

Health Vulnerability to COVID-19: A Barangay Level Assessment for Bocaue, Bulacan

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Abstract

Bulacan is one of the provinces in the Philippines with the highest number of confirmed CoVid-19 cases making its citizens the most vulnerable to the virus. This paper conducted a barangay-level vulnerability assessment with one of its municipalities, Bocaue, by adopting the three (3) dimensions of exposure, sensitivity, and resilience. Twelve (12) indicators of vulnerability to CoVid-19 were identified through related literature and the vulnerability index of each barangay was computed using a scoring method. Only one (1) barangay, Antipona, possessed high vulnerability ($VICOV19 = 0.6250$) while 84.21% or sixteen (16) barangays belonged to the low to moderate category ($0.2500 \leq VICOV19 \leq 0.5417$) and two (2) barangays fall under very low vulnerability ($VICOV19 \leq 0.2000$). The key indicators of a barangay's vulnerability to CoVid-19 include the number of detected cases (exposure), population density (sensitivity), residential type (resilience), and income (resilience). The study also recommended mitigating strategies to minimize the vulnerability of the barangays which include the allocation of a higher budget for emergency use, strict implementation of CoVid-19 quarantine protocols, and local government's special attention and strict policy implementation on vulnerable places such as hospitals and workplaces.

Keywords

CoVid-19, vulnerability assessment, scoring method, barangay level, mitigating strategies

1. Introduction

Vulnerability is the quality and state of people that affect their ability to respond to the impacts of natural hazards (Blaike et al., 2005). Turner et al. (2003) proposed a conceptual framework discussing three dimensions and the functions of vulnerability which includes: exposure, sensitivity, and resilience. In health care, vulnerability is a ubiquitous occurrence (Boldt, 2019). Being vulnerable physically, mentally, and emotionally such as easily getting sick or being easily hurt that leads to sadness or anxiety, pointing out to health vulnerability. Grabovschi et al. (2013) stated that health vulnerability is affected by two factors: individual and environmental. Individual factors can be either inherited or developed, while environmental factors can be either physical or socioeconomic.

Vulnerability assessment (VA) is a tool used for assessing the vulnerability of an entity and is used for managing risks (Fay & Patterson, 2017). Depending on the type of hazards, vulnerability assessment varies in different ways. It may be adapting to climate change or handling disaster risks or poverty and development (Weis et al., 2016). To assess vulnerability in a certain area, a vulnerability index was conducted, which is a measure of a population's exposure to some risk. Various researches were studied and taken into account, and gave the researchers idea to include various

health vulnerability indicators. Studies conducted by various researchers (Cohen, 2020; Calderón-Larrañaga et al., 2020; Parisi & Sangiorgio, 2020; Dating et al., 2020) were all related to health vulnerability assessment. However, none of these studies focused on the assessment of vulnerability to CoVid-19 at the barangay level, thus resulting in a lack of available information to be used to aid in flattening the curve of confirmed cases in the Philippines. This study identified the indicators of health vulnerability to CoVid-19 and data on these factors were assessed to calculate the health vulnerability index of barangays at the subject municipality of Bocaue, Bulacan. Recommending mitigation strategies were also discussed to minimize vulnerability and the impact of the CoVid-19 pandemic on the municipality.

2. Literature Review

Vulnerability is a quality of an individual or group and their condition affecting their ability to predict, control, prevent, and recover from the effects of natural hazards. The framework proposed by Turner et al. (2003) identified the three dimensions of vulnerability which are exposure, sensitivity, and resilience. Exposure is the first indicator of vulnerability since it is determined based on the distance between a hazard source and the target such as persons or objects, it is likely to affect or impact; thus, the vulnerability will be influenced by the ability of the exposed to act to minimize harm (Nwokedi, 2020). Sensitivity, however, is the degree or the likelihood to which a system can be affected, either adversely or beneficially, by exposure to risks (Babu, 2019; Weis et al., 2016). Lastly, resilience, or better known as adaptive capacity, is the ability of a system to adjust after exposure to hazard, to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its costs or consequences (Yusuf and Francisco, 2009; Liu et al., 2013).

