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Improving Design and Physical Boundary in Temporary Post-Disaster Relief Shelters: Analysis of Existing Literature

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Acknowledgments

Abstract

Natural disasters such as floods, hurricanes, cyclones, storms, earthquakes, wildfires, and landslides displace people. As responses at the community resilience level, the temporary post-relief shelter is critical for the community's rapid recovery. Converting existing public facilities is the fastest way to respond to a crisis. However, the Hurricane Katrina Superdome Shelter alerted society to the prevalence of sexual assault in transitory catastrophe contexts. Not only has sexual abuse occurred, but prior shelters did not equip every user with physical barriers to suit their needs.

This study examined academic journals, articles, and books to identify issues with natural disaster shelters created between 2000 and 2024. The design approach for the shelter layout was sought after analyzing the literature, which included instructions from the Federal Emergency Management Agency, Red Cross, CDC, the Sphere Handbook, The UN Refugee Agency, and ICC/NSSA Standard for the Design and Construction of Storm Shelters, as well as the ADA Checklist for Emergency.

Based on the existing literature, establishing physical barriers is critical to ensuring the safety of disaster survivors, maintaining proper hygiene/sanitation in the facility, improving the mental health of staff members and temporary shelter residents, and meeting the specific needs of a specific group; all of which play an important role in the community's rapid recovery.

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1. INTRODUCTION

a. Introduction

This study is intended to expand the undergraduate study that I did which is related to the topic Alternative Care Sites (ACS), in the community. The research is trying to seek the reasons for the improvement in the community public natural disaster shelters and how they could be improved to serve the community better when natural disasters (such as flood, earthquake, hurricanes and wildfire etc.) occur in the community. For a summary of the undergraduate study, in 2019 when Covid-19 spread through the United States, the number of patients in hospitals were overwhelming and the medical facilities couldn't handle all the patients. Each state's government decided to open the Alternative Care Sites to treat the patients in the existing facilities with the purpose to serve the acute and non-acute patients, even though the Government spent a huge amount of money, the facilities weren't used very much. For example, the Javits Convention Center had 1900 beds and 1,095 patients. SUNY Stony Brook, SUNY Old Westbury, and Westchester County Center each had 1,038 / 1,022 / 100 beds, and the facilities remained unused. The study's goal was to convert the community's public schools to ACS and test the layout to see how many patients can be served in the gymnasiums of high schools/middle schools in the United States and compare it to serving patients from colleges and large convention centers, as well as serving disaster survivors in Alternative Care Sites after natural disasters such as Tornadoes (See figure 1 and 2).

From the previous study, I decided to stretch the knowledge of community resilience to respond to natural disasters specifically and provide the basic necessity in the built environment to the natural disaster survivors. The biggest problem in the world when the hurricane, storms, and the earthquakes and the wildfire strike the community is people get dislocated from their own houses and the governments and the organizations provide the place to stay temporarily until they find the new place to settle by themselves. In these chaotic situations, there have been serious problems arising in the disaster relief shelters. Well known story is Hurricane Katrina Superdome Shelter. Media and academic journals criticized that the state of New Orleans wasn't ready for the disaster at all.

- **Hurricane Katrina**

Hurricane Katrina was one of the most powerful hurricanes to hit the United States in the twenty-first century, as well as the third deadliest hurricane in American history.

According to the American Red Cross "Non-Traditional Shelter Case Studies," Hurricane Katrina began as a Category 1 storm in Southern Florida on August 29th, 2005, and grew to a Category 3 hurricane when it hit the Gulf of Mexico and reached southeast Louisiana. This calamity claimed the lives of 1,833 people, destroyed 300,000 homes, and forced 1 million people to seek temporary shelter. There were four mega shelters and five open shelters available to Hurricane Katrina victims. [1] (See Table 1)

Hurricane victims were transported to the Caesars Superdome in Louisiana, which held 18,000 people. Gold (2005), a Seattle Times reporter, claimed in an article that the Superdome was used as a shelter for survivors, and the environment in the aftermath of the disaster was horrible. Scott Gold (writer for the Seattle Times) reported in his writings that the toilets in the Superdome were dysfunctional, and many urinated on the floor where they slept. The floors were covered in urine and feces. At least two people were raped within the superdome, indicating that it was unsafe. One man committed suicide, and others were died in natural phenomenon. (Six people died in the Superdome). [2]

b. Problem Statement

As it was previously mentioned, one of the major problems in the physical infrastructure of natural disasters is it tears down the whole community. Buildings get demolished and they are hard to recover or rebuild right away. [3] In the community, the victims from these extreme weather events need to be evacuated and placed in a safe environment. According to “Leaving Millions Behind” from World Disasters Report 2018 by International Federation of Red Cross and Red crescent Societies,

1) 84% of natural threats noted by “EM-DAT The Emergency Events Database” is weather related hazards (Floods 40.5%, Storms 26.7%, and other weather related 16.9%)
2) 95% of 2 billion of people had been affected by weather related disasters from 2008 to 2017.
3) In 141 countries, $1,658 billion dollars were spent due to those weather-related disasters.

1 Non-Traditional Shelter Case Studies American Red Cross December 31, 2011 https://www.nationalmasscarestrategy.org/wp-content/uploads/2014/07/full-case-studies-final-29dec2011.pdf

2 Gold, Scott. “Trapped in the Superdome: Refuge Becomes a Hellhole.” The Seattle Times, September 2, 2005. https://www.seattletimes.com/nation-world/trapped-in-the-superdome-refuge-becomes-a-hellhole/.

3 “How Do Floods Create Humanitarian Crises?” The IRC. Accessed March 24, 2024. https://www.rescue.org/article/how-do-floods-create-humanitarian-crises.

From 2008 to 2017, 41% of the disasters happened in Asia, 24% was Americas, 20% Africa, 11% was Europe, and 4% Oceania. 46% of estimated damage was Asia, 44.1 % was Americas, 7% was Europe, and 4% was Oceania. [4] (See figure 3)

Below are the major hurricanes that were hit in the United States since the 2000s, and the number of the deaths, the cost of the damage, and the number of the displaced people.

When existing facilities are converted into a space to serve natural disaster survivors, previous issues must be addressed before people enter the facility. The phenomenon in society is that the citizens are not willing to use the community shelters when the local government provides those in the aftermath of the disaster.

After Hurricane Ian, only 354 people and 11 animals stayed even though Lee County's special needs shelter has a capacity of serving 764. According to the report, the shelter had several problems such as losing power and using the emergency back-up power, the toilet broke and flushing the toilet with the water, and no air conditioning system led to the poor indoor air quality, and lastly people didn't feel comfortable in the shelter. [5]

When a wildfire occurred in California, USA in 2018, the original form of public shelters (existing public infrastructure was converted to temporary emergency shelters) did not attract many visitors. People stayed outside even though the campsite lacked bathrooms and showers, and it was uncomfortable sleeping in the fabric tents. [6]

When Hurricane Irma struck Florida, USA in 2017, causing widespread power outages, the Palmetto Ridge High School was converted into special needs shelters to provide people with what they needed, particularly seniors and people with disabilities, but it was rarely used. [7]

Every year during the rainy season (June through mid-October), cyclones and floods inundate 21% of Bangladesh's territory. [8] Additionally, before the monsoon seasons (April - May) and after the monsoon seasons, cyclones hit Bangladesh majorly more than other countries, and 40% of the cyclone records in the world are from Bangladesh. [9] Bangladesh has developed more cyclone and flood shelters than other countries. Despite the

4 Leaving millions behind - IFRC. Accessed November 3, 2023. https://www.ifrc.org/sites/default/files/2021-09/B-WDR-2018-EXECSUM-EN.pdf.

5 Marbury, Justice. "Florida Shelters Can Help during Storms. Why Don't More People Use Them?" Democrat and Chronicle, September 20, 2023. https://www.democratandchronicle.com/story/news/2023/09/20/during-florida-hurricanes-special-needs-shelters-can-aid-caregivers/70897427007/.

6 Spearing, Lauryn A., Keri K. Stephens, and Kasey M. Faust. "Shelter Shopping: Where the Built Environment and Social Systems Meet." International Journal of Disaster Risk Reduction 58, (2021): 102161.

7 Marbury, Justice. "Florida Shelters Can Help during Storms. Why Don't More People Use Them?" Democrat and Chronicle, September 20, 2023. https://www.democratandchronicle.com/story/news/2023/09/20/during-florida-hurricanes-special-needs-shelters-can-aid-caregivers/70897427007/.

8 Floods in Bangladesh : A Comparative Hydrological Investigation on Two Catastrophic Events. / Komatsu, Mitsuru.In: Journal of The Faculty of Environmental Science and Technology, Okayama university, Vol. Vol.8, No. No.1, 2003, p. 53-62.

9 Haque, Ubydul, Masahiro Hashizume, Korine N. Kolivras, Hans J. Overgaard, Bivash Das, and Taro Yamamoto. "Reduced Death Rates from Cyclones in Bangladesh: What More Needs to be done?" Bulletin of the World Health Organization 90, no. 2 (2012): 150-156.

government's attempts to construct and design shelters, the rate of use has declined since the crisis struck the country owing to concerns about sexual assaults. [10]

Furthermore, survivors of natural disasters suffer from Post Traumatic Stress Disorder (PTSD), and sexual violence increases in these chaotic situations. Since Hurricane Katrina, interviews, surveys, and other types of research have been conducted to develop and improve guidelines, codes, to provide solutions to natural disasters shelter settings.

c. Research Questions

Based on this background information, the research questions of this study were developed as:

Research Question 1: "What issues did the existing community post-disaster relief shelters face during recent natural disasters (from 2000 to 2024).?"

Research Question 2: "What important design and structural elements do natural disaster shelters need to have and why are they essential?"

Research Question 3: "How can we handle these issues for the next possible natural disaster?"

d. Hypothesis

This research hypothesizes that if the temporary natural disaster shelters include efficient design elements such as strong exterior walls, additional internal physical boundaries, ample hygiene infrastructure, and sufficient living space for individual, we can address the requirements of a broader range of people, ensure the safety of all genders and young children, and reduce the conflict in the aftermath of a disaster.

