Framework Design on Health Care System Resilience: A Fuzzy AHP Approach

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Abstract

An established resilient healthcare system is vital in any governmental structure to protect the public's well-being during unexpected events such as occurrence of disasters. In the Philippines, barangay is the basic political unit with immediate access to the people affected by disasters. This study aims to design a framework to determine the resilience of the healthcare system at the smallest local government unit using the fuzzy analytic hierarchy approach (FAHP) approach. The FAHP is used to establish the contributing factors and sub-factors in the design of a resilient healthcare system. The final results show that disaster preparedness as the main priority factor with a rating of 44.77%. Service Continuity followed far behind at 16.60%, and then followed closely by Resources and Recovery Adaptation at 14.74% and 14.63%, respectively. Safety and Vulnerability came last in the prioritization ranking at 9.25%.

Keywords

Healthcare resilience, Fuzzy AHP, framework design, barangay

1. Introduction

The Philippines is one of the countries located in the Pacific Ring of Fire which makes it more vulnerable and exposed to natural disasters. In fact, it has ranked 4th in the list of countries that are most prone to natural disasters based on a 20-year evaluation of the United Nations Office for Disaster Risk Reduction (UNISDR) (Foreign Service Institute, 2016). To support this fact, Global Facility for Disaster Reduction and Recovery (2017) states that there is at least 60% of the total land area of the country that is exposed to multiple hazards such as typhoons, storm surges, floods, volcanic activities, earthquakes, drought, and tsunamis. It also reports that about 565 natural disasters have struck the country leaving an estimate of $23 billion damages and 70, 000 lives lost. Furthermore, Philippine Health Review describes the damages left by these natural disasters as indelible marks that greatly affected the culture, economy, and the whole of society. Some of the most recent terrible disasters are the Typhoon Yolanda in 2013, also referred to as the strongest that ever landed in the planet (Mullen, 2013), that caused 6,000 reported fatalities and 1.1 million homes damaged, volcanic eruption of Mayon Volcano in 2018 which forced people in the affected radius to evacuate and leave their livelihood unprotected, and the El Niño or nationwide drought that have always affected the livelihood of many Filipino farmers and other businesses. Amidst the global pandemic, on November 2020, another super typhoon with international name, Goni, badly hits Luzon affecting millions of Filipinos.

To strengthen the country's institutional capacity to uphold the rights to life and property, the Republic Act of 10121 was established in 2010. RA 10121 provides the legal basis for policies, plans and programs to deal with disasters resulting to the establishment of disaster key agency, the National Disaster Risk Reduction and Management Council (NDRRMC). The healthcare system resilience of the Local Government Unit (LGU) is one of NDRRMC's tasks. Through the creation of NDRRMC, the country has made progress in DRRM. Through the new disaster agency and the help of local and international organizations, the government was able to shift from emergency relief operations towards risk mitigation and preparation. Global Facility for Disaster Reduction and Recovery (GFDRR) together with the World Bank was able to improve the country's financial resilience by providing the government liquidity worth $500 for post-disaster recovery.

Disasters are also health emergencies. The absence of healthcare integration can result to its inaccessibility in times of emergency that can cause illness and fatalities. This makes the role of healthcare system in times of disaster very crucial especially with the increasing frequency that disaster strikes (Swathi, Gonzales, and Delgado, 2017). Moreover, World Health Organization (WHO, 2011) does not only emphasize the importance of healthcare during disasters but also its capacity to withstand the shock of disasters so it will be able to function in crisis.