Vulnerability assessment (VA) is a method used to evaluate the vulnerability of an object or the object that is at risk. This can be used as a tool for handling risks or to control the threat-accompanying risks. VA requires determining all the components that could be at risk from a given threat. Local information such as survey data may be used to list the components at risk. VA is important since it can help to mitigate risk levels by organizing effective disaster reduction (Coburn et al., 1994). Assessing vulnerability comes in various forms depending on the field from which they are drawn. Weis et al. (2016) conducted a study and stated that these fields include climate change adaptation, disaster risk management, or poverty and development. They also implied that these fields were operated separately but are dependent on each other. Measurement of exposure or vulnerability of a certain location or population to a hazard is called a vulnerability index. Dating et al. (2020) utilized a VICov-19 index to measure the vulnerability of local areas in the Philippines. This index was said to be used for monitoring, evaluating, and assessing the current state of the said areas. It included dimensions and indicators and was computed using a given formula. The National Capital Region (NCR) was identified as relatively vulnerable in comparison to other regions.

Last December 2019, a new coronavirus disease called CoVid-19 paved its way, spreading to about 200 countries across the world since its discovery in China. The pandemic the world is facing right now is considered the greatest global health crisis of all time and the greatest battle ever fought since World War II (UNDO, 2020). The transfer of this virus can be from a known specific person to person, or interaction with the community (Arsenault, 2020). It can cause mild respiratory problems, pneumonia, or even death. A study conducted by Singh (2020) showed that almost all households are aware of the pandemic, its symptoms, and its needed precautionary measures, but only a few have adopted it positively by storing items needed for an emergency, having a balanced diet, getting insurance to cover expenses, and participating to CoVid-19 tests. Additionally, numerous factors can also influence people's health vulnerabilities towards CoVid-19.

Previous literature mentioned several key indicators to measure the vulnerability of a certain population or group. According to the study of IFRC (2020), people differ their exposure to risks based on their socio-demographic profile, which includes social and ethnic groups, gender, age. On the other hand, Dating et al. (2020) study developed the four dimensions of vulnerability. Another significant finding was seen in the study of Calderon-Larranaga (2020); wherein the data gathered show that the pandemic expresses a disproportionate preference for individuals who are not only biologically, but also socially vulnerable. It indicated that the specific age groups of the older population were most vulnerable to the disease. Social factors such as income class and literacy rate can greatly affect people's vulnerability to the virus. Moreover, a person's psychological state and behaviors were also associated with general diseases such as colds, which can also increase the risk and progression of having CoVid-19 (Cohen, 2020). These behaviors pointed out to the risky ones including smoking, alcohol abuse, acute binge drinking, and lack of exercise. On the other hand, psychological state pertains to the negative emotions a person has due to intrapersonal and economic stresses. Another

factor affecting one's health vulnerability is his exposure to the virus due to his residential type, and employment rate of the community he is in with regards to the effectiveness of lockdown, social distancing, mask the use of residents (Chatterjee et al., 2020). Lastly, the study of Parisi and Sangiorgio (2020) indicated the parameters contributing to the spread of the virus which include activities, companies, and institutions.

3. Methods

A conceptual framework shown in Figure 1 was created to visualize the process of this study's methodology. There were three (3) phases in general: (1) literature review to identify the factors of health vulnerability to CoVid-19 and classify these factors according to the dimensions of vulnerability proposed by Turner et al. (2003); (2) data assessment through the scoring method with the use of rubrics; and (3) barangay vulnerability index computation using the formula adopted by Sathyan et al. (2018). In addition, a discussion of applicable risk reduction measures against the prevailing virus was created for this municipality using benchmarking.

