dwellings in cities where the distribution was naturally occurred without any political or theoretical pre-occupation and emerged based on the economic practices and the industries (Lewis Mumford, 1954). At present, under the "New Urbanism," practices neighborhoods are considered as a unit in urban design where neighborhoods are defined as a coherent, friendly self-contained residential unit within a locality (Clarence Perry, 1900). The residential segregation in localities is a fundamental reason for health disparities in many countries (Williams and Collins, 2001). A clear segment between the residential clusters can be identified in urban areas thriven by the demographic, socio-economic factors that are influenced by the urban form. The disparities of income level are the prominent factor of residential segregation that cause many other aspects in localities such as inequality, low–income settlements, lack of infrastructure facilities, and poor quality of life with fewer health care facilities.

The research topic, "Patterns of urban housing shape Dengue distribution in at neighborhood and country scales" (M.E. Osama, S. Chong, A. B. Eltahir, 2018) discuss the comparison of dengue victims in low-rise and high-rise areas of Singapore and other factors related to agglomeration of housing and infrastructure. According to the researchers, there's a significant impact of urban drainage and hydrology in the spread of dengue plague as well as overcrowding is also a risk factor that contributes to the high death rates. A major outcome that is identified for urban planning is that the dengue spread is lower in high-rise housing apartments than in low-rise buildings. It is highlighted to consider the density of urban drainage to mitigate both dengue plague and flash-flooding incidents.

As discussed in the literature review, urban planning cause major health issues that collapse the entire system in situations like covid-19 and dengue plague. Therefore, identifying urban planning as a tool to mitigate the issues is

an effective urban planning approach for the present world that gone through covid-19 as well as dengue plague ended up with economic crisis in many countries including Sri Lanka.

3. Methodology

This research is both qualitative and quantitative approach to identify the impact and the relationship between urban elements and the neighborhood patterns in the spread of Dengue and Covid-19 in cities. Under this research, the urban elements, dwelling types, neighborhood patterns, availability of health resources will be analyzed using urban planning techniques.

To identify the correlation between geographical variables and disease infections the strong association of urban elements, socio-economic factors, and demographics will be analyzed using data statistics and analysis methods using SPSS, GIS, RS, and Excel. To examine the building geometry, mainly factors such as building height, building density will be calculated using the standards identified for urban environments.

Under the urban elements, the road network will be examined basically under road width which is a significant indicator in the spread of diseases and health status in cities. (Combra, 1988). Furthermore, the availability of green spaces among buildings is found as a positive aspect in the spread of communicable diseases ((Chan and Liu, 2018) that will be analyzed under the urban elements. Also, socio-demographic parameters will be analyzed statistically to identify the composition of peoples' lifestyles and routines in the selected area and how it impacts the spread of dengue rate in the area.

Building height, building density, and road width is obtained from the field data and evaluated using excel and SPSS software. Using the NDVI analysis the green exposure with the variation of green space will be represented. Finally using cluster analysis, the high-risk factors among the urban elements and the various neighborhood patterns for the spread of covid-19 ad dengue will be identified. The research will provide a model to stimulate the thriving factors for the spread of dengue in urban areas that can be used as a model by future urban planning practitioners to avoid the spread of plagues in settlements.

4. Data Collection

According to the spread rate of the Dengue plague and the Covid-19 pandemic in Sri Lanka, the highly urbanized areas have been affected more than rural areas. The Colombo MC area has reported the highest spread of diseases.

Considering the multiple factors identified to be studied under the analysis process, the need for a study area that contains all the required characteristics and easily accessible was a significant fact. Therefore, based on the data availability and suitability for the study Colombo – 15 area which is in CMC was selected as the major study area for the study. For further analysis, a few case studies identified within the study area have been used.