Walls, roofs, and floors are the most basic examples of architectural boundaries or barriers. These pieces separate the space from one another. Low fences can also be used to form boundaries. These boundaries may also be

10 Rahman, M. Aminur, Fuad H. Mallick, M. Shahjahan Mondal, and Mohammad Rezaur Rahman. "Flood Shelters in Bangladesh." Hazards, Risks, and Disasters in Society, 2015, 145–59. https://doi.org/10.1016/b978-0-12-396451-9.00009-3.

expressed graphically, such as lines or different colors by each other. These set boundaries may provide limited spaces between indoor and outdoor, up and down, or public and private. [11] [12] [13]

e. Methodology - A Standalone Systematic Literature Review

This study follows the steps of the standalone "Systematic Literature Review" method, which is one of the literature review methods proposed by Chitu Okoli based on the journal “A Guide to Conducting a Standalone Systematic Literature Review,” (2015). There is no primary data collected in this study, instead relying on existing secondary data to assess and comprehend the research question. [14]

The purpose of this literature review is to identify critical issues in design elements of disaster relief shelters and propose potential solutions for the previous temporary disaster relief shelters based on existing literature to implement those in the design of possible future natural disaster shelters. To identify problems and solutions in recent articles, journals, and books. The literature which were dated from the 2000s to 2024(the current date) were only reviewed. In a process of reviewing the paper, the researcher extracted the section of each literature that is coded to the problems and solutions related to hypothesis and the literature review, finally compared, and contrasted the solutions to analyze the data.

The investigation focused on secondary credible sources such as the literature found from the database of Rochester Institute of Technology Library Database was the main database source along Emerald Insight(https://www.emerald.com/insight/), National Library of Medicine(https://www.nlm.nih.gov/), IEEE Xplore(https://ieeexplore.ieee.org/Xplore/home.jsp), Science Direct(https://www.sciencedirect.com/), Sage Journal(https://journals.sagepub.com/), Springer(https://link.springer.com/), ASCE Library(https://ascelibrary.org/). The topic-related guidelines from Red Cross, Federal Emergency Management Agency(FEMA), National Mass Care Strategy, and codes from International Council Codes and National Storm Shelter Association(NSSA) were reviewed together to get the specific information regarding the need of the disaster survivors in the natural disaster shelters. By analyzing these resources, the study sought to uncover major challenges related to the safety, hygiene,

11 “‘Boundaries’ in Architecture and Design in Discussion at Rocagallery.Com.” ROCA Bathrooms. Accessed April 24, 2024. https://www.roca.com/news/roca-gallery-boundaries-architecture-design.

12 publisher, Shamim AhmadFollow this. “Boundaries in Architecture: Architectural Dissertation.” Issuu, December 20, 2020. https://issuu.com/shamimahmad1995/docs/boundaries_in_architecture_architectural_dissert.

13 1. Robert Hesson, “Basic Elements of Architecture - Analysing Architecture,” Northern Architecture, January 28, 2024, https://www.northernarchitecture.us/analysing-architecture/basic-elements-of-architecture.html.

14 Okoli, Chitu (2015) "A Guide to Conducting a Standalone Systematic Literature Review," Communications of the Association for Information Systems: Vol. 37, Article 43. Available at: http://aisel.aisnet.org/cais/vol37/iss1/43

and mental health encountered by disaster survivors during their shelter experiences following catastrophic events and solutions that can be solved.

While conducting the research, the search terms originated from the questions below to filter out the literature. Keywords used to locate relevant literature included phrases such as ‘Post Disaster Relief Shelter,’ ‘Natural Disaster Shelters,’ ‘Natural Disaster Emergency Shelters,’ and ‘Community Emergency Shelters.’ Additionally, the term ‘Experience’ was incorporated to capture people’s opinions related to these shelters.

During the document review process, literature that did not include natural disasters was not selected. For example, the literature related to other catastrophe emergency shelters such as fallout shelters, man-made disaster shelters were excluded from this study.

After reviewing the literature, a total of 21 literature were selected and a total of 11 guidelines from FEMA, Red Cross, and National Mass Care Strategy, CDC, and etc, and 1 related code from International Code Council were utilized to answer the research questions. In the search for answers to privacy and hygiene issues in temporary emergency shelters, a couple of literature sources on Alternative Care Sites were also included to support the hypothesis of the study.

One of the literatures highlighted the characteristics of the temporary emergency shelter which people consider the most when they choose to stay at the shelters. The CEM (Customer Experience Management) Questionnaire Survey was conducted to identify the people’s selection over the emergency public shelter in the journal titled “Choice of emergency shelter: valuing key attributes of emergency shelters” written by Ali Asgary, Nooreddin Azimi. The authors indicated the attribute of “safety and security,” “privacy,” “hygiene,” being close to friends and family members and the total number of people in the emergency shelter is extremely assessed by the people whether they decide to go to the emergency disaster shelters from the government’s facilities such as the community centers, the public schools, and the convention centers. According to the attributes found in the literature that influence people's choice to go to emergency shelters, the "safety and security", "privacy", "hygiene", "crowding", and "the number of people in the shelter" overlapped with the most number of the issues found while conducting the literature review, confirming the direction of the research questions.[15]

15 Asgary, Ali and Nooreddin Azimi. "Choice of Emergency Shelter: Valuing Key Attributes of Emergency Shelters." International Journal of Disaster Resilience in the Built Environment 10, no. 2/3 (2019): 130-150.

Certain literature contained overlapping issues and solutions while conducting the literature review. Mainly, the problem of a lack of prevention to sexual assault, disease control, and the mental health led by a lack of privacy and overcrowding had high correlated issues and the solutions. To quantify the data of the characteristics, the codes which were labeled by design elements were counted: safety and security, hygiene infrastructure, mental health and special needs. Between the 21 chosen literatures, 10 mentioned the crowdedness of the space, and 9 argued that shelter does not protect from the outdoor environments. 7 pieces of literature discuss water hygiene and sanitation, while another seven discuss disaster survivors' PTSD and the importance of the community. Inadequate/inoperable hygiene systems were mentioned six times, while sexual violence was mentioned 5 times. The data extraction section includes one of the articles related to alternative care sites and information from the United States Army Corps of Engineers to support the solutions. The guidelines were not included when quantifying the data. (See figure 3 and 4 to check the types of the study that were included in the literature and the percentages of each design elements problem)

- Definition of Community Resilience

The definition of community resilience is important to understand to study the temporary natural disaster relief shelter. According to the major organizations such as FEMA(Federal Emergency Management Agency), NIST(National Institute of Standards and Technology), RAND(Research and Development), National Association of County and City Health Officials, U.S Climate Resilience Toolkit, U.S Department of Health & Human Services - ASPR(Administration for Strategic Preparedness & Response), Science Direct, Community resilience is defined as a community's capacity to plan for potential natural disasters, adapt to changing conditions, and tolerate and recover quickly from disruptions. Communities must be prepared to act before a crisis impacts since the early response determines how quickly normal conditions could be restored. The earlier the community recovers the less damage is caused to all parts of society. It is critical to recognize that community resilience is achieved by collaborating across several industries; it isn't solely about architecture or a certain field. The community works together. According to the NIST's website and the research from the organization titled "State of the research in community resilience:

progress and challenges“, community resilience encompasses a wide range of issues including engineering, social sciences, earth sciences, physical infrastructure, economics, and other fields. [16] [17] [18] [19] [20] [21] [22] [23]

2. DATA EXTRACTION

We've been discussing how to obtain reliable information from prior natural disaster shelter situations, which will help us understand the difficulties and solutions with shelter design features in greater depth. However, in order to have a better understanding of how to improve shelter design, we must first investigate the various categories, and typologies of emergency disaster relief shelters.

a. Categories of Emergency Post Disasters Relief Shelters and Alternative Care Sites.

One source stands out for its thorough examination of the several different types of shelters and disaster relief shelter designs. In the literature titled "An overview of the design of disaster relief shelters," the authors explain the types of disaster relief shelters that they derived from the Sphere handbook (2018), Red Cross guidelines, and another book. According to the research, there are several fundamental types of shelters available immediately after a disaster. The management team must select which sorts of shelters will be available to disaster survivors. Shelters are classified into four types: emergency, temporary, temporary housing, and permanent. Emergency Shelter is designed for a short period of time and provides the most basic level of shelter assistance, which implies that there will be no cooked meals or medical equipment accessible to the residents. Disaster survivors may obtain temporary housing for a few weeks. Disaster survivors are placed in temporary accommodations for six months to three years after returning to their usual life. During the permanent housing stage, the structure must be strong enough to endure and recover quickly from future potential hazards and tragedies. These categories of the disaster relief shelters are organized in table 2.

16 “Community Resilience.” Community Resilience | National Risk Index. Accessed March 24, 2024. https://hazards.fema.gov/nri/community-resilience.

17 “Community Resilience.” Community Resilience - an overview | ScienceDirect Topics. Accessed March 24, 2024. https://www.sciencedirect.com/topics/social-sciences/community-resilience.

18 “Community Resilience.” Community Resilience | National Risk Index. Accessed March 24, 2024. https://hazards.fema.gov/nri/community-resilience.

19 “Community Resilience.” NACCHO. Accessed March 25, 2024. https://www.naccho.org/programs/public-health-preparedness/community-resilience.

20 “Community Resilience.” NIST, January 4, 2024. https://www.nist.gov/community-resilience.

21“Community Resilience | Rand.” Community resilience. Accessed March 24, 2024. https://www.rand.org/topics/community-resilience.html.

22 “Community Resilience.” community_resilience. Accessed March 24, 2024. https://aspr.hhs.gov/at-risk/Pages/community_resilience.aspx.

23 Koliou, Maria, John W. van de Lindt, Therese P. McAllister, Bruce R. Ellingwood, Maria Dillard, and Harvey Cutler. “State of the Research in Community Resilience: Progress and Challenges.” Sustainable and Resilient Infrastructure 5, no. 3 (January 8, 2018): 131–51. https://doi.org/10.1080/23789689.2017.1418547.

According to the literature, all types of shelters must provide roofed places, protection from the weather, personal safety, access to clean water and sanitation, and closeness to health care facilities as soon as possible following the disaster. The literature discusses socio-cultural elements that must be considered while designing shelters to assist people. The ability to construct partitions in shelters protects people's privacy essentially. Lockable doors and windows can also be supplied as an additional security feature. [24]

The primary distinction between Alternative Care Sites and Natural Disaster Shelters is that Natural Disaster Shelters focus on meeting the basic needs of people, whereas Alternative Care Sites focus on providing medical treatments to patients. [25] Tent structures were the most popular structure for responding to natural disasters, and most recently, public buildings have been converted to respond to disasters much faster. (Building modular or tent structure shelters takes time, and when a natural disaster strikes unexpectedly, responding is difficult. According to the International Federation of Red Cross and Red Crescent Socities's "Post-disaster shelter: Ten designs" (2013), the duration of stay in such shelters may be limited, so speed and cost considerations should be taken into account when building this type of shelter. [26]

b. Typology of the temporary shelter facilities

The decision of types of the temporary shelters varies depending on the environmental, economic, technical and socio cultural factors when designing new disaster-relief shelters for the survivors.