A healthcare system is deemed resilient if it is prepared in response to shocks (Kruk et. al, 2017) while being able to maintain critical functions and eventually recover back to its original condition or adapt to a better one (Zhong et al., 2014). Well-developed health systems are naturally more resilient in the face of disasters. It is composed of facilities - private, public, and non-governmental - which work together and can withstand hazards for operation in emergencies (WHO, 2011). Disaster mortalities and damages on human economy and development are the impact of a disrupted health care system during times of emergencies, which compounds the importance of a resilient health system. (Swathi, et al., 2017) While the progressive view of the government's policies leaning towards prevention rather than response (Rey, 2015) (LSE, 2010), it is reflected in the NDRRMC structure that healthcare is not fully integrated into DRRM. The Department of Health's (DOH) role in the NDRRMC is relegated only to disaster response, recovery and rehabilitation. The thematic area of NDRRMC in disaster prevention and mitigation and disaster preparedness does not include the presence of healthcare system or even a healthcare department (NDRRMP 2011-2028). This kind of view in the national level confines the barangay level to basic disaster drills, evacuation location, and basic operation in rescue. The presence of active medical training, stockpiles, and other medical needs are nonexistent; hence, the absence of a healthcare system that is proactive in preparation and mitigating risks.

Development of a resilient health systems in involves a focus and general view of the whole system. A study by Zhong, et al. (2014) established the four key domains of a resilient healthcare systems such as hospital safety, disaster preparedness and resources, continuity of essential medical services and recovery and adaptation. An integrated approach to health system development through the understanding of concepts makes up a resilient healthcare system. While the complexity and contextualization of hospital system and a local government system differ, the study of Zhong relates to literature definition of resilience (Cook, et al., 2000), (Cook and Nemeth, 2006), (Nemeth, et al., 2008) and resilient healthcare system (WHO, 2011), (Kruk, et al., 2017).

In 2011, WHO established its view on what comprises an adaptable and resilient health care system by introducing general guidelines that includes surge capacity, flexibility, and business continuity planning. Several researches such as Zhong et al. (2017) and Kruk et al. (2017) have used the general guidelines to develop a framework for healthcare resilience. A deeper understanding, however, is still needed to relate it to the background of a community to be implemented on, particularly for this study, the barangays in the Philippines. A study by Swathi et al. (2017) focused on how a low-income country with no substantial resources like the Philippines can strengthen surge capacity. This is just one factor among many others for consideration in building resilient health care systems. Studies like this can be further built upon to develop a framework that is specific for application in the Philippine setting.

Existing frameworks for resilient health systems are general and encompassing. Kruk, et al. (2017) does not prescribe their index as the national benchmark because of heterogeneity to contextual application. Moreover, the conceptualization of health resilience is deemed not to be prescriptive, but rather dynamic and flexible that can adapt to complexity of response to disasters. (Haldane, et al., 2017) This heralded to very few literature measuring factors of healthcare system resilience against each other, and gave rise to general frameworks. These general frameworks are conducted independent of each other, but will be used and integrated in this study to create a more comprehensive framework that is exact to the context of the level of a Philippine barangay.

Using the existing studies on frameworks for a resilient health system, this study measures the level of resilience in the smallest government unit such as a barangay. Identification of key domains of a resilient health system commonly applies meta-synthesis using cross-sectional surveys (Zhong, 2014; Samsuddin, et al., 2017), case studies (Kruk, et al., 2017), and organizational literatures (Gilson, et al., 2016). Through the methods stated, the healthcare system is deeply understood through historical context, definitions, and elements (Bartolucci and Hillegass, 2017). This allows for a deep interpretation of the current system for the proposal of the key domains of a resilient health system. On the other hand, merely identifying these domains lays a gap from prioritization of these key domains which is deemed crucial in decision making and resource allocation.

The study by Zhong et al. (2014) developed a hospital resilience index through a scoring model with associated weights per key factor of resilience, thus making it a quantitative measure. The weights were assigned through a binary survey answered by experts however has an underlying assumption that the sum of scores across all domains of each factor is the resulting weight of that factor. This neglects the existence of a hierarchy between factors as the scores are made independently and not based on comparison among factors. That being said, here is where multiple criteria decision-making bridges this gap. Multiple criteria decision-making (MCDM) allows for ranking of alternatives or factors in order to best reach a goal (Abbas et al., 2015) with a complex criteria structure (Ozdagoglu, A. and Ozdagoglu, G., 2007).