According to Census and Statistics Department, the total population in Colombo District is about 2,324,349 while 561,314 of the total population lives in the CMC area. As well, according to the data obtained from the D1 MOH office in New Bazaar, the total population living in the Colombo-15 area is about 134,382. (Referred to 2012). Furthermore, about 118,594 housing units have been identified in the CMC area while 9601 of them are row houses/line rooms 2144 are hut/shanty houses as well as 18,256 are flats that are used to resettle the people in underserved settlements.

The site selection has been done based on the research need and the identified justifications as described below to obtain the outputs through this study. The primary data were collected through questionnaire surveys, informal discussions, and field observations. Apart from that, secondary data related to the study area were collected, such as the demographic and natural conditions of the study area. By using these data, the spread of diseases among people, living conditions, and the different neighborhood patterns could be identified.

For deeper analysis, within the selected study area Colombo-15, CMC District 1, 10 case studies have been identified based on population distribution, income levels, neighborhood types, and a high spread of covid-19 and dengue plague. 500m buffer from the selected area have been considered for the analysis.
List of Case Studies are as follows.

1. Mihijaya Sewana Flat - Constructed at Henemulle housing scheme by UDA under the Urban Regeneration Program (URP) which consists of 1647 housing units.
2. Samithpura - Located within the Sammanthranapura GN division in Colombo DS division near the Kelani River.
3. Kelani Ganga Mill Road - Area consists of individual, permanent housing units owned by the residents.
4. Crow Island - Surrounding area consists of middle and high-income households and single houses with multiple stories.
5. Pichchamalwatta - Located on the left riverbank near the Kelani River outfall that belongs to Sammanthranapura GN Division within Colombo-15.

6. Sri Wickramapura - Located next to PichchamalWatta in Sammanthranapura GN Division. The housing characteristics and the composition of people are similar to the pichchamal watta because both areas consist of underserved settlements on the left riverbank of the Kelani River.
7. Aluthmawatha Road – Located in Modara DS Division which is inhabited by middle-income and high-income residents.
8. Kadirana Watta – It is an undeserved settlement in Colombo-15, identified by UDA as a site to demolish and resettle the people.
9. Modara Street - consists of single housing units mostly more than two stories occupied by middle-income and high-income residents who work in both government and private sectors.
10. Methsanda Sewana - "Methsanda Sewana" flats are in the Henemulle housing scheme which is constructed by UDA under Urban Regeneration Program to resettle the people in underserved settlements in Colombo North (Col-15). "Methsanda Sewana" consists of 947 housing units and the population comprise of low-income and middle-income people resettled from the surrounding area.

Based on the justifications Colombo-15 is selected as the major study area and using cluster sampling the total area is clustered and then based on the information collected, 10 case studies have been selected for the study. Under this study, it is required to identify the different urban elements, other factors, and neighborhood patterns for the spread of diseases and plagues. For that, an assumption was made that, "Multiple factors, elements and neighborhood patterns in urban areas have a direct impact on the spread of diseases like Dengue and Covid-19". Then based on data availability and ability to conduct the questionnaire surveys, field observations were conducted within a 1km area along the road in the selected case study areas and 5 households from each case study were interviewed for the study.

5. Analysis and Findings

This section basically compiled the findings obtained through an analysis conducted by the cluster analysis, NDVI analysis to achieve the key objectives of the study mentioned in section 1.6 above. Identified urban design characteristics and neighborhood patterns are evaluated based on the identified variables.

5.1 CHARACTERISTICS OF THE SAMPLE

The extent of the sample was selected as a 1km area along the road per case study. Based on the observations, about 25 or fewer housing units were included within a 1km area along the road and therefore, 5 households from each case study were interviewed. Although the flats were somewhat different from the scenario, 5 households from each flat were interviewed to continue the similarity when selecting the sample to avoid any biased output.

Among the selected household almost 90% of the houses were owned by the residents, but regarding the flats, tenure is belonging to the UDA and residents have partial ownership that should be continued by paying annual taxes and fees for 30 years until they receive the full ownership for the houses.