- Environmental Factor

The level of comfort in natural disaster shelters is determined by the seasons, temperature, and climate, and these are the major considerations when designing new temporary disaster shelters. Because of these factors, any type of disaster relief shelter must have heat sources, proper clothing, blankets, and proper ventilation systems. When new shelters are created and supplied rather than converting existing public facilities, the materials used must be recyclable after they are no longer in use. Water, sanitation, and hygiene infrastructure are necessary components of disaster shelters so that survivors may wash themselves and maintain their health and well-being.

- Economical Factor

24 An Overview of the Design of Disaster Relief Shelters."Elsevier, 2014. doi:10.1016/S2212-5671(14)01019-3.

25 1. Hospital alternate care site, accessed April 25, 2024, https://www.cms.gov/files/document/covid-state-local-government-fact-sheet-hospital-alternate-care-sites.pdf.

26 Post-disaster shelter: Ten designs, 2013. https://www.shelterprojects.org/tshelter-8designs/10designs2013/2013-10-28-Post-disaster-shelter-ten-designs-IFRC-lores.pdf.

The community's economic situation has a significant influence on the speed and phase of recovery. It defines if the current facilities will be used, if the shelters will be erected, what materials will be used, and how long the shelters will last.

- Technical Factor

Easy construction and disassembly, materials, and insulation, how it can protect against additional risks, and how the shelters will handle user behaviors and disaster-related stress must all be considered.

- Socio Cultural Factor

When designing and planning shelters, it is important to consider the differences in culture, persona, financial position, security, and privacy since they influence the orientations and specifics of the planning and layout. Additionally, strong communication among the community throughout the early stages of disaster response is critical. All community communication means, including social media, television, radio, community websites, texts, phone calls, newspapers, posters, and community announcements, must be used to notify the community of the shelters' presence and to plan the next phase of recovery. [27]

According to the Disaster Sheltering Handbook by the Red Cross, the facilities in the community can be turned into natural disaster relief shelters. The suitable buildings are the public schools, municipal buildings, available commercial or government space, union organization facilities, facilities of religious, civic or community organizations, and unoccupied vacant buildings. Transforming the convention centers and the sports stadiums were the common solutions due to those structures being able to serve the large group at once. The tent structures of the shelters can be established in the vacant lands and the parking lots. [28]

c. Problems and Solutions for Disaster Relief Shelters

After examining various types and fundamental designs of disaster relief shelters, we will proceed to discuss the typical design considerations. These will be categorized into four sections: safety and security, hygiene, mental health, and special needs.

27 “Community Resilience.” Community Resilience - an overview | ScienceDirect Topics. Accessed March 24, 2024. https://www.sciencedirect.com/topics/social-sciences/community-resilience.

28 American-red-cross-sheltering-handbook.PDF. Accessed March 24, 2024. https://crcog.org/wp-content/uploads/2017/12/American-Red-Cross-Sheltering-Handbook.pdf.

i. Safety and Security

From a safety and security standpoint, three prevalent issues arise in the design of disaster relief shelters. Firstly, occupants often struggle with extreme temperatures or face the need for repeated evacuations due to ill-suited facility choices during shelter planning. Secondly, disaster victims face the risk of theft targeting their belongings. Lastly, inadequate conditions within the shelters, including insufficient lighting, the lack of the privacy between individuals, a lack of gender-sensitive layout in the shelters, make women, young children, LGBTQ+, and transgender individuals vulnerable to sexual assault.

According to the literature, the shelters often didn't provide strong protection from the weather or the other natural disasters.(See figure 5 - 2017 Hurricane Harvey victims had to be evacuated again from the shelter since the facility was flooded) The quotation below is from the literature related to California's wildfire that happened in 2018 when people stayed in the tents at Walmart parking lot that illustrates one of the examples of shelter not having protection of the outdoor elements to the people.

"As expected at an outdoor shelter, the tent city did not provide protection from the weather. People were relying on hair dryers to keep their children warm and struggled to sleep during cold nights. Given the issues surrounding the built environment, it is striking that people chose to stay at an outdoor shelter. Factors outside the built environment (e.g., services provided, atmosphere, people there) likely had a notable impact on shelter choice. " [29]

The other literature titled "Improving Resilience Capacity of the Policies and Planning for Temporary Shelters in Crises and Disasters highlights the importance of placing the shelters in the location with no hazards by preparing in advance due to the other social problems that can get severe such from harsh living conditions. [30] Due to the lack of the inspection and the preparedness prior to the natural disaster, people could suffer from the weather and the natural elements in the shelters. As indicated in the aforementioned quotation, residents of disaster shelters require robust protections against severe weather conditions, including extreme cold and strong winds. In previous post-disaster relief shelters, survivors resorted to makeshift solutions such as layering additional blankets and using plastics for insulation. If the shelter lacks adequate resistance to heat and cold, occupants must independently seek out materials to mitigate their vulnerability.

To mitigate the issue of inadequate sturdy physical barriers safeguarding residents from outdoor elements, it is advisable to house inhabitants in buildings featuring intact external walls, roofs, and doors. These structures

29 Spearing, Lauryn A., Keri K. Stephens, and Kasey M. Faust. "Shelter Shopping: Where the Built Environment and Social Systems Meet." International Journal of Disaster Risk Reduction 58, (2021): 102161.

30 Okay, Nilgün, Ebru Inal, Gül Yücel, and Oya Açıkalın Rashem. "Improving Resilience Capacity of the Policies and Planning for Temporary Shelters in Crises and Disasters." In Disaster Risk Reduction for Resilience, 111-129. Cham: Springer International Publishing, 2022.

possess a robust exterior that shields residents from strong winds, as opposed to tent-based systems equipped with cooling and heating, which experienced significant failures during the heavy snowfall of 2014-2015. [31]

Each shelter guideline suggests a specific required indoor temperature, which must either be standardized or left to the discretion of the management team during the design of disaster relief shelters. In the CDC guidelines the indoor temperature needs to be between 68.5°F to 75°F in the winter and 75°F to 80.5°F in the summer,[32] and the UN Emergency Shelter Solutions and Standards, it needs to be between 59°F and 66°F for people's comfort level. [33] Disaster relief shelters are recommended to be selected to prevent extra hazards while picking emergency natural shelters. Hurricane Shelters are not recommended to be situated in 100-year floodplains or 10-mile emergency planning zones within nuclear power plants. [34] [35] Flood zones can be checked using FEMA's flood zone map or each state's GIS data. [36]

When designing shelters, the materials must take into account safety against risks, and these structures can vary based on the type of disaster. Concrete, for example, serves as the primary structural component of flood-resistant buildings and cyclone/flood shelters. Timber, bamboo structure, and steel are the materials and structures used to construct earthquake-resistant buildings. [37]

Apart from the design deficiencies that fail to adequately protect occupants from outdoor elements, temporary shelters frequently lack sufficient security measures to prevent theft. In the context of natural disaster shelters, victims often express concerns about the safety of their belongings. The absence of robust security systems at the entrances of public emergency shelters or tent shelters makes it relatively easy for non-residents to gain unauthorized access and pilfer personal items [38] (See figure 6 - after 2018 California's wildfire people stayed in the tent at Walmart parking lot)

31 Mulhall, Elizabeth. "The Snow Storm." UNHCR Canada, October 7, 2019. https://www.unhcr.ca/news/2015-01-09/.

32 Environmental health disaster shelter assessment guide. Accessed March 17, 2024. https://emergency.cdc.gov/shelterassessment/pdf/Shelter_Assessment_instruct_508.pdf.

33 "Emergency Shelter Solutions and Standards." UNHCR. Accessed March 24, 2024. https://emergency.unhcr.org/emergency-assistance/shelter-camp-and-settlement/shelter-and-housing/emergency-shelter-solutions-and-standards.

34 The Tohoku Disaster: Responding to Japan's 3/11 ... Accessed April 13, 2024. https://www.hks.harvard.edu/sites/default/files/centers/research-initiatives/crisisleadership/files/Tohoku%20Disaster_Taubman%20Center_2012%2011%2014_red_web_Part%202.pdf.

35 Standards for hurricane evacuation shelter selection. Accessed April 13, 2024. https://www.floridadisaster.org/globalassets/library/arc-hesss---standards-for-hurricane-evacuation-shelter-selection.pdf.

36 "Flood Data Viewers and Geospatial Data." FEMA.gov. Accessed April 2, 2024. https://www.fema.gov/flood-maps/national-flood-hazard-layer.

37 Flood shelters. Accessed April 2, 2024. https://www.ctc-n.org/sites/www.ctc-n.org/files/resources/flood_shelters.pdf.

38 Choi, Yu Ra, Eun Jeong Kim, and Mi Kyung Kim. "A Planning Guide for Temporary Disaster Shelters Focusing on Habitability." Indoor + Built Environment 29, no. 10 (2020): 1412-1424.

Limiting the number of entrances to one can help to control the crimes in the natural disaster shelters so that the staff can check the individuals when they enter the shelters and when they depart the buildings. It is recommended that suitable security measures be implemented at the shelter entrances. The shelter's entrance is likewise secured and supervised by employees. (See figure 8 - an example of implementing the security measure at the entrance in the temporary disaster shelters).

In the context of safety concerns and solutions related to thefts and robberies within disaster relief shelters, the subsequent paragraphs underscore the significant occurrence of sexual violence in these environments. For instance, a post-hurricane survey conducted by the National Sexual Violence Resource Center (NSVRC) revealed that 30% of sexual violence incidents occurred at evacuation points within disaster shelters, which had the highest occurrence rate among incident locations. [39] Additionally, after the earthquakes in Japan (2011) and Haiti (2010), cases of sexual violence were reported in disaster relief camps and facilities almost every day. [40] [41] In a specific case cited within the Red Cross's 'Gender-sensitive Approaches for Disaster Management' guidelines, a transgender woman in Nadu, India experienced sexual assault following a tsunami which is provided below.