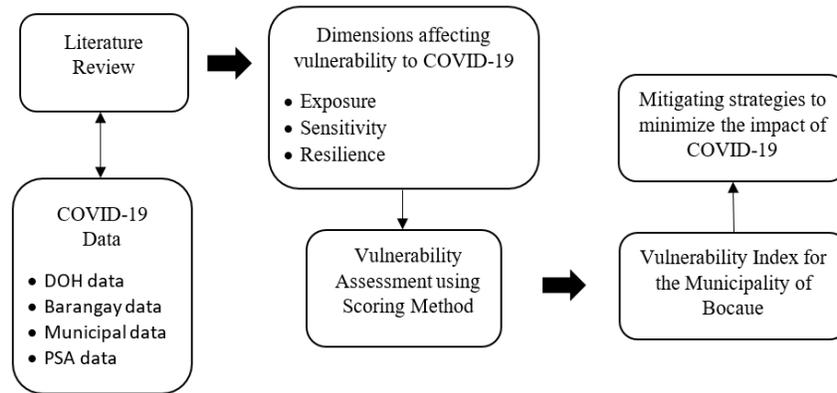


Figure 1. Conceptual Framework

Data collected for each indicator of vulnerability were analyzed and rated using a scoring method. According to Product Plan (2020), weighted scoring uses numerical values to rank a specific variable. It is quite useful in determining factors one should prioritize. Moreover, as stated by Project Management (n.d.), the scoring method evaluates a criterion or indicator of an assessment by setting a score. It was said to be usually done using a point spread wherein each point corresponds to a meaning that can be easily identified as low or high. A rubric for evaluation to assign specific scores or rates on each indicator of vulnerability was prepared. Equal weights were used upon creating the index for it has been known to be a straightforward technique in identifying indices (Gan et al., 2017). Table 1 presents the list of CoVid-19 indicators, its description, functional relationship to vulnerability, and corresponding indicator weight. To get the weights of each indicator, Equation 1 was applied.

$$Indicator\ weights\ (W_m) = \frac{1.00}{no.of\ indicators} \quad (1)$$

Conducting vulnerability assessment can be done in various ways and procedures depending on which field one has specialized. The study adopted the methods applied by various researchers (Sathyan et al., 2018; Pham et al., 2020; German, et al., 2021) in calculating the vulnerability index of each barangay. The first step in the process was normalizing the ratings or scores using Equations 2 and 3, a process employed in computing for Human Development Index (HDI) by UNDP (1990).

$$X_{norm} = \frac{Xi - Xmin}{Xmax - Xmin} \quad \text{for } \uparrow \text{ or } (+) \text{ functional relationship} \quad (2)$$

$$X_{norm} = \frac{Xmax - Xi}{Xmax - Xmin} \quad \text{for } \downarrow \text{ or } (-) \text{ functional relationship} \quad (3)$$

where,

X_{norm} = the normalized value of each indicator
 X_i = value of indicator i
 X_{max} = maximum value of the indicator of vulnerability component
 X_{min} = minimum value of the indicator of vulnerability component

Normalization allows the indicators included in the rubrics into their context and lets the data define which cases are “good” and “worst” (Himmel, 2015). It is to be noted that the functional relationship of each indicator to vulnerability was considered.

Table 1. Indicators of Barangay Vulnerability to CoVid-19

Dimension	Indicators	Meanings	Functional Relationship
Exposure	C1- No. of Detected Cases	Number of detected CoVid-19 cases divided by the total population (Percentage)	↑
Exposure	C2- No. of Suspected Cases	Number of suspected CoVid-19 cases divided by the total population (Percentage)	↑
Exposure	C3- No. of Medical Facilities	Total number of Hospitals and Infirmary	↑
Exposure	C4- No. of Accommodation Establishments	Total number of Resorts, Hotels, and other overnight lodging units	↑
Exposure	C5- No. of Rural Health Units	Total number of Rural Health	↑
Sensitivity	C6- Gender	Number of men divided by the Total Population (Percentage)	↑
Sensitivity	C7- Senior Citizens	Number of senior citizens aged 60 years and above divided by the Total Population (Percentage)	↑
Sensitivity	C8- Children	Number of children aged 15 years and below divided by the Total Population (Percentage)	↑
Sensitivity	C9- Population Density	Number of people per square kilometer	↑
Resilience	C10- Literacy Rate	Number of Literate people divided by Total Population (Percentage)	↓
Resilience	C11- Barangay Income	Average annual income	↓
Resilience	C12- Residential Type	Types of Houses according to Structure	↓