Based on the field observations, as shown in figure 18, the housing type of the selected case studies, majority of the housing type is single house single-story houses about 32% and 24% of dwelling units are single house two-story buildings. The selected case study consists of 20% flats and 10% of hut/shanty houses. The building pattern is identified that 80% of the building pattern in the selected area is horizontal development, while 20% is vertical development.

Household information and demographic data collected through the questionnaire survey indicated that 44% of interviewees have finished education by o/ls and only 32% managed to finish a/ls. Around 12% have dropped school from scholarship and below ages.

Occupation information indicates that about 60% of the residents interviewed are engaged in self-employ while 20% are from the government sector and 17% are from the private sector. Among the interviewees 3% are unemployed.

Furthermore, the availability of electricity and water supply is at a satisfactory level where only a few shanty houses didn't have the access to electricity and drinking water directly. Solid waste is collected by Municipal Solid Waste collector trucks regularly, but during the field observations, trash piles in front of the neighborhoods were seen.

Table 1 - Characteristics of the sample case studies

Total Number of interviews		**50**	**Percentage**
Housing Type	**Housing type**	**Count of Housing type**	
	Flat	10	20%
	hut/shanty	5	10%
	single House more than two storied	7	14%
	Single house single story	16	32%
	single House two-storied	12	24%

Tenure	Tenure	Count of Tenure	
	Owned	38	76%
	rented	2	4%
	Rented (UDA Owned)	10	20%
Neighborhood Pattern	**Neighborhood pattern**	**Count of Neighborhood pattern**	
	horizontal	40	80%
	Vertical	10	20%
Education Level	**Education Level**	**Count of Edu. Level**	
	a/l	16	32%
	Higher education	6	12%
	O/l	22	44%
	scholarship	6	12%
Employment Sector	**Employment sector**	**Count of Emp. sector**	
	Other	1	3%
	government sector	7	20%
	Private sector	6	17%
	Self-employment	21	60%
Water Supply	**Water supply**	**Count of Water supply**	
	Pipe borne/Main-line	42	84%
	Tap outside (Mainline)	8	16%
Waste Disposal	MSW Collector Truck	100%	100%
Infected with Dengue	Yes	22	44%
	No	28	56%
Infected with Covid-19	Yes	30	60%
	No	20	40%

5.2 IDENTIFICATION OF THE GREEN EXPOSURE IN THE AREA

5.2.1 NDVI Analysis

Colombo metro region is identified as a rapid urbanization region in south Asia. (Source: An Urban Heat Island Study of the Colombo Metropolitan Area, Sri Lanka, Based on Landsat Data 1997–2017). Decrease of the vegetation cover with rapid urban growth is the major cause of the heat formation. Further, rapidly increasing impervious surfaces such as high-rise buildings, roads, parking lots, pavements are another reason for the heat increase in urban areas. Colombo-15 area comprises of all these thriving factors that cause the urban heat island effect which is a direct factor for health status in an area.

The outputs of NDVI analysis are as mentioned below that are categorized as high-dense vegetation, dense vegetation, normal dense vegetation, low dense vegetation, and minus values are considered as water extent.