"Hasina, a transgendered qualified plumber, lived in her boyfriend's house in Tamil Nadu, India. She could not find a job and therefore begged for a living in order to save for her studies. However, after the 2004 tsunami, Hasina's boyfriend threw her out of their temporary shelter. She was forced to sleep out in the open and was gang-raped several times. Hasina felt that a common shelter for people from transgendered communities would have provided a sense of security and prevented some of the trauma she experienced. [42]

Moreover, two studies related to flood/cyclone shelter designs in Bangladesh have indicated that individuals declined to utilize the shelters due to insufficient measures in place for preventing gender-based violence [43] [44] Because of the chaotic situations the percentage of physical violence is high after the natural disasters, and the vulnerable demographics such as children, women, LGBTQ+, transgender populations can be targets for any physical violence and the sexual crimes (See figure 7 at appendices - after Hurricane Michael in the emergency shelter an old man was arrested by touching a 6-old girl underneath her clothes). Due to the turmoil of mental status

39"Hurricanes Katrina/Rita and Sexual Violence: Report on Database of Sexual Violence Prevalence and Incidence Related to Hurricanes Katrina and Rita." National Sexual Violence Resource Center. Accessed March 23, 2024. https://www.nsvrc.org/publications/nsvrc-publications/hurricanes-katrinarita-and-sexual-violence-report-database-sexual-vi.

40 "Haiti: After the Earthquake: Initial Mission Findings, March 2010." Amnesty International, August 10, 2021. https://www.amnesty.org/en/documents/AMR36/004/2010/en/.

41 1. SoraNews24, "Women Speak out about Sexual Violence after Great East Japan Earthquake," Japan Today, accessed April 23, 2024, https://japantoday.com/category/crime/women-speak-out-about-sexual-violence-after-great-east-japan-earthquake.

42 Gender-sensitive approaches for disaster management, 2010.

43 Rahman, M. Aminur, Fuad H. Mallick, M. Shahjahan Mondal, and Mohammad Rezaur Rahman. "Flood Shelters in Bangladesh." Hazards, Risks, and Disasters in Society, 2015, 145–59. https://doi.org/10.1016/b978-0-12-396451-9.00009-3.

44 Shahin, Md, Maruf Billah, Md Mozahidul Islam, Ahmed Parvez, and A. K. M. Mostafa Zaman. "Cyclone Shelters Need Sustainable Development." International Journal of Disaster Resilience in the Built Environment 11, no. 5 (2020): 659-678.

after natural disasters, the number of cases regarding sexual assaults rise within a few months right after every natural disaster. Hurricane Katrina is the typical example of this phenomenon in the community as it stated in the previous chapters that a young girl was raped in the shelter and the offender was caught in the action, and At least two people were sexually abused in the superdome evacuation center after Hurricane Katrina. Also, as the cyclone shelters don't have gender sensitive bathrooms, and shower features, the women in Bangladesh are hesitant to go to the shelters after the disaster which illustrates the importance of physical boundaries in the disaster relief shelters for individuals.

The design of the shelters must consider these facts. These problems increase the mental health problems after the natural disasters and increase the suicidal rates among the victims which isn't very helpful for the recovery of society. Based on the existing literature, evacuees faced additional challenges due to a lack of proper lighting which led to sexual violence. Several disaster shelters have reported concerns about provoking sexual assaults because the rapes have occurred when there was insufficient lighting and the surroundings were dark.

To address this problem, a couple of the guidelines highlight that the biological gender segregation of the sleeping areas, restrooms, and showers needs to be considered while designing the layout of natural disaster shelters. The establishment of additional physical boundaries between individuals involves complete separation of specific groups. In the context of shelter layouts, this entails dividing and designating living spaces for each gender on entirely separate floors or in different rooms. For LGBTQ+, transgender people, and single mothers with young kids, at least one room needs to have a gender-neutral restroom. Since sexual violence has been directed towards LGBTQ+ and transgender males as well as heterosexual males not only females, there are concerns that it may also result in victims among men when the space is segregated. To safeguard the public, a number of governments pursue solutions to this problem by offering distinct buildings for sex offenders with criminal records.

The layout of the natural disaster shelters should also include an entrance that can be used for safety intake procedures, such as registering people, getting their picture IDs, and checking people's weaponry as they enter and depart the building. Each sector, including registration, must have trained workers designated to it. [45] A private area with a semi-open structured partition system should be supplied for expectant mothers who must breastfeed. Toilets,

45 Housing sex offenders in emergency shelters. Accessed March 17, 2024 http://www.iaem.org/portals/25/documents/CHHS-Memo-%20Housing-Sex%20Offender-in-Emergency-Shelters.pdf.

bathing, and all the sanitary facilities must have locking systems so that the vulnerable demographics can protect themselves from the attack.

Proper lighting is vital for shelters that accommodate survivors of catastrophic events. According to the 2020 ICC 500/NSSA Standard for the Design and Construction of Storm Shelters, emergency lights must provide at least 1 foot candle (equivalent to 10.764 Lux) of illumination. Additionally, the National Disaster Management Institute in South Korea (2014) recommends emergency lights with a capacity of at least 3.72 Foot Candles (40 Lux). Emergency generators should also be installed in these facilities. It's important to note that while shelter codes do not specify gender segregation for living space of the occupants and hygiene infrastructure. However, they do require enclosed space for water closets in both hurricane and tornado shelters, which forms part of the physical boundary within the space (Section 702.3.3 and section 703.3.3). [46] [47] Given that not all guidelines and codes explicitly address lighting standards beyond emergency lighting, it is essential for disaster shelter guidelines and codes to specify illuminance requirements more rigorously. This measure aims to prevent sexual violence incidents within shelters by ensuring adequate indoor lighting.

ii. Hygiene and Sanitation

The subsequent subsection describes the challenges and corresponding resolutions pertinent to hygiene and sanitation within temporary disaster relief shelters. These elements are paramount in the architectural design of such shelters and serve as a critical criterion for occupants when selecting accommodations following the safety, as evidenced by extant scholarly works. Furthermore, this subsection meticulously examines the design considerations for disease prevention, sanitation facilities, and the allocation of areas designated for clean drinking water.
In the disaster relief shelter design, since there are no additional boundaries between the people, a few thousand people are in an open area together, the disease has a high chance of spreading quickly. Overcrowding in shelters can lead to the spread of diseases such as respiratory infections, viruses, Hepatitis A and E. The combination of poor hygiene and overcrowding can lead to skin infections among shelter residents. Crowding is common in populations

46 (ICC), International Code Council. "2020 ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters: ICC Digital Codes." 2020 ICC 500 ICC/NSSA STANDARD FOR THE DESIGN AND CONSTRUCTION OF STORM SHELTERS | ICC DIGITAL CODES. Accessed March 17, 2024. https://codes.iccsafe.org/content/ICC5002020P1/icc-nssa-standard-for-the-design-and-construction-of-storm-shelters.

47 National Disaster Management Research Institute. Accessed March 24, 2024.https://www.ndmi.go.kr/eng/main.do.

displaced by natural disasters and can facilitate the transmission of communicable diseases .[48] (See figure 9 - the number of outbreak related stomach illness after Hurricane Katrina)

Ensuring an isolated space for sick patients is crucial in the layout design. A single virus can easily spread throughout the entire shelter's dormitory area, underscoring the need for a physical boundary that separates sick individuals from the healthy population. The issue with the crowding in the disaster relief shelters is able to be solved with the maximum capacity calculation. According to the Sphere Project Handbook (2018), the maximum capacity of each shelter must be calculated using the available space in each building, which is determined by the floorspace area. There is also the assumption that the entire floor space does not support the shelters because the building does not have all vacant areas. The formula in the Sphere Project Handbook assumes that 60% of the total building area can be used for shelters which is presented below. [49]

Maximum capacity (number of people) = ((Building area* 0.6) / 3.5 m2*)
*(3.5m2 = 37.67 ft2)

Calculating the maximum capacity in the buildings and controlling the population number in each shelter prohibits the crowdness in each shelter. In the context of disease control within natural disaster shelters, the strategies employed in Alternative Care Sites during the Covid-19 pandemic exhibit significant overlap in mitigating virus transmission among patients. Specifically, acutely ill individuals were housed in modular pods adjacent to hospital beds, ensuring their isolation from healthy counterparts. These modular isolation pods, also referred to as prefab pods, offer a dual benefit: they address privacy concerns while effectively preventing the spread of airborne viruses. Developed by the United States Army Corps of Engineers, these 10' x 10' modular units play a crucial role in disease prevention. [50]

Moreover, I align with the literature's argument that utilizing school facilities' layout represents the optimal strategy for managing influenza cross-contamination. By segregating sick individuals into separate classrooms and allowing healthy staff to occupy different floors within the buildings, we can effectively reduce the risk. Considering that school layouts are standardized across most countries, this approach can be readily replicated in other

48 Watson, John T., Michelle Gayer, and Maire A. Connolly. "Epidemics after Natural Disasters." Emerging Infectious Diseases 13, no. 1 (January 2007): 1–5. https://doi.org/10.3201/eid1301.060779.

49 "The Sphere Handbook 2018." Sphere. Accessed March 24, 2024. https://spherestandards.org/handbook-2018/.

50 Arena to healthcare concept (A2HC) - army corps of engineers, 2020. https://www.usace.army.mil/Portals/2/docs/Contracting/AlternateCareSites/Arena to Healthcare Concept (A2HC)- 2020 03 30.pdf.

educational facilities [51] In the context of managing airborne diseases, it is essential to assess and regulate HVAC systems for proper air circulation. Additionally, considering the guidance from literature and official recommendations, distributing hygiene kits becomes crucial to prevent the transmission of water-borne illnesses or outbreaks during natural disasters relief settings. I recommend that shelter layouts take into account storage space requirements for housing all hygiene kits, estimating their capacity based on FEMA's recommended quantities [52] [53] In the next following paragraphs, I identified challenges related to the provision of hygiene infrastructure in the context of designing temporary disaster relief shelters by examining the existing literature. This infrastructure encompasses facilities such as toilets, showers, and hand-washing stations. Notably, various guidelines and codes prescribe distinct standards for determining the required quantity of hygiene facilities based on population size. The problems with the hygiene infrastructure that were found in the literature were inadequate and inoperable sanitary facilities contribute significantly to the spread of germs in the temporary natural shelter settings and leads to the unhygienic conditions in the shelters. [54] Outdoor tents used as spontaneous shelters lack adequate hygienic infrastructure, such as toilets, showers, and hand-washing facilities. [55] Furthermore, the findings from the research showed the cleanliness of the restrooms have a considerable impact on the health of the shelter occupants. Most notably, there have been reports that diarrheal sickness, norovirus, Salmonella, and toxic and nontoxic V. cholerae was spread in the natural disaster settings in the United States following Hurricane Katrina (2005) and Hurricane Allison(2001). [56] This issue has a strong correlation with clean water security and proper hygiene infrastructure. Ensuring clean and safe water contributes to maintaining disaster relief shelters in a hygienic condition and provides residents with opportunities for cleanliness. I strongly suspect it will also reduce the chance of outbreaks in the shelters. (See figure 10 - the example of clean and ample number of hygiene infrastructure, and figure 11 shows unhygienic toilets which were correlated to the outbreaks in the shelter after 2011 Tohoku earthquake).