This paper applies MCDM, specifically Fuzzy Analytic Hierarchy Process (Fuzzy AHP) as a method in creating a framework for a resilient health system. Fuzzy AHP is an advancement of the traditional AHP, wherein the developed method captures the uncertainty of decision-makers in deciding the value of different criteria (Kabir and Hasin, 2011). In the AHP approach, the multi-criteria decision analysis is decomposed into different criteria each with a weight derived from the judgment of its value by a group of experts and decision makers. The limitation of AHP is it does not address the vagueness of subjective judgment and the differences of views to the influence of set criteria. A related study that uses AHP in establishing a composite index of coastal communities' resilience uses AHP and this study aims to conduct a similar approach using FAHP. Orencio and Fujii (2014) approaches risk mitigation in the coastal communities of Baler, Aurora, Philippines using AHP. The important criteria were determined in order to construct the AHP model through asking 20 decision-makers of their priorities of the presented alternatives. Using Saaty and Vargas (1991) scale, the factors are judged to the decision-maker's preference. However, the AHP scale cannot capture the deterministic preferences of decision-makers, which can result to inaccurate framework.

From the literature review, there are few studies focusing on the use of MCDM approach in the framework design on healthcare resilience. The use of Fuzzy AHP opens up to a different perspective since it is a newly applied approach for healthcare resilience studies. With the use of the Fuzzy AHP technique, appropriate weight values can be determined in order to identify the priorities in the key domains of a resilient health system. As the forefront of disaster preparedness and response, DRRMC at barangay level should be known and strengthened. This study develops a framework design to evaluate healthcare system resilience.

2. Methodology

This research focused on developing a framework design for the resilience of the barangay healthcare systems in the Philippines.

2.1 Participants

There are two sets of experts with three members each are considered in the study. The sets of experts include the local health officers with more than 10 years of experience residing in the concerned community and certified by the government. The experts are selected mainly because of their direct involvement in the health aspect of the community. sanitation, and hygiene promotion activities, nutrition in emergencies, and mental health and psychosocial support.

2.2 A Fuzzy AHP Approach

The framework design is based on a Fuzzy AHP framework consisting of identified factors and subfactors of healthcare resilience. This study applies the geometric mean method developed by Buckley (1985). Using geometric mean maintains a consistent reciprocity within the triangular fuzzy numbers when they are aggregated (Aczél and Saaty, 1983). The triangular fuzzy numbers (TFNs) that comprise the pairwise comparison matrix is relative to each other wherein importance of factor i against j and factor j against factor i are the inverse of one another therefore the ratio scales should be preserved thus making geometric mean appropriate compared to arithmetic mean which only preserves intervals (Forman & Peniwati, 1998).

Three local health experts were asked to answer the survey consisting of a series of pairwise comparisons across the factor and subfactor levels. Saaty's pairwise comparison scale was used to assign importance for each factor: 1, 3, 5, 7, and 9. The values were then converted into its corresponding TFN which implies a fuzzy event through the three real numbers (l, m, and u) consisted by the TFNs. The verbal representations of AHP's fundamental 9-point scale are defined by triangular fuzzy numbers (l, m, and u) for comparison of dominance in importance of factor i over factor j as presented in Table 1.