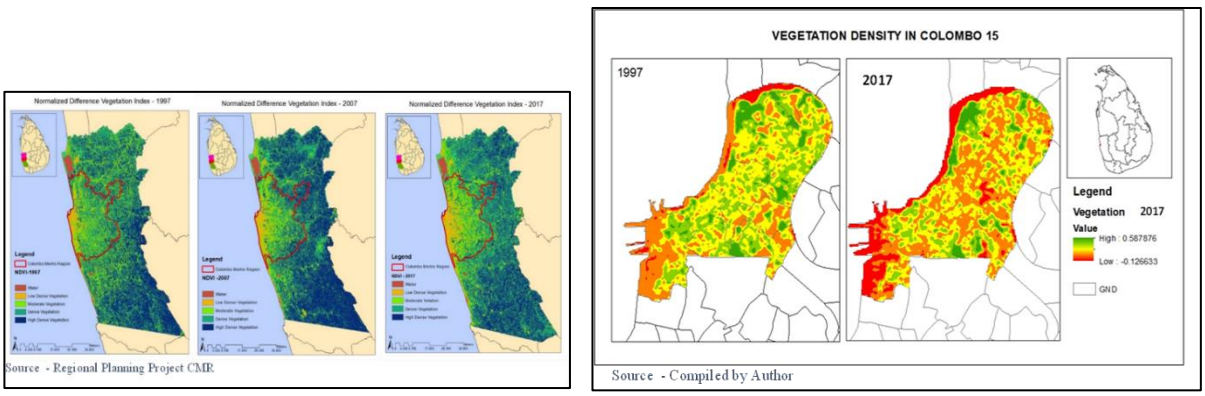


Figure 1 - NDVI Analysis for CMR

NDVI analysis outputs in the different periods from 1997, 2007, and 2017 indicate the reduction of vegetation cover in CMR over time. The transformation of dense vegetation areas to low dense vegetation areas is highlighted in areas belonging to CMC.

5.2.2 NDBI Analysis

This analysis indicates the variation of the built-up areas periodically. Here, positive values indicate the built-up areas, and the high-density area is shown in dark brown color.

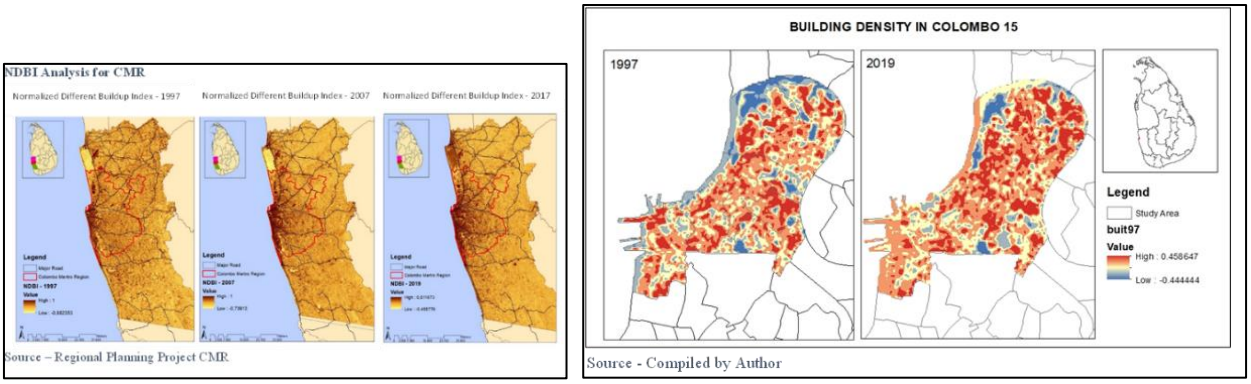


Figure 2 - NDBI Analysis for CMR

Urban Heat Island Effect indicated the higher temperature levels compared to surrounding areas and more significantly the temperature is higher at the night compared to daytime mostly when the wind is weak. Based on the NDVI and NDBI analysis the vulnerability of CMR to affected by the Urban Heat Island effect can be identified as a very high rate. Lack of vegetation cover and increasing building density cause the higher vulnerability to UHI in the CMC area.

Bad impacts of UHI directly on the health status of an area have affected the community living in selected case study areas mostly due to the Covid-19 pandemic. Due to UHI, an increase in energy consumption occurs when electricity demand increases for cooling purposes. According to researchers, a 0.60C increase in temperature demands a 2% of electricity increase in urban areas (D. Aleo, 2010).