51 Yen, Muh-Yong, and Fuh-Yuan Shih. "Transforming Schools into Pre-Designed Alternative Care Sites as Part of Preparedness Plan for Pandemic H5N1 Influenza." Journal of the Formosan Medical Association, vol. 107, no. 9, 2008, pp. 673-676.

52 Haque, Ubydul, Masahiro Hashizume, Korine N. Kolivras, Hans J. Overgaard, Bivash Das, and Taro Yamamoto. "Reduced Death Rates from Cyclones in Bangladesh: What More Needs to be done?" Bulletin of the World Health Organization 90, no. 2 (2012): 150-156.

53 Commonly used sheltering items catalog. Accessed March 17, 2024. https://www.fema.gov/sites/default/files/documents/fema_commonly-used-sheltering-items-catalog.pdf.

54 Akaishi, Tetsuya, Kazuma Morino, Yoshikazu Maruyama, Satoru Ishibashi, Shin Takayama, Michiaki Abe, Takeshi Kanno, Yasunori Tadano, and Tadashi Ishii. "Restoration of Clean Water Supply and Toilet Hygiene Reduces Infectious Diseases in Post-Disaster Evacuation Shelters: A Multicenter Observational Study." Heliyon 7, no. 5 (May 2021). https://doi.org/10.1016/j.heliyon.2021.e07044.

55 Spearing, Lauryn A., Keri K. Stephens, and Kasey M. Faust. "Shelter Shopping: Where the Built Environment and Social Systems Meet." International Journal of Disaster Risk Reduction 58, (2021): 102161.

56 Liang, Stephen Y., and Nicole Messenger. "Infectious Diseases after Hydrologic Disasters." Emergency Medicine Clinics of North America 36, no. 4 (November 2018): 835–51. https://doi.org/10.1016/j.emc.2018.07.002.

Each guideline provided by organizations such as the Red Cross, CDC, FEMA, and the ICC-regulated building codes specifies the appropriate quantity of hygiene infrastructure. However, the absence of uniformity in regulations and standards also poses a challenge: varying numbers can cause confusion for shelter management teams during the planning process. Despite this, it remains crucial to ensure that sufficient hygienic facilities are available to serve the entire shelter population. When establishing tent structure shelters, prioritize the installation of temporary hygiene amenities, including restrooms, handwashing stations, and showers near the camp sites. These facilities are essential for the well-being of displaced individuals. Tables 3, 4, and 5 outline the required number of hygiene stations in temporary natural disaster shelters by each guideline and code. As per CDC shelter assessment recommendations, it is advisable to provide a minimum of one operational shower facility and handwashing station for every 15 individuals, along with one toilet for every 20 occupants. [57] Notably, the "2020 ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters" reveals that hurricane shelters necessitate more hygiene stations than storm shelters. [58]

Lastly, a lack of safe and clean water sources has been a problem after the disasters, and I strongly believe these problems need to be considered when the design of the shelters is provided after examining a couple of literature. Based on the following research, the sanitation of water is the major root of hygiene of the displaced population in the temporary disasters. Securing clean water enables them to wash their bodies, drink safe water, and clean the shelter floors. Not having clean tap water can be the root cause of increasing respiratory and gastrointestinal infection in the shelters after people get evacuated. Following a severe natural disaster, water sources such as community wells and a water pipe from the local municipal government are highly likely to become contaminated, even though the water system is equipped with filters. [59] [60] [61] [62] [63] [64]

57 Environmental health disaster shelter assessment guide. Accessed March 17, 2024. https://emergency.cdc.gov/shelterassessment/pdf/Shelter_Assessment_instruct_508.pdf.

58 Watson, John T., Michelle Gayer, and Maire A. Connolly. "Epidemics after Natural Disasters." Emerging Infectious Diseases 13, no. 1 (January 2007): 1–5. https://doi.org/10.3201/eid1301.060779.

59 Bashawri, Abdulrahman, Stephen Garrity, and Krisen Moodley. "an Overview of the Design of Disaster Relief Shelters."Elsevier, 2014. doi:10.1016/S2212-5671(14)01019-3.

60 Choi, Yu Ra, Eun Jeong Kim, and Mi Kyung Kim. "A Planning Guide for Temporary Disaster Shelters Focusing on Habitability." Indoor + Built Environment 29, no. 10 (2020): 1412-1424.

61 Commonly used sheltering items catalog. Accessed March 17, 2024. https://www.fema.gov/sites/default/files/documents/fema_commonly-used-sheltering-items-catalog.pdf.

62 Gold, Scott. "Trapped in the Superdome: Refuge Becomes a Hellhole." The Seattle Times, September 2, 2005. https://www.seattletimes.com/nation-world/trapped-in-the-superdome-refuge-becomes-a-hellhole/.

63 Khaji, Ali, Bagher Larijani, Seyed Mohammad Ghodsi, Mohammad A. Mohagheghi, Hammid R. Khankeh, Soheil Saadat, and Seyed Mahmoud Tabatabaei. "Ethical Considerations for Living in Temporary Shelters (i.e., Camps) Following a Natural Disaster." Archives of Bone and Joint Surgery 7, no. 5 (2019): 445-452.

64 Akaishi, Tetsuya, Kazuma Morino, Yoshikazu Maruyama, Satoru Ishibashi, Shin Takayama, Michiaki Abe, Takeshi Kanno, Yasunori Tadano, and Tadashi Ishii. "Restoration of Clean Water Supply and Toilet Hygiene Reduces Infectious Diseases in Post-Disaster Evacuation Shelters: A Multicenter Observational Study." Heliyon 7, no. 5 (May 2021). https://doi.org/10.1016/j.heliyon.2021.e07044.

In the context of planning natural disaster shelters, critical considerations include allocating space for water storage and establishing designated areas for loading and unloading water deliveries after reviewing the literature, guidelines, and codes. Given the potential contamination of the city's water supply during disasters, storing bottled water and utilizing filters emerges as the most effective approach to ensure safe water availability. To mitigate unwanted odors, it is essential not to locate water storage near the space where the residents stay. [65] While specific storage space parameters are absent from existing guidelines, regulatory codes overseen by organizations like the ICC/NSSA emphasize the importance of addressing water capacity concerns in shelter design. I argue expressing water storage in terms of square footage or square meters, rather than gallons, will facilitate rapid assessment of natural disaster shelters. [66] Furthermore, insights from literature, including case studies involving repurposed mosques as disaster shelters, underscore the need to incorporate rain harvesting systems into shelter facilities. [67]

iii. Mental Health

The following section discusses the problems with individuals' mental health in disaster relief shelters, as well as design solutions to have less impact and reduce the occurrence rate of any incident in the shelter. Following a disaster, individuals in the community become overwhelmed with post-traumatic stress disorder and suffer from severe mental health issues, resulting in a number of incidents in disaster relief shelters. In addition, many people find the setting in disaster relief shelters uncomfortable. This problem also contributes to the sexual violence mentioned at the beginning of the chapter. This topic will address the mental health consequences of insufficient personal space, a lack of privacy between individuals, the need for community gathering space, and the desire for isolated space for staff.

The following problems of mental health are found in most of the literature, and it seems very common in the disaster shelter setting as very confusing conditions and environment after the huge disasters, and living in the conditions which aren't their comfort space. Especially, as the natural disaster generated more than 10,000 displaced populations each time, when housing these individual numbers in any temporary facilities which aren't intended to

65 Shelter guidance aid and shelter staffing matrix – October 2010. Accessed March 17, 2024. https://www.nationalmasscarestrategy.org/wp-content/uploads/2014/07/sheltering_guidance_aid_october_2010.pdf.

66 (ICC), International Code Council. "2020 ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters: ICC Digital Codes." 2020 ICC 500 ICC/NSSA STANDARD FOR THE DESIGN AND CONSTRUCTION OF STORM SHELTERS | ICC DIGITAL CODES. Accessed March 17, 2024. https://codes.iccsafe.org/content/ICC5002020P1/icc-nssa-standard-for-the-design-and-construction-of-storm-shelters.

67 Asif, Nayeem and Nangkula Utaberta. "Evaluating the Role of Mosque as an Emergency Shelter during Natural Disasters." In Urban and Transit Planning, 567-574. Cham: Springer International Publishing, 2020.

be living spaces, it's been very hard to allocate enough space for individuals to live and sleep. Also, people didn't have enough spacing for their cots and temporary beds from the others, people feel intrusion of privacy very easily with overcrowded populations. (See figure 12 & 13 - examples of crowding in the shelter)

UN Refugee Agency's Emergency shelter standards and solutions, FEMA's Multi-Agency Shelter Plan Template Space Considerations, CDC Environmental Health Disaster Shelter Assessment Required Spacing Per Occupant, 2020 ICC 500 UCC/NSSA Standard for the Design and Construction of Storm Shelters provides the adequate space for individuals in the shelters. [68] UN's standards provide the numbers depending on the climate of the region as 3.5m2(37.67 ft2), and in the warm weather, and 4.5m2(48.43 ft2) ~ 5.5m2(59.2 ft2) per person. FEMA's guidelines provide adequate space per duration of the shelter. If it is a short-term shelter 40 sq.ft per person is provided and for long term and mega shelter 60~80 sq.ft is provided. In FEMA's guideline, 100 sq.ft needs to be guaranteed for the disabilities irrelevant to any duration of the shelters. CDC's guidelines offer adequate space for individuals in sleeping areas by function of the shelters. If people are served in evacuation shelters, 20ft2 seems very inadequate, and the literature converting mosque states that 20ft2 is a dedicated prayer space for the people. [69] General shelters offer 40ft2 per person, and the shelters which provide medical services such as Alternative Care Sites offer 60~100ft2 per person. Only CDC regulates adequate spacing between each individual's space and I believe this needs to be regulated in all guidelines or codes for the shelter to keep privacy and prohibit overcrowding.