Table 1. Linguistic Rating Scale with Triangular Fuzzy Numbers (Promentilla, Aviso, & Tan, 2015)

Value	Linguistic Scale	Description	Triangular Fuzzy Number (TFN)
1	Equally Important	Factors *i* and *j* are of equal importance	(⅓, 1, 3)
3	Moderately More Important	Factor *i* is slightly more important than *j*	(1, 3, 5)
5	Strongly More Important	Factor *i* is strongly more important than *j*	(3, 5, 7)
7	Very Strongly More Important	Factor *i* is very strongly more important than *j*	(5, 7, 9)
9	Extremely More Important	Factor *i* is extremely more important than *j*	(7, 9, 11)

By applying the FAHP approach, the survey allows prioritization of factors and subfactors that constitute a resilient barangay healthcare system. Though the traditional AHP is a prominent decision-making methodology in the healthcare sector, it is insufficient with regards to the fuzziness of decisions. Fuzzy AHP addresses the fuzziness through applying Fuzzy Triangular Numbers (TFN) in determining the respective weights of the factors. Figure 1 illustrates the fuzzy AHP model. There are five key factors considered in the study, namely, safety and vulnerability, disaster preparedness, resources, service continuity, and recovery and adaptation. Safety covers the safety within the healthcare facility as well as the safety of standard procedures (Kohn, Corrigan, Donaldson, 2000) while Vulnerability is the awareness of the incapacities of the healthcare facility especially in attending to patients during emergency situations (WHO, 2010). Disaster preparedness means the level of preparedness of healthcare system when responding to shocks caused by disasters. Disaster preparedness require a lot of effort for the healthcare system such as leadership in the organization, community cooperation and communication, established strategic disaster plans, and trainings and drills that simulate disaster situations. Resources has three underlying sub-factors disaster stockpiles, logistics management, and emergency staff. In this factor, the demand when a disaster strikes is anticipated so as to become prepared when disaster comes and the barangay is still in recovery. Healthcare facility becomes resilient if there is enough supply that can last until the barangay is recovered, and adequate number of staffs is present to accommodate the needs of the people. Service continuity is the ability of the healthcare system to remain on its standard procedures and stable performance even on a sudden change of healthcare demand (Cimellaro, et.al, 2010). It brings with it three sub-factors which are emergency critical care capability, surge capacity, and lifeline availability. Recovery and adaptation is the last reserve of the healthcare systems in case the abovementioned factors are not met. It is crucial for healthcare facilities to be able to recover instantly from a disaster and adapt to what is present. Moreover, this factor has three sub-factors that determine the healthcare capability to recover and adapt, namely, reconstruction and recovery mechanisms, capability assisting community recovery, and adaptation strategies.

Similar to AHP, Fuzzy AHP begins with the comparison of the factors among each other and the comparisons of subfactors with each other under one given factor. The design of the survey consists of pairwise comparisons which determine the weights of each respective factor and subfactor with respect to healthcare resilience.