The increased energy consumption and cooling have a direct impact on the emission of greenhouse gasses and the creation of fine particulates that pollute the air quality. These factors directly impact people who live in condominiums, huts, shanty settlements as well as luxury apartments and single houses too. Depending on factors such as chemical composition, humidity level, UV radiation, and temperature, the ability of the virus to spread is high in urban areas (Thomas B., Isabella M., Alhamed, 2021).

Furthermore, the inability to stay inside during the lockdown period due to high temperature and poor living conditions have resulted spread of covid-19 among residents in flats and undeserved settlements because people used to gather in corridors and outsides during the lockdown. There's no significant relationship between UHI and the spread of Dengue.

5.3 CONFIGURING NEIGHBORHOOD QUALITY USING LIVING CONDITION DIAMOND.
The theory of "Living Condition Diamond" is a framework that enhances the understanding of a settlement quality. It expressed a cross-sectional snapshot of settlement conditions.

Living Condition Diamond is used to determine the living conditions in different neighborhoods comparatively using the parameters tenure, infrastructure, unit quality, and neighborhood pattern. Based on these parameters the quality of life in the area is evaluated by assigning weights for different variables essential to ensure good quality of life.

Likert Scale indicating the weighted scores

Based on the assumptions made by the author using the Likert scale, the total of the assumed score of quality of living condition was calculated using weighted scores hypothetically considering these three measures.

According to calculations, the living conditions in the Crow Island area, Methsanda Sewana Aluthmawatha Rd, Modara Street, and Mihijaya Sewana areas have good quality living conditions. Poor living conditions have been identified in Samithpura, Kelani Ganga Mill Road, Pichchamal Watta, Sri Wickramapura, and Kadiranawatta according to the given parameters identified through field observations and survey. The outputs depict that the single unit single-story housing units, horizontal neighborhoods with no proper ventilation, space, road width, green exposure with high vulnerability have low-quality living conditions.

Furthermore, the areas with single unit two or more than two-story houses and flats have the basic requirements needed to ensure good quality living environment by providing proper drainage and solid waste management, front, rear spaces, proper ventilation, good utility supply, and tenure that enhance the quality of life indicating good quality based on the assumptions made through the Likert scale. However, extremely good quality housing units were not observed among the selected case studies.

Table 2 - Living quality of Case Studies based on Living Condition Diamond Parameters

		Assumed Quality based on weight			Mihiaya Sewana		Samithpura		Kelani Ganga Mill Road		Crow Island		Pichchamalwatta		Sri Wickramapura	
Characteristics	Weight	Extremely Good	Good	Low	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total
Infrastructure																
Water	5	25	15	10	5	25	2	10	3	15	5	25	2	10	3	15
Electricity	5	25	15	10	5	25	2	10	3	15	5	25	2	10	3	15
Roads	5	25	15	10	3	15	1	5	2	10	4	20	1	5	2	10
Drainage	5	25	15	10	3	15	1	5	1	5	2	10	1	5	1	5
Solid Waste Disposal	5	25	15	10	5	25	1	5	1	5	3	15	1	5	2	10
Unit Quality																
Plot Size	4	20	12	8	5	20	2	8	2	8	5	20	2	8	2	8
Front Space	3	15	9	6	2	6	1	3	1	3	4	12	1	3	2	6
Rear Space	3	15	9	6	2	6	1	3	1	3	4	12	1	3	1	3
Neighborhood pattern																
Vulnerability	4	20	12	8	5	20	5	20	5	20	3	12	5	20	5	20
Access to services	5	25	15	10	4	20	2	10	3	15	4	20	3	15	3	15
Density	4	20	12	8	5	20	5	20	5	20	4	16	5	20	5	20
Tenure	5	25	15	10	3	15	2	10	2	10	5	25	2	10	2	10
Assumed Quality		265	159	106		225		109		129		212		114		137