It is essential to provide enough space for each person to alleviate their mental health issues when setting up natural disaster shelters in any kind of venue. The data on adequate space for individuals is displayed in the tables below. In the UN Refugee Agency's Emergency Shelter Solutions and Standards, in cold weather, it is recommended to provide [70] The code regulated by ICC/NSSA provides a minimum area of seating areas, wheelchair users, and people who are relocated in a bed or stretcher and the type of the disasters. In the tornado shelter, the minimum standing/seating area for the people is 5 sq.ft The space for wheelchair users is 10 sq.ft., and people who are relocated in a bed or stretcher need 30 sq.ft. In a hurricane shelter, the standing/seating area is 20 sq.ft which is equal to CDC's evacuation shelter sleeping area. The space for using a wheelchair also gets 20 sq.ft. Lastly, people

68 Environmental health disaster shelter assessment guide. Accessed March 17, 2024. https://emergency.cdc.gov/shelterassessment/pdf/Shelter_Assessment_instruct_508.pdf.
69 Asif, Nayeem and Nangkula Utaberta. "Evaluating the Role of Mosque as an Emergency Shelter during Natural Disasters." In Urban and Transit Planning, 567-574. Cham: Springer International Publishing, 2020.
70 "Emergency Shelter Solutions and Standards." UNHCR. Accessed March 24, 2024. https://emergency.unhcr.org/emergency-assistance/shelter-camp-and-settlement/shelter-and-housing/emergency-shelter-solutions-and-standards.

who are relocated in a bed or stretcher get 40 sq.ft which is equal to the UN's living space for individuals in cold weather and CDC's general shelter (see Table 8,9 and 10). There are no dedicated living/sleeping areas specified in the code. Additionally, as it was mentioned in the previous chapter, the Sphere handbook provides the formula to calculate building's capacity to prevent overcrowding in the shelter, also the handbook guides the minimum area of individuals as 3.5m2 per person.

The solution for intrusion of privacy aligns with the other problems' solution in the earlier chapters such as creating internal partitions in the living area of the occupants of the shelters. Paper partitions with light fabrics which were developed by Shigeru Ban were used after the 2010 Japan earthquake and provide privacy to the people in the disaster relief shelters. (See figure 14 & 15 - examples of the partitions in the living area in the emergency shelters) Because of the risk of sexual assault, it is advised that the top of the partitions and cubicles remain open. To protect people's privacy, several spaces can be separated which also establishes physical boundaries in the design of the shelters. For instance, the medical area should be set apart. For the overcrowding problems, each shelter shouldn't have more than 2,000 people.[71] Also, the maximum capacity of populations needs to be calculated and the population needs to be controlled following the Sphere Project Handbook (2018) which was mentioned in the disease control under the hygiene and sanitation subchapter [72] In Bangladesh, the smaller scale of cyclone shelters were recommended in the literature due to the overcrowding and the privacy problem to control the privacy of individuals with the layout of small scale of the facilities and below is the actual sentence which was extracted from the literature which proposed several layout of the disaster relief shelters.

"Instead of developing large cyclone shelters, a dense network of small, sturdy and safe multipurpose buildings should be developed." [73]

In the literature, it is described that in a smaller size natural disaster relief shelter environment, the floor plans must be designed to protect each person's privacy by not displaying the resident's living area directly from the communal spaces, meeting areas, and other activity rooms. [74]

71 Basile, Alyssa L. "Disaster Relief Shelter Experience during Hurricane Sandy: A Preliminary Phenomenological Inquiry." International Journal of Disaster Risk Reduction 45, (2020): 101466

72 "The Sphere Handbook 2018." Sphere. Accessed March 24, 2024. https://spherestandards.org/handbook-2018/.

73 Haque, Ubydul, Masahiro Hashizume, Korine N. Kolivras, Hans J. Overgaard, Bivash Das, and Taro Yamamoto. "Reduced Death Rates from Cyclones in Bangladesh: What More Needs to be done?" Bulletin of the World Health Organization 90, no. 2 (2012): 150-156.

74 Latka, Jerzy F. 2018. "Emergency and Relief Architecture: Motivation and Guidelines for Temporary Shelters". A+BE | Architecture and the Built Environment 7 (19):267-330. https://doi.org/10.7480/abe.2017.19.3759.

As a couple of the literature highlighted, there are several spaces created separately to support the psychological recovery of the shelter populations. To create physical boundaries by separating the space totally, or creating designated areas for certain groups should be developed in the layout in the disaster relief shelters. According to staff workers at the Hurricane Sandy Mega Shelter, most of the residents felt overwhelmed, tired, and upset, making it difficult for them to sleep or increasing the tension of the emotions. These difficulties may have been exacerbated by living with strangers, being understaffed, having limited privacy, constant light and noise, and being around people in distress. [75] Based on the literature which explained the conditions of Hurricane Harvey's George R. Brown Center shelter staff provided isolated counseling areas in Hall E, and 232 occupants visited the area within two weeks. (See figure 16 and 17) [76]

A couple of surveys and interviews which were conducted in the several studies have found community areas and recreational areas play important roles in the disaster relief shelters which the layout of the disaster relief shelters must include. The literature which conducted the study of examining the social media and the news articles to find people's opinions regarding the formal shelter settings and the outdoor tent settings after California's wildfire in 2018, it is revealed that more than half of displaced populations didn't choose to stay in the formal setting since they needed a strong social bond from the outdoor setting, and they didn't believe it won't be achieved in the formal shelters. [77] One study which performed the 'Axial Line Analysis' and 'VGA' by depth map X software, to examine the previous disaster relief shelter layouts, and compared the case studies of mega shelters' layout narrated that most of the disaster relief shelter layouts don't provide the important factor which is focusing on recovery of the disaster victims, and the study emphasized the centralized community area and recreational area provides the solution of wayfinding of the occupants and also the faster psychological recovery. [78]

The importance of community space is illustrated in the below quotation which is from the design of emergency shelters in Bekaa Valley (Eastern Lebanon).

75 Basile, Alyssa L. "Disaster Relief Shelter Experience during Hurricane Sandy: A Preliminary Phenomenological Inquiry." International Journal of Disaster Risk Reduction 45, (2020): 101466

76 Shah, Asim A., Nizete Valles, Sophia Banu, Eric A. Storch, and Wayne Goodman. "Meeting the Mental Health Needs of Hurricane Harvey Evacuees." The American Journal of Psychiatry 175, no. 1 (2018): 13-14.

77 Spearing, Lauryn A., Keri K. Stephens, and Kasey M. Faust. "Shelter Shopping: Where the Built Environment and Social Systems Meet." International Journal of Disaster Risk Reduction 58, (2021): 102161.

78 Kim, Young Ook, Joo Young Kim, Ha Yoon Yum, and Jin Kyoung Lee. 2022. "A Study on Mega-Shelter Layout Planning Based on User Behavior" Buildings 12, no. 10: 1630. https://doi.org/10.3390/buildings12101630

"Community space: Health (physical and mental) and education centers. Self-help groups and livelihood options. Community playground is essential for children to play and for people to come to a place and communicate and support each other" [79]

Similarly, it is mentioned in a couple of studies, the previous disaster relief shelters rarely provided the community areas or the recreational areas, not many guidelines and codes indicate the required size of those spaces for design of temporary emergency shelters. Based on National Disaster Management Institute in South Korea (2014), the recommended community space size is 0.7 m2(7.5 ft2) per person. [80]

Recreational areas with activities are crucial for fostering mental health after a disaster, according to the "Sheltering Handbook Disaster Services (2012)." Consequently, it is imperative to establish communal and leisure areas in natural disaster shelters to bolster the resilience and general well-being of survivors. [81] The communal and recreational spaces in large shelters should be centralized. At least 1.17 square meters are needed for communal meeting places where people may dine, relax, and mingle in the little shelters that house 4–6 people. [82] Conceptual Layout of Shelters provided by FEMA allocated the recreational area with 100'x100' space for 200,000 ft2 exhibition hall. [83] A recreational Area with trained staff must be needed for the seniors. (See figure 21)

According to the nurse from Hurricane Sandy mega shelter, the break area or counseling area for the staff was extremely beneficial in the shelter setting because it allowed all the staff to completely escape from the overwhelming environment. [84] One of the studies which was mentioned earlier which studied the hierarchy of the space in the natural disaster shelters, argued that it is recommended to provide an empty transition space between the living area of survivors and the management team to create physical boundaries of each group. This aspect always needs to be considered when the layout of the shelters is developed. Every journal which illustrates the experience in the mega shelter of each hurricane disaster did not reveal how many staff were in the shelters in the study. [85]

79 Al Azzawi, Neebal, Lubna Amir, Pallavi Tiwari, and Emad S. Mushtaha. "Sustainable and Resilient Design for Emergency Shelters in Flood Risk Communities: Case Study: The Informal Settlements in the Bekaa Valley (Eastern Lebanon)."IEEE, 2020. doi:10.1109/ASET48392.2020.9118276.

80 National Disaster Management Research Institute. Accessed March 24, 2024.https://www.ndmi.go.kr/eng/main.do.

81 American-red-cross-sheltering-handbook.PDF. Accessed March 24, 2024. https://crcog.org/wp-content/uploads/2017/12/American-Red-Cross-Sheltering-Handbook.pdf.

82 Mounaim, Abdel, Naniek Widayati Priyomarsono, and Rudy Trisno. "Emergency Shelter Design for Disaster Preparation." IOP Conference Series. Materials Science and Engineering 852, no. 1 (2020): 12152.Mounaim, Abdel, Naniek Widayati Priyomarsono, and Rudy Trisno. "Emergency Shelter Design for Disaster Preparation." IOP Conference Series. Materials Science and Engineering 852, no. 1 (2020): 12152.