The next step is to assign weights to each indicator. Because the given factors were equally important for assessing the three dimensions of vulnerability, a balanced weight approach using Equation 1 was used in this study. Additionally, a study conducted by Papathoma-Kohle et al. (2019) cited Beccari (2016) who studied 106 papers about index construction for natural hazard risk assessment and showed that most studies were based on equal weighting. It is often believed that the technique of using equal weighting for methodological purposes makes the paper less subjective. (Chowdhurr, 1991, as cited in Sathyan et al., 2018). The paper also implied that giving equal importance to all variables is perfectly acceptable. After calculating the indicator weights, they were used to compute for the final health vulnerability index expressed as Equation 4:

$$VICOV19 = \frac{W_m X_{norm1} + W_m X_{norm2} + W_m X_{norm3} + W_m X_{norm4} + \dots + W_m X_{norm12}}{12(W_m)} \quad (4)$$

where,

W_m = the weight of each indicator

X_{norm} = the normalized value of each indicator

Calculation of the indices concerning the three (3) dimensions of exposure, sensitivity, and resilience was also important and was done to compare and analyze the dimensional vulnerability of the 19 barangays in Bocaue. These were calculated using Equations 5, 6, and 7 indicated below.

$$Exposure = \frac{W_m C1 + W_m C2 + W_m C3 + W_m C4 + W_m C5}{5(W_m)} \quad (5)$$

$$Sensitivity = \frac{W_m C6 + W_m C7 + W_m C8 + W_m C9}{4(W_m)} \quad (6)$$

$$Resilience = \frac{W_m C10 + W_m C11 + W_m C12}{3(W_m)} \quad (7)$$

The VICOV19 index varies between 0 to 1, from the least vulnerable to the most vulnerable. In other words, a higher resulting value indicates greater vulnerability. Table 2 shows the range of values and its interpretation in terms of vulnerability using five (5) scales.

Table 2. Vulnerability Index Category

Category	Index Values
Very Low Vulnerability	0.0000 to 0.2000
Low Vulnerability	0.2001 to 0.4000
Moderate Vulnerability	0.4001 to 0.6000
High Vulnerability	0.6001 to 0.8000
Very High Vulnerability	0.8001 to 1.0000

Data used in this study were gathered from various sources such as the Bocaue Municipal Office (BMO), Bocaue Municipal Health Office (BMHO), Department of Health (DOH), Philippine Statistics Authority (PSA), and other legitimate websites that provided all the statistical information about CoVid-19.

4. Results and Discussion

4.1 Barangay Health Vulnerability Index Concerning Exposure, Sensitivity and Resilience Dimensions

Table 3 shows the summary of the vulnerability indices concerning exposure dimension. Bocaue's barangays ranged from very low to moderate exposure categories ($0 \leq VICOV19 \leq 0.2917$) with an average index value of 0.1008, classified under low exposure.

Table 3. Vulnerability index: Exposure dimension

Category	Scale		Frequency	Percentage
Very Low Exposure	0	0.0666	7	36.84%
Low Exposure	0.0667	0.1332	9	47.36%
Moderate Exposure	0.1333	0.1999	1	5.26%
High Exposure	0.2000	0.2665	1	5.26%
Very High Exposure	0.2666	0.3333	1	5.26%