	Aluthmawatha Road		Kadiranawatta		Modara Street		Methsanda Sewana	
Characteristics	Score	Total	Score	Total	Score	Total	Score	Total
Infrastructure								
Water	5	25	2	10	5	25	5	25
Electricity	5	25	2	10	5	25	5	25
Roads	3	15	1	5	4	20	3	15
Drainage	3	15	1	5	3	15	4	20
Solid Waste Disposal	3	15	2	10	3	15	4	20
Unit Quality								
Plot Size	4	16	1	4	4	16	5	20
Front Space	3	9	1	3	3	9	2	6
Rear Space	3	9	1	3	3	9	2	6
Neighborhood pattern								
Vulnerability	3	12	5	20	2	8	5	20
Access to services	4	20	2	10	5	25	4	20
Density	5	20	5	20	4	16	5	20
Tenure	5	25	2	10	5	25	30	15
Assumed Quality		206		110		208		212

Extremely Good Quality	265
Good Quality	159
Low Quality	106

5 – Excellent	4 – Good	3 – Moderate	2 – Low	1 - Bad

5.4 CLUSTER ANALYSIS

Cluster Analysis is used to cluster the variables based on different factors that show similar variance. It basically groups data according to the similarity of responses to multiple, different variables. Under this study, the spread of covid-19 and dengue spread in the selected areas in Colombo-15 will be determined through different variables, multiple factors, and neighborhood patterns that have been identified during field observations and questionnaire surveys. It helps to identify the thriving factors in the different neighborhoods based on the characteristics for the spread of diseases.

5.4.1 Spread of Dengue and Covid-19 clustered by Height, FAR, Front Space, Rear Space, and No. of floors

- Ward's Method

Ward's method is highly efficient and assesses the cluster membership by calculating the total sum of squared deviations from the mean of a cluster.

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	48	50	.820	0	0	6
2	19	20	1.820	0	0	7
3	12	18	5.065	0	0	9
4	15	17	20.289	0	0	7
5	16	35	1275.888	0	0	10
6	48	49	2942.728	1	0	8
7	15	19	5445.091	4	2	9
8	47	48	8778.898	0	6	11
9	12	15	16283.082	3	7	10
10	12	16	62223.838	9	5	11
11	12	47	233681.179	10	8	0

The agglomeration schedule coefficients indicate the tight clustering of variables and a few less-formed clusters.

In the first stage of the Dendrogram obtained using Ward linkage above, four responses have been recorded in one cluster that is 47, 48,49, and 50 that belongs to Dengue and Covid-19 patients reported from Methsanda Sewana. In the next cluster, 2 closely related clusters were identified as 16 and 35