83 Mega-shelter Planning Guide, 2010. https://www.fema.gov/pdf/emergency/disasterhousing/mspg.pdf.

84 Basile, Alyssa L. "Disaster Relief Shelter Experience during Hurricane Sandy: A Preliminary Phenomenological Inquiry." International Journal of Disaster Risk Reduction 45, (2020): 101466

85 Mega-shelter Planning Guide, 2010. https://www.fema.gov/pdf/emergency/disasterhousing/mspg.pdf.

iv. Special Needs

In the last chapter of this study, the importance of creating space for elderly and children in the design of disaster shelters will be discussed. Facilities which can serve elderly and children was one of the characteristics which led people to choose shelters following the topics discussed above in the one of the literature. Tragically, during natural disasters, seniors are disproportionately affected. For instance, during Hurricane Katrina, a staggering 75% of fatalities were individuals aged over 60. Similarly, in California's 2018 Campfire, a significant proportion of victims fell into this age group. Hurricane Florence also saw more than 67% of its victims being seniors. FEMA's "Guide to Expanding Mitigation Making the Connection to Older Adults" emphasizes that the individuals aged over 60s and above frequently don't abide the emergency planning from the government since the post-disaster shelters are not designed to serve the senior populations. [86] This aspect is well illustrated in the quotation below from the interview of the nurse at Hurricane Sandy mega shelter.

"I think our seniors. These were folks who are living on the edge at home. They manage, but they struggled to manage. By far, I think those folks struggled the most in a shelter situation. For nothing else, just the distance to a bathroom, no one they felt secure with, and this is horrible." [87]

Seniors aged 60 and above formulate a particularly vulnerable population in the disaster settings. [88] Their physical and mental conditions differ significantly from those of young adults and individuals in their 40s and 50s (See figure 18). Specifically, many seniors grapple with health challenges related to both their physical well-being and mental health. Mobility issues, vision impairments, and hearing difficulties are common among this demographic. Sometimes seniors don't understand the whole situation of the disasters as arguing with staff that they need to be back to their usual life when normal daily activities are paused due to the disasters. [89]

Young children are the vulnerable demographics in the shelters as well. A few publications stating that children are the most resilient group since they can recover quickly, they generally rate their shelter experience positively. On the other hand, young children experience emotional distress as a result of family loss like other

86 Guide to expanding mitigation making the connection to ... Accessed March 24, 2024. https://www.fema.gov/sites/default/files/documents/fema_mitigation-guide_older-adults.pdf.

87 Basile, Alyssa L. "Disaster Relief Shelter Experience during Hurricane Sandy: A Preliminary Phenomenological Inquiry." International Journal of Disaster Risk Reduction 45, (2020): 101466

88 Basile, Alyssa L. "Disaster Relief Shelter Experience during Hurricane Sandy: A Preliminary Phenomenological Inquiry." International Journal of Disaster Risk Reduction 45, (2020): 101466.

89 Guide to expanding mitigation making the connection to ... Accessed March 24, 2024. https://www.fema.gov/sites/default/files/documents/fema_mitigation-guide_older-adults.pdf.

groups, and as previously stated in the earlier chapter, kid groups must be protected against dangers. (See figure 19) [90]

As the nurse from Hurricane Sandy Mega Shelter mentioned, it is recommended to design the layout of the shelter with the considerations for the people older than 60s so they get easier access to their separate needs such as bathrooms, showers, and the medical needs. [91] It is advised that the Rapid Shelter Assessment Team review the shelters quickly before they are utilized and give management information on how space may be integrated with the special requirements of older adults, people with disabilities, and children. This scenario includes medical requirements, pets, and cognitive or physical impairments. [92]

The facility must have a clear width of 36 inches for wheelchair access, according to the "ADA Checklist for Emergency". At least one restroom must include a 60-inch diameter circle or a "T"-shaped turn space. The toilet seats and the cots in the sleeping area must be the same height as the wheelchair seat.(17 to 19 inches above the floor). Bathroom doors must have at least 32 inches of clear passage width and a 90-degree door opening. Wheelchair-accessible routes should not have any steps or level changes that exceed ½ inch. [93]

The staffing matrix does not include workers for the older adult groups. (The mass shelter template has no designated areas for the older adult groups separately). According to the National Mass Care Strategy's Non-Traditional Shelter Concept of Operations Template, the recreational area with staffing must be developed specifically for older people who require care services, and the staff members must be dependable. [94]

This children's area doesn't define their sleeping area or living area. It is meant to provide them with daily activities in the shelters. Children's spaces with counseling services must have clean floor mats and be free of harmful things, especially tiny items, and need to be centralized in the open area while designing post-disaster shelter layouts. (See figure 20) I believe children's space shouldn't be enclosed and would protect children's from the sexual violence. The space can be created to include any toys and activity objects that meet consumer safety criteria, such as no choking hazards or sharp blades. Staff must oversee the entire children's space. In a layout, this space, the diaper changing station, and the family interaction area must be addressed independently. Conceptual

90 Protecting children post-disasters - world vision. Accessed March 17, 2024. https://www.worldvision.org/wp-content/uploads/child_protection_v3.pdf.

91 Basile, Alyssa L. "Disaster Relief Shelter Experience during Hurricane Sandy: A Preliminary Phenomenological Inquiry." International Journal of Disaster Risk Reduction 45, (2020): 101466.

92 American-red-cross-sheltering-handbook.PDF. Accessed March 24, 2024. https://crcog.org/wp-content/uploads/2017/12/American-Red-Cross-Sheltering-Handbook.pdf.

93 ADA Checklist for Emergency Shelters." ADA Checklist for Emergency Shelters. Accessed March 23, 2024. https://archive.ada.gov/pcatoolkit/chap7shelterchk.htm.

94 Non-traditional shelter concept of operations template. Accessed March 24, 2024. https://www.nationalmasscarestrategy.org/wp-content/uploads/2014/07/non-traditional-shelter-concept-of-operations-template-final-29dec2011.pdf.

Layout of Shelters provided by FEMA allocated the 40’x40’ of children area for 200,000 ft2 exhibition hall. (See figure 21)

Results

This study aims to find the design problems in the previous community emergency shelters which were provided right after the disaster and seek the way of enhancing the previous disaster relief shelter beforehand the next possible extreme events. There are numerous points that need to be addressed in the emergency shelters, not only the safety, hygiene, mental health, and the special needs, these are common problems that have been found in the shelters. By going through the articles, academic journals, thesis documents from the other universities, guidelines from FEMA, Red Cross, and codes written by the International Code Council, research questions which were created in the beginning of the study.

Table 11 at appendix represents the results of findings in this study. To answer the research questions of seeking the major problems in the natural disaster shelters, the important elements in the shelters, and the way of implementing the design in the shelter, the problems in the temporary natural disaster shelters were prevalent safety, hygiene, mental health, and not meeting certain age groups' needs were prevalent in the natural disaster shelters while going through the literature. As we see in the table above, Cajundome, which served 18,000 people over 58 days, didn't have any major issues like other temporary disaster shelters in the left atypical section. In Hurricane Katrina Cajundome, the disaster survivors established privacy by themselves, and the director of Cajundome managed not to have any physical threats and put efforts to create social bonds between hurricane Katrina survivors.[95]

As we see in this result, the design implementation we've found in the data analysis section such as having strong exterior of the shelters, not to be in the danger zones of the other natural disaster threats, creating personal space and ensuring privacy with any physical boundaries, having adequate and clean hygiene infrastructure minimizes the conflicts in the natural disaster shelters. Furthermore, these traits can be implemented in the temporary natural disaster shelters plan and prepared ahead before the disaster strikes in the community. People suffering from mental health remain after any natural disasters, and providing isolated counseling services to both natural disaster survivors and the staff in the shelters is critically important.

95 Taylor, Claire. "How the Cajundome Changed the Future of Aid after Hurricanes." The Daily Advertiser, August 29, 2016. https://eu.theadvertiser.com/story/news/local/2015/08/21/katrina-cajundome-set-standard/32149231/.

d. Summary

Characteristic	Design Strategy	Problems	Solutions		Source
Safety and Security	Protection from the weather and the natural elements	No proper protections from the severe weather conditions, coldness, and additional threats from nature.	Robust doors, windows, and walls to withstand high winds. Shelters must be insulated and maintain inside temperature between 59°F and 66°F		L1, L3, L5, L9, L10, L11, L12, L15, L19, L21, G3
			Disaster Relief Shelters are not recommended to be situated in 100-year floodplains or 10-mile emergency planning zones within nuclear power plants.		
			The structure of shelters can be varied depending on the type of disaster. 1) Flood Shelter: Concrete, Brick 2) Earthquake Resistant Building : Wood(Timber) and Steel		
	Prevention from theft	No adequate security system	The entrance/exit should be limited to only one to control the situation		L5, L11, L12, L21
			Private Storages with locks		
			Providing proper Security Systems at the entrance should be provided. Secured and monitored entrance with trained staff.		
	Prevention from sexual assault targeting Children, Women, LGBTQ+, and Transgender	No proper lightings	Equipped with at least 1~ 3-foot candles (10~40 Lux) of illuminance		L1, L6, L11, L12, L15, L16, L22, G10
		No gender-sensitivities bathrooms, showers, sleeping areas	The biological gender segregation of the sleeping area, restrooms, and showers		
			Providing at least one gender-neutral bathroom and a shower for LGBTQ+, Transgenders, and single moms with young sons. Providing a private area with a semi-open structure for the pregnancy and the breastfeeding		
		No lock on the bathroom doors	Locking systems with all sanitary facilities		
		Challenges to segregate sex offenders from the vulnerable demographics	Housing sex offenders separately, incorporating registration areas at the entrance and checking the individuals with photo IDs		
Hygiene and Sanitation	Hygiene Infrastructure	Inadequate/Inoperable hygiene systems	Number of Hygiene Infrastructure Requirements [Long Term / Mega Shelter (Based on 1000 people)] : 1 shower per 25 individuals 1 toilet per 20 individuals 1 hand wash sink per 20 individuals	[Short Term / Standard Shetler (Based on 200 people)] : 1 shower per 48 individuals 1 toilet per 20 individuals 1 hand was sink per 20 individuals. The hygiene infrastructure requirements are different between the Red Cross, CDC, and International Code Council.	L9, L11, L12, L15, L21, L22, C1, G4