Among the indicators of exposure, the number of detected cases obtained the highest indicator values. The barangays of Bagumbayan, Biñang 1st, and Turo were identified to be vulnerable in the said dimension. This is due to the increased contact of people to CoVid-19 positive patients. Moreover, failure of following the health protocols contributed to the sudden increase of detected cases in Bocaue. The number of suspected cases was the second indicator to acquire a substantially higher score. One factor that contributed to this was caused by the prolonged progress of the tests conducted on Patients Under Investigation (PUI). As stated by Kretzschmar (2020), the impact of delays of CoVid-19 test results can increase the onward transmission of the virus to the community. As per the medical facilities, the range of the indicator scores acquired varies from 0 to 0.08 which lies to be the third indicator to affect exposure to CoVid-19. As Dating et al. (2020) stated, the greater number of medical infrastructures leads to higher vulnerability. This was also proven by the study of Nguyen et al. (2020) which showed that even health workers with adequate Personal Protective Equipment (PPE) contribute to the spread of the virus to the community. The said barangays only have one (1) to two (2) facilities leading to low vulnerability. Accommodation establishments have the same values for all barangays except the communities of Lolomboy, Poblacion, and Turo. These barangays were categorized as low vulnerability, indicating that a small number of establishments can help minimize the spread of the virus. According to the Centers for Disease Control and Prevention (2021), multifamily housing such as apartments, condominiums, townhouses, duplexes, and quadruplexes will contribute to the transmission of exposure of residents and staff which can lead to an increased potential risk to viruses. Lastly, the number of rural health units obtained the lowest score in the conducted index. This indicator was obtained through Dating et al. (2020)'s study which assessed how the infrastructure dimension deals with the healthcare workforce. Having sufficient rural health units can increase the accessibility of non-emergent patients and can weigh down the population in hospitals. Health units are tasked to improve plans and resources to properly conduct specialized services to the community, especially to vulnerable people.

Table 4 presents the summary of the vulnerability indices concerning the sensitivity dimension where Bocaue's barangays ranged from low to very high sensitivity categories ($0.1042 \leq VICOV19 \leq 0.2708$) with an average index value of 0.1842, classified under moderate sensitivity.

Table 4. Vulnerability index: Sensitivity dimension

Category	Scale		Frequency	Percentage
Very Low Sensitivity	0	0.0666	0	0
Low Sensitivity	0.0667	0.1332	4	21.05%
Moderate Sensitivity	0.1333	0.1999	14	73.68%
High Sensitivity	0.2000	0.2665	0	0
Very High Sensitivity	0.2666	0.3333	1	5.26%

Results showed that the vulnerability indices for sensitivity ranged from 0.125 to 0.270, falling under the moderate vulnerability category. The population density was the biggest contributor to the barangays' sensitivity to the virus. Antipona ($\rho N = 118.69$), Biñang 1st ($\rho N = 92.42$), Lolomboy ($\rho N = 93.88$), and Caingin ($\rho N = 88.56$) were notably susceptible compared to other barangays with indicator values ranging from 0 to 0.02. Data in these barangays obtained a rubric score of 4 where the population density is between 76 to 100 people per square kilometer. Residents living in these areas are compressed, thus being more exposed and sensitive to the risk of the virus. The second most significant component is the gender ratio of residents where all barangays' index values range from 0 to 0.08. Various studies and a surveillance report from the World Health Organization (2021) all concluded that the occurrence of CoVid-19 symptoms was found to be higher in males than in females. Males have higher angiotensin-converting enzyme 2 (ACE2) concentrations in their blood which can enable the said virus to infect healthy cells in their body. Moreover, the population of children aged 15 and below comes in third with an indicator value ranging from 0 to 0.08. Like gender, data on this age group took only around 30-45% of the total population of each barangay and 40% of Bocaue as a whole. The least concerning indicator is the population of senior citizens aged 60 years old due to their much lower population, comprise of about 6-12% of the total population of each barangay and only 7% of Bocaue as a whole. This can be supported by the small number of confirmed and suspected CoVid-19 cases of Bocaue, with 0.0005% of the population infected, almost at 0%.

Table 5 exhibits the summary of the vulnerability indices concerning resilience dimension. The barangays' index values ranged from $0.0486 \leq VICOV19 \leq 0.25$ with an average index value of 0.1053, classified under low resilience.