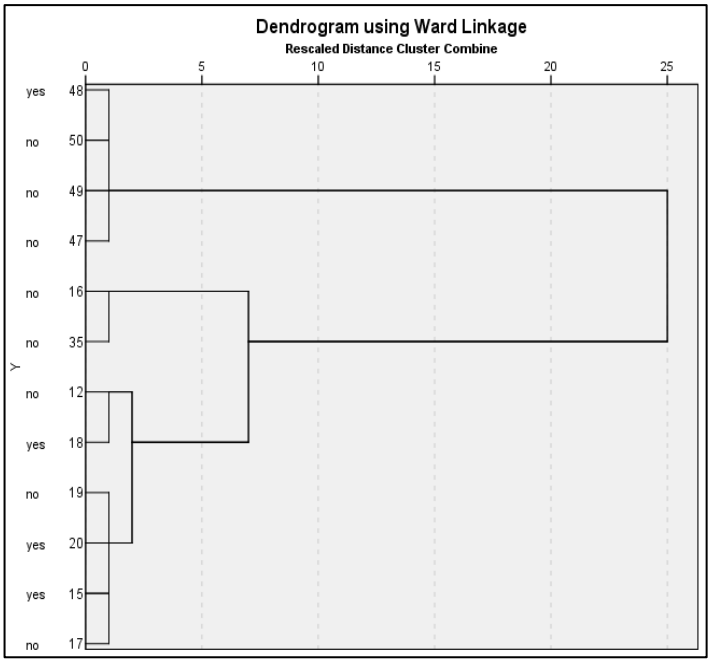


Figure 3 - Dendrogram using Ward Linkage

which are Crow island and Aluthmawatha rd. area. The next two responses are 12,18 which are Kelani Ganga mill road and Crow Island. The next four responses create a cluster of 15,17,19 and 20, which belongs to Kelani Ganga mill road and Crow Island. The first stage indicates the cluster relationship between the characteristics found in Crow island, Kelani Ganga mill road, and Aluthmawatha road.

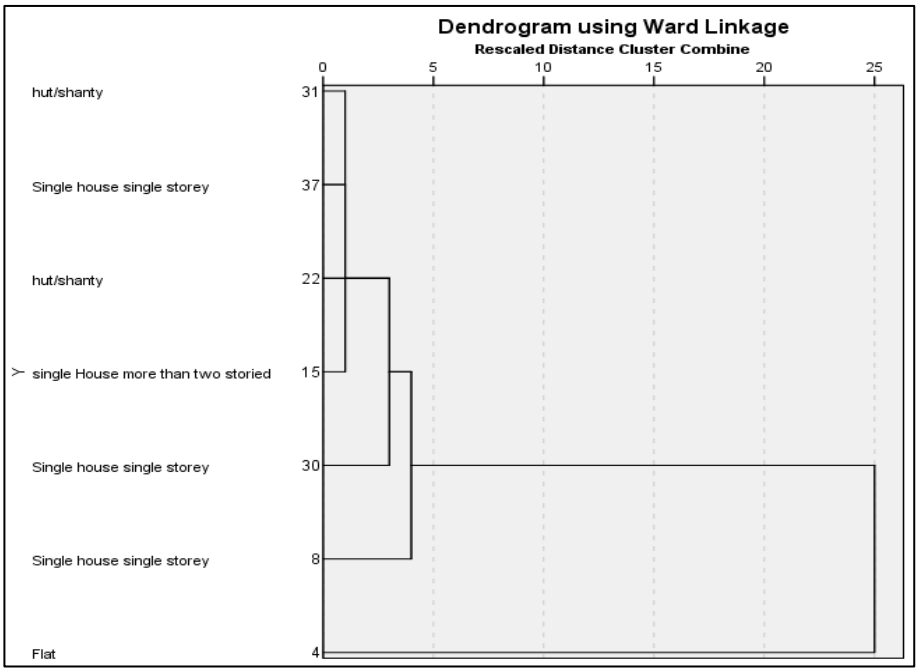
In the second stage the similar variances between 12,18 and 19,20 formed a cluster and in the third stage the clusters 16,35 and the 12,18 cluster, 19,20 cluster formed one cluster showing the strong relationship between Crow island, Aluthmawatha rd., and Kelani Ganga mill road. The final stage indicates the less formed cluster between the Methsanda Sewana area and other areas based on Dengue and Covid-19 victims.

Through this analysis, the characteristics in Crow island, Aluthmawatha rd., Kelani Ganga mill road, and Methsanda Sewana have been identified as the least affecting areas for the spread of Dengue and Covid-19 as the Y-axis highlights "No" as the main response which indicates that none of the individuals in the families from those areas are infected with either covid-19 or dengue fever.

According to the dendrogram, other areas of the selected case studies, Mihijaya Sewana, Pichchamal watta, Kadiranawatta, Sri Wickramapura, Modara street areas are highly vulnerable to the spread of dengue and covid-19 based on housing characteristics.

5.4.2 Evaluate the rate of dengue and covid-19 victims based on housing type.

In the first stage, the dendrogram clusters the housing types such as hut/shanty, single house single story, and single house more than two-story into one group indicating the similarity of these housing types for the spread of covid-19 and dengue. Then, a cluster containing hut/shanty houses and single house single-story houses is formed and together with it, another cluster with single house single story type cluster is formed. In the final stage, the previous clusters formed a cluster with flat-type housing.