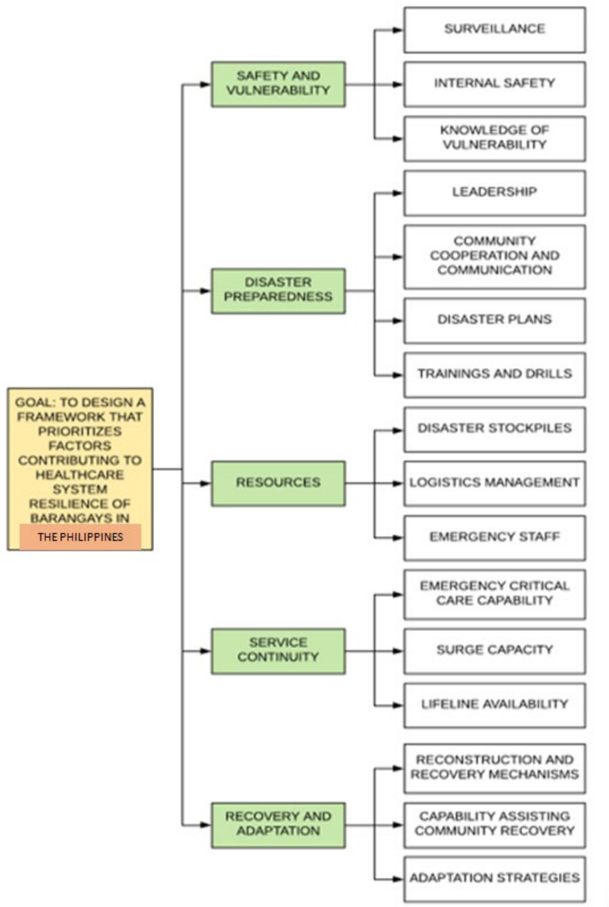

Figure 1. Fuzzy AHP Model

3. Results and Discussions

This section presents the results of ranking by the two sets of experts. There are two different local government units being evaluated in the study, two of the most populated barangays (i.e, Barangay L and Barangay T) in the municipality. Set A experts evaluated barangay L and set B experts evaluated barangay T. Table 2 illustrates the normalized weights of each factor and its corresponding ranks from the two sets of experts evaluating the barangays. Disaster Preparedness leads the prioritization ranking by a large margin with its weight of 44.77% in barangay T. Service Continuity followed far behind at 16.60%, and then followed closely by Resources and Recovery Adaptation at 14.74% and 14.63%, respectively. Safety and Vulnerability came last in the prioritization ranking at 9.25%.

However, it can be noticed that in barangay L, the priorities are different. Service Continuity ranks first at 35.39% while it only ranked second in barangay T at 16.60%. From this result, it can be deduced that Service Continuity remains an important factor with it placing second, but the healthcare center of barangay T has more pressing need for the development of their disaster preparedness with it ranking first at a large margin. Disaster Preparedness is one of the four thematic areas of NDRRMP, which layouts the country's vision for a "safer, adaptive and disaster resilient Filipino communities toward sustainable development." This area is also the evaluated critical issue that pervades the non-functionality of local DRRM system wherein the barangays are the forefront of action (Rappler, 2015). The evaluation of NDRRMC's provision that yielded this result was done in 2015. From this, it can be inferred that barangay T is still unsuccessful in addressing the need for a proactive healthcare system.

Table 2. Summary of Factor Ranking

Global Aggregated Ranking			
Barangay L		Barangay T	
Criteria	*Weight*	*Criteria*	*Weight*
Service Continuity	35.39%	Disaster Preparedness	44.77%
Safety and Vulnerability	28.43%	Service Continuity	16.60%
Resources	16.63%	Resources	14.74%
Disaster Preparedness	15.40%	Recovery and Adaptation	14.63%
Recovery and Adaptation	4.15%	Safety and Vulnerability	9.25%

The tabulated list of the computed global prioritization and identified ranking of each subfactor could be seen in Table 3. For Barangay L, the global top priority among all the subfactors is the Lifeline Availability under the Service Continuity Factor at 23.69%. It was followed by the subfactors Surveillance and Knowledge of Vulnerability, which are both under the factor Safety and Vulnerability, at 15.52% and 11%, respectively. The remaining subfactors follows at small percentages of less than 10%. The top 8 sub-factors comprise half of the subfactors and totals to 82.77% of the global weight. For Barangay L, it can be clearly seen that Leadership among others topped the subfactors with a 17.32% and was then followed by Community Cooperation & Communication with a 13.32%. The next top priorities, highlighted by the bold letters, did not measure far from each other ranging from 5% - 10%, while the least priority was found to be Internal Safety with a rating of 2.04%. The top eight (8) priorities accounted to more than half of the total global prioritization at 69.78% and this should be first addressed by the local officers.