Table 5. Vulnerability index: Resilience dimension

Category	Scale		Frequency	Percentage
Very Low Resilience	0	0.0666	6	31.58%
Low Resilience	0.0667	0.1332	11	57.89%
Moderate Resilience	0.1333	0.1999	2	10.53%
High Resilience	0.2	0.2665	0	0
Very High Resilience	0.2666	0.3333	0	0

Results showed that the vulnerability indices for resilience ranged from 0.08 to 0.25, falling under low vulnerability (highly resilient). The barangay income was the biggest contributor to Bocaue's resilience to the virus. The majority of the barangays earn a good income which made them afford healthcare goods and services such as personal protective equipment (PPEs), masks, and CoVid-19 test kits; and provide these to their residents efficiently as expounded by Tabuga et al. (2020). The second most notable among the indicators is the residential types of each barangay which an indicator value range of 0 to 0.07 was calculated, with barangays Antipona (WmRT=0.0714), Bagumbayan (WmRT=0.0536), and Bunducan (WmRT=0.0536) having the lowest resilience. These barangays' citizens mostly settle in living quarters and other housing units such as trailer and squatter areas where the human population in each residential area is compressed and densely populated, making social distancing impossible. As stated by CDC (2020), congregate or shared housing occurrences such as communal spaces, community activities, and close living quarters increase the risk of acquiring the virus. Not only their type of settlement increases their chances of being exposed to the virus, but also their livelihood and scarcity of resources (UN Habitat, 2020). The employment rate of each barangay came in last with a dominant indicator value of 0, classified under very low vulnerability. Of the total municipality population, 90.4% or 108,186 citizens are employed.

4.2 Overall Barangay Health Vulnerability Index

Table 6 present the summary of the health vulnerability index of the 19 barangays in Bocaue while Figure 2 illustrates the graph of the barangays' indices. The index values ranged from very low to moderate exposure categories ($0.2875 \leq \text{VICOV19} \leq 0.625$) with an average index of 0.3904. Only the barangay of Antipona (1), possessed very high vulnerability. The barangays of Bagumbayan (2), Bambang (3), Biñang 1st (5), Bunlo (9), Lolomboy (13), Poblacion (14), Sulucan (15), and Turo (18) were classified as moderately vulnerable while Batia (4), Biñang 2nd (6), Bunducan (8), Caingin (10), Duhat (11), Taal (16), Tambubong (17), and Wakas (19) possessed low vulnerability to CoVid-19. In addition, the barangays of Bolacan (7) and Igulot (12) were categorized under very low vulnerability.

Table 6. Summary of Barangay Health Vulnerability Index

Category	Scale		Frequency	Percentage
Very Low Vulnerability	0	0.2	2	10.53%
Low Vulnerability	0.2001	0.4	8	42.11%
Moderate Vulnerability	0.4001	0.6	8	42.11%
High Vulnerability	0.6001	0.8	1	5.26%
Very High Vulnerability	0.8001	1	0	0

The study showed that index values for medical facilities, accommodation establishments, rural health units, and employment rate were similar in most of the barangays, while a strong variation was observed in the indicators no. of confirmed CoVid-19 cases, no. of suspected cases (PUI), population density, residential types, and income class. A higher no. of confirmed and suspected cases leads to greater exposure to the virus of the people in the community while the residential type influences how fast a virus can spread. Thousands of healthcare workers were contaminated early in the epidemic in China, and the number of infected healthcare workers and subsequent new cases is now growing elsewhere around the world (Shmerling, 2020). Likewise, contributing to the heightened risk of infection of residents is the kind of house they are currently living in. Multifamily housing such as apartments, condominiums, townhouses, duplexes, and quadruplexes pose the greatest challenge regarding this matter (Centers for Disease Control and Prevention, 2021). Another concern is population density where Antipona posted the highest data among the barangays, a population of 2,298 living in a small land area of 19.825 square kilometers. Lastly, income depends on

the performance of each barangay. Sources of income include payment of fees, taxes, and permits which are all based on the no. of operating businesses and citizens of a barangay.