Therefore, the dendrogram displays a strong relationship between hut/shanty type and single house single story type for the spread of dengue and covid-19. Although flat type housing also enhances the spread of diseases, it is different from the other housing types that created a less formed cluster.

According to the outputs, housing types of single house two-story, and more than two-story houses are less vulnerable to the spread of dengue and covid-19 than other housing types. Furthermore, hut/shanty houses and single-house single-story units are highly vulnerable to the spread of diseases.

6. Conclusion and Recommendations

The study has highlighted the significance of evaluating the different urban elements and neighbourhood patterns from the perspective of the spread of diseases to mitigate future pandemics and plagues in cities.

- **Identify the types of urban elements in cities and their scope for the spread of Dengue and Covid-19 among people in urban areas.**

After the analysis, the thriving factors such as lack of infrastructure facilities including road width, front space, rear space, drainage, solid waste management, stormwater management (rain gutters), and the high building density causing UHI have resulted in the spread of diseases.

- **Examine the interrelationship between the different types of dwelling and neighborhood patterns for the spread of Dengue and Covid-19 in cities.**

Based on the research outputs, mainly the horizontal neighborhood patterns with single house single story characteristics together with poor living conditions increase the vulnerability. Areas with good living conditions have comparatively low spread even though they comprise single-house single-story houses. But the demographic data and high building density are key factors in Colombo 15 for the spread of diseases.

- **Identify the vulnerability of different neighbourhoods to Dengue plague and the Covid-19 pandemic based on urban design characteristics.**

Building height is a significant factor that affects the spread of covid-19 and dengue. Flat-type housing and houses with more than one story have reported less spread of diseases that provide a good explanation for future urban planning to more focus on building height and good living conditions to mitigate the spread of plagues and pandemics. Due to data unavailability regarding the spread of covid-19 among people and the risk factors that are updating every moment as a new situation happened, the parameters and variables used for the analysis are limited for a few sources. But this study can be carried out broader and deeper with other data such as complete patient details and accessed healthcare facilities. Availability of healthcare facilities in the area, the change of lifestyle before and after the covid-19 situation, etc. Regarding the spread of dengue further analysis can be done with data collected from other districts and the impact of climate change on the spread.

7. Acknowledgment

This research is supported by the module coordinators, supervisors, and lecturers of the Department of Town and Country Planning, University of Moratuwa, Medical staff of the D1 MOH office, New Bazaar, and Modera Maternity Home.

8. References

Acuto, 2020, *Engaging with global urban governance during a crisis*, Dial. Hum. Geogr.,10 (2) (2020).
C. Bertram, K. Rehdanz, (2015), *The role of urban green space for human well-being, Ecological Economics*, 120 (12) (2015), pp. 139-152
Zakaria Jadi, 2021, "*Step by Step explanation of Principal Component Analysis"*
Vasna Joshua, S. Grace, J.G. Emmanuel, 2021, *Spatial mapping of covid-19 for Indian cities"*
D. Vlahov, S. Galea, 2002, *"Urbanization, Urbanicity and Health"* 79, pagesS1–S12
C.H. Cheng, C.L. Chow, W.K. Chow, (2020), "*Trajectories of large respiratory droplets in indoor environment: a simplified approach".*
F. Ali-Toudert, H. Mayer, (2006), *"Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate"* Build. Environ., 41 (2006), pp. 94-108
I.Y.S. Chan, A.M.M. Liu, (2018), *"Effects of neighborhood building density, height, green space, and cleanliness on indoor environment and health of building occupants"* Build. Environ., 145
B.F.J. Manly, (1986), *Multivariate Statistical Methods - A Primer*, (third ed.), Chapman & Hall, New York (1986), pp. 76-89