Table 3. Summary of Sub-factor Rankings

Global Aggregated Ranking				
Rank	Barangay L		Barangay T	
	Criteria	*Weight*	*Criteria*	*Weight*
1	Lifeline Availability	23.69%	Leadership	17.32%
2	Surveillance	15.52%	Community Cooperation & Communication	13.32%
3	Knowledge of Vulnerability	11.00%	Disaster Plans	8.75%
4	Surge Capacity	9.42%	Logistics Management	7.18%
5	Emergency Staff	7.28%	Emergency Critical Care Capability	6.82%
6	Disaster Stockpiles	7.08%	Adaptation Strategies	5.91%
7	Community Cooperation & Communication	4.62%	Trainings and Drills	5.39%
8	Disaster Plans	4.16%	Lifeline Availability	5.09%
9	Trainings and Drills	3.61%	Reconstruction and Recovery Mechanism	4.88%
10	Leadership	3.01%	Surge Capacity	4.69%
11	Reconstruction and Recovery Mechanism	2.40%	Emergency Staff	3.87%
12	Emergency Critical Care Capability	2.28%	Knowledge of Vulnerability	3.86%
13	Logistics Management	2.27%	Capability Assisting Community Recovery	3.85%
14	Internal Safety	1.91%	Disaster Stockpiles	3.69%
15	Adaptation Strategies	1.12%	Surveillance	3.35%
16	Capability Assisting Community Recovery	0.62%	Internal Safety	2.04%

All expert judgements got a consistency ratio of below 10% thus passing the consistency tests. This proves that the judgements of each expert were consistent to be used as reliable basis of results. The group consistency ratio of the two sets of experts also passed the 5% limit at 3.86% and 4,28%, respectively. This suggests that the individual judgements of the experts have low enough differences to achieve a consensus in prioritization.

4. Conclusions and Recommendations

The resilience healthcare system at a barangay level determines the capacity of the community to withstand the effects before, during, and after a disaster strikes it. This is in line with the disaster risk reduction and management objective that aims to prepare, train, and equip everyone in case a disaster strike. However, several circumstances such as mistaken prioritization of needs lead the community to fail to achieve such therefore resulting to more casualties. This research gives importance to the designing a framework that could identify the factors that affect the resiliency of the barangay's healthcare system with the use of fuzzy AHP approach.

From the results obtained, it can be seen that priorities vary from one barangay to another. Although the barangays under study are neighboring barangays with the same sets of needs, it is very evident that the way they look at priorities are different. The Fuzzy AHP model was used effectively in defining the differences in each. Furthermore, this study could be used for future references but it is also highly suggested to increase the scope of the study and the number of interviewees so as to have more insights and comparisons on the study.

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Biographies

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Dennis Paul Orge finished his Bachelor of Science in Industrial Engineering at the De La Salle University Manila – Laguna Campus, Philippines. He was a consistent dean's lister throughout his entire stay in the university and graduated *cum laude*. He was one of the pioneer executive board members of Industrial Management Engineering Society in the Laguna Campus and also served in the College of Engineering Student Government (A.Y. 2017 – 2018). Aside from his academic activities, he also currently owns and runs an e-commerce website.

Mary Grace Valdez completed her Bachelor of Science in Industrial Engineering at the De La Salle University Manila – Laguna Campus during the conduct of the study. She was an academic scholar in high school under the Lasallian Instructional Gift for Adopted Pupils or the LINGAP Foundation and then became a Centennial Scholar in college under the same foundation. She has spearheaded and produced many notable projects through active involvement in different organizations in the university and in the community such as Council of Student Organizations, Laguna Campus Student Government, Industrial Management Engineering Society, Environmental Conservation Organization, Lasallian Student Representative, and the Rotaract Club of Nuvali.

Giselle Joy Esmeria is currently a fulltime Assistant Professor at the Department of Industrial Engineering of De La Salle University Manila - Laguna Campus. She holds a Bachelor of Science degree in Industrial Engineering from Mapua Institute of Technology and a Master of Engineering Management with specialization in systems management from University of the City of Manila. She is a Certified Professional Industrial Engineer with more than 8 years experience in manufacturing industry. She has taught courses in quality management, statistics, production operations management and other related engineering and business courses. Her research interests include optimization, manufacturing and disaster management. She is a member of the Philippine Institute of Industrial Engineering and currently pursuing a degree in Doctor of Philosophy in Industrial Engineering at De La Salle University Manila, Philippines.