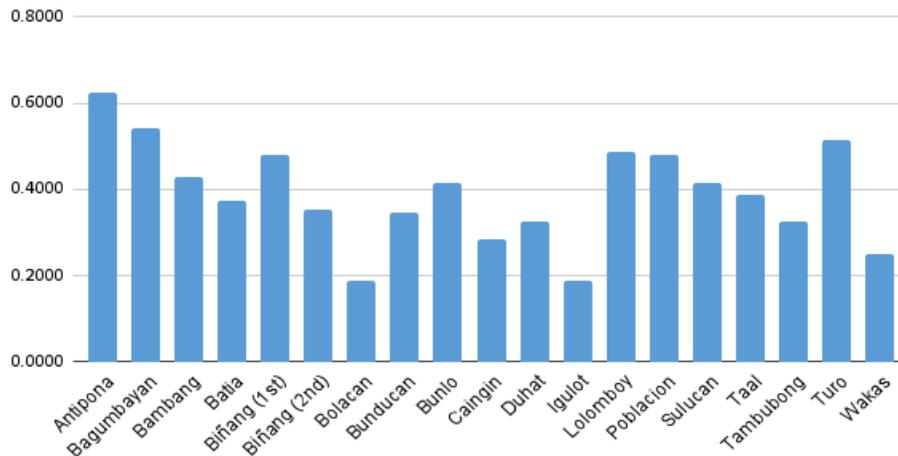


Figure 2. Overall Barangay Health Vulnerability Index

4.3 Mitigating Strategies to Reduce Barangays' Vulnerability to CoVid-19

Appropriate strategies should be based on the best available data of a community and decision-making will vary based on the transmission and circumstances in the area (CDC, 2020). Among the strategies recommended by CDC include promotion of behaviors that prevent spread, maintaining healthy environments, maintaining healthy operations, and preparation when someone gets sick. Local government officials in the municipality should allocate enough budget for health and devise a contingency plan in preparation for possible prolonged impact or implication of the CoVid-19 pandemic. The health protocols should be strictly implemented and monitored in each barangay, while real-time information of CoVid-19 patients and suspects should be properly communicated to the municipal health office so that prompt action may be done if needed. Authorities must also pay attention to vulnerable settings such as hospitals, workplaces, schools, and other sources of outbreaks (CDC, 2021).

5. Conclusion

Vulnerability assessment provides a straightforward approach to investigate the vulnerability of local barangays to the CoVid-19 virus. Through literature review, the study identified 12 indicators of health vulnerability clustered into the dimensions of exposure, sensitivity, and resilience. Using the scoring method, the vulnerability indices of each barangay in Bocaue were computed. Results showed that the barangay of Antipona is the most vulnerable among all barangays, posing a high index value of 0.6250. Consequently, eight (8) barangays which are Bagumbayan, Bambang, Biñang 1st, Bunlo, Lolomboy, Poblacion, Sulucan, and Turo were classified as moderately vulnerable while Batia, Biñang 2nd, Bunducan, Caingin, Duhat, Taal, Tambubong, and Wakas acquired low vulnerability to CoVid-19. The other two (2) barangays of Bolacan and Igulot characterized very low vulnerability. Data on five (5) of the indicators which include no. of confirmed CoVid-19 cases, number of suspected cases (PUI), population density, residential types, and income class showed strong variations while the similar score was posted on indicators medical facilities, accommodation establishments, rural health units, and employment rate since data for most of the barangays were the same. Proper health budget allocation and strict implementation of health protocols should be done by each barangay to prevent the rise of CoVid-19 cases. Additionally, the local government unit should also devise a contingency plan in preparation for possible prolonged impact or implication of the CoVid-19. Researchers in the future may conduct vulnerability assessment studies using other methods and utilize the most recent data related to the pandemic.

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