	Disease Control	Being in an open area with a couple thousands of people	Identifying sick people and isolating them to a separate area The layout of schools helps the control of cross-contaminations due to the various purposes of the rooms. For airborne disease controls, HVAC systems need to be checked and the air circulation needs to be examined and controlled. The layout of the shelters needs to include the storage of hygiene kits.		L10, L11, G4
		Crowding	Setting up physical drapes/partitions/walls between residents can minimize the cross-contamination of diseases. Ex. Paper Partitions and Prefabricated Modular Pods.		
	Securing safe and sustainable water sources	Unpurified/unfiltered water (Contaminated community wells and water pipes from the local municipal government)	Providing Ample Bottled Water Supply Storage Capacity 1~2 Gallons / Per Person/ Per day for drinking water	3~5 Gallons / Per Person/Per day for all uses (At least a two-week supply is needed depending on the duration of the shelters)	L3, L4, L5, L7, L9, L10,L11, L12, L16, G4, G5
		Stomach related illness (Outbreak)	Storing and providing individual water filters		
Mental Health	Sufficient Personal Space	Insufficient each person's space	Providing enough space of 40 ft2(3.5 m2) on average per person		L9, L17, L19
			At least 2.5ft spacing between cots/beds/mats		
			Limitation of populations: 2,000 under		
	Setting a physical wall for each individual's privacy	Crowdedness	Maximum capacity (number of people) = ((Building area* 0.6) / 3.5 m2)		L9 ~ L12, L17, L19 ~ L23, G1, G2, G5, C1
			Creating physical partitions (Top remains open to prevent sexual violence)		
			Smaller scale of shelter with no direct visual of sleeping area of residents from other activities rooms		
	Creating Space by Functions	People's need of social bonds and the sense of community	Community Area: 0.7m2 per person / 7.5 ft2 per person for mega shelter. (Centralized in the layout of the shelter planning.)		L8,L11, L12, L13, L16, L17, L21, L23, G1
			Recreational Space: 4-6 people temporary disaster shelter : 1.17 m2 (12.6 ft2) 100'x100' for 200,000 square foot exhibition hall(1,126 individual spaces - Centralized in the layout of the shelter planning.)		
		Post Traumatic Stress Disorder	Providing counseling service with the guaranteed residents' privacy (Separate Area)		
		Staff's mental health issues	Totally separated break space for staff Ex. Different rooms or the different floors for their mental health.		L17
Special Needs	Providing Space by Age Groups	Seniors' tendency to avoid staying in the natural	Providing space adjacent to the bathrooms or the other medical services to seniors		G7, G8,L11,

		disaster shelter settings due to uncomfortableness	At least one toilet needs to be accessible. (a 60-inch diameter circle or a “T”-shaped turn space”)	L12, L16, L17
		Seniors’ suffering from severe physical and medical conditions more than other age groups ex. mobility issues, hearing difficulties, vision impairments and unable to accept the situations.	Bathroom doors with at least 32 inches of clear passage width and a 30-degree door opening.	G7, G8, G9, G13, L2 L11, L12
			The toilet seats in the bathroom and the cots in the sleeping area must be the same height as the wheelchair seat. (17 to 19 inches above the floor).	
			Wayfinding helps the impaired vision residents.	
			No abrupt level changes over 1/2 inches and no steps in the passages.	
			Accessible Route - 36 inches need to be guaranteed to serve people with wheelchairs.	
		Children’s PTSD	Conceptual Shelter Layout from FEMA provides 40’x40’ of children area in 200,000 square foot exhibition hall. (Capacity 1,126 individual spaces - 40 ft2)	L11, G1, G9
		Needs of special care to protect from being the target of any physical assaults and harms	Providing children's spaces with counseling services (Centralized in the layout of the plan)	

[Table 13] Natural Disaster Shelters Design Strategy Summary Table

The back of the documentation contains lists of numbered literature, codes, and guidelines that are linked to the source’s column.

3. CONCLUSION

The purpose of this study was to identify difficulties that developed in post-disaster assistance shelters from 2000 to 2024. It also focused on key elements that should be included in facilities and approaches for tackling these issues in the construction of future natural disaster shelters. The study's goal is not necessarily to identify the best facility for turning into a natural disaster refuge. Instead, it tries to improve methods for converting any available structures into such shelters with additional physical boundaries to construct a spatial hierarchy, since it appears that critical components are now absent, and to produce natural disaster shelters more effectively.

According to the papers, the study's main issues include a lack of safety and cleanliness, as well as a cause of mental health, and there are gaps in the space, such as communal space, which people value highly in disaster shelters for a quick recovery. Furthermore, as a result of the emergency, shelters have had poor sanitary infrastructure, insufficient and undesignated space capacity for people, a failure to divide victims by biological

genders, and a lack of privacy, resulting in additional victims. For these reasons, physical boundaries should be constructed to govern people's movements and prevent repeat catastrophes in shelters.

This study contains limitations in the findings. As a result, this study only contains secondary data, there is no primary research, and the large scales of natural disasters are not always as frequent as the shooting incident. The real implications for the existing facilities during the actual incident appear to be too difficult. It is still recommended that existing facilities conduct regular inspections of their ability to accommodate disaster survivors and prepare in advance. Furthermore, because it is a standalone systematic review rather than a team effort, there may be limitations in terms of the number of studies and the area covered with the restricted time.

To contribute to the field, this study compiles research evidence on natural disasters and educates guidelines and codes to improve natural disaster shelters and promote community resilience planning in advance. There are additional characteristics of natural disaster shelters that are just as important as GIS locations and comfort levels, such as indoor air quality, HVAC, structure, renewable energy, and so on, as detailed in the methodology section. The literature on GIS location was found to be significant, but it was excluded from this study. The future study should look into other characteristics to better design natural disaster shelters for the needs and safety of the people who use them. In addition, it is recommended that the existing public facility be assessed ahead of time.

Bibliography

“A Look Back at Hurricane Katrina.” A Look Back at Hurricane Katrina | HUD USER. Accessed March 16, 2024. https://www.huduser.gov/portal/pdredge/pdr-edge-frm-asst-sec-092121.html.

“A Practical Guide to Gender-Sensitive Approaches for Disaster Management.” A Practical guide to Gender-sensitive Approaches for Disaster Management | Protection, Gender & Inclusion, November 9, 2010. https://pgi.ifrc.org/resources/practical-guide-gender-sensitive-approaches-disaster-management.

ADA Checklist for Emergency Shelters.” ADA Checklist for Emergency Shelters. Accessed March 23, 2024. https://archive.ada.gov/pcatoolkit/chap7shelterchk.htm.

Aguilar-Barajas, Ismael, Nicholas P. Sisto, Aldo I. Ramirez, and Víctor Magaña-Rueda. "Building Urban Resilience and Knowledge Co-Production in the Face of Weather Hazards: Flash Floods in the Monterrey Metropolitan Area (Mexico)." Environmental Science & Policy 99, (2019): 37-47

Akaishi, Tetsuya, Kazuma Morino, Yoshikazu Maruyama, Satoru Ishibashi, Shin Takayama, Michiaki Abe, Takeshi Kanno, Yasunori Tadano, and Tadashi Ishii. “Restoration of Clean Water Supply and Toilet Hygiene Reduces Infectious Diseases in Post-Disaster Evacuation Shelters: A Multicenter Observational Study.” Heliyon 7, no. 5 (May 2021). https://doi.org/10.1016/j.heliyon.2021.e07044.

Alshawawreh, Lara. "Architecture of Emergencies in the Middle East : Proposed Shelter Design Criteria."Edinburgh Napier University, 2019.

American-red-cross-sheltering-handbook.PDF. Accessed March 24, 2024. https://crcog.org/wp-content/uploads/2017/12/American-Red-Cross-Sheltering-Handbook.pdf.

Arena to healthcare concept (A2HC) - army corps of engineers, 2020. https://www.usace.army.mil/Portals/2/docs/Contracting/AlternateCareSites/Arena to Healthcare Concept (A2HC)- 2020 03 30.pdf.

Asgary, Ali and Nooreddin Azimi. "Choice of Emergency Shelter: Valuing Key Attributes of Emergency Shelters." International Journal of Disaster Resilience in the Built Environment 10, no. 2/3 (2019): 130-150.

Asif, Nayeem and Nangkula Utaberta. "Evaluating the Role of Mosque as an Emergency Shelter during Natural Disasters." In Urban and Transit Planning, 567-574. Cham: Springer International Publishing, 2020.

Basile, Alyssa L. "Disaster Relief Shelter Experience during Hurricane Sandy: A Preliminary Phenomenological Inquiry." International Journal of Disaster Risk Reduction 45, (2020): 101466.

Bashawri, Abdulrahman, Stephen Garrity, and Krisen Moodley. "An Overview of the Design of Disaster Relief Shelters."Elsevier, 2014. doi:10.1016/S2212-5671(14)01019-3.

“‘Boundaries’ in Architecture and Design in Discussion at Rocagallery.Com.” ROCA Bathrooms. Accessed April 24, 2024. https://www.roca.com/news/roca-gallery-boundaries-architecture-design.

Bradford, NM and R. Sen. "Multiparameter Assessment Guide for Emergency Shelters: Disaster Relief Applications." Journal of Performance of Constructed Facilities 19, no. 2 (2005): 108-116.

Breckon, Donald J., John R. Harvey, and R. Brick Lancaster. Community Health Education: Settings, roles, and Skills for the 21st Century. Gaithersburg, MD: Aspen Publishers, 1998.

Choi, Yu Ra, Eun Jeong Kim, and Mi Kyung Kim. "A Planning Guide for Temporary Disaster Shelters Focusing on Habitability." Indoor + Built Environment 29, no. 10 (2020): 1412-1424.

“Climate Change Adaptation: Water Technology.” WaterAid UK. Accessed March 23, 2024. https://www.wateraid.org/uk/the-crisis/water/water-technology.

“Community Resilience.” Community Resilience - an overview | ScienceDirect Topics. Accessed March 24, 2024. https://www.sciencedirect.com/topics/social-sciences/community-resilience.

“Community Resilience.” Community Resilience | National Risk Index. Accessed March 24, 2024. https://hazards.fema.gov/nri/community-resilience.

“Community Resilience.” NACCHO. Accessed March 25, 2024. https://www.naccho.org/programs/public-health-preparedness/community-resilience.

“Community Resilience.” NIST, January 4, 2024. https://www.nist.gov/community-resilience.

“Community Resilience | Rand.” Community resilience. Accessed March 24, 2024. https://www.rand.org/topics/community-resilience.html.

“Community Resilience.” community_resilience. Accessed March 24, 2024. https://aspr.hhs.gov/at-risk/Pages/community_resilience.aspx.

Commonly used sheltering items catalog. Accessed March 17, 2024. https://www.fema.gov/sites/default/files/documents/fema_commonly-used-sheltering-items-catalog.pdf.

Cordero-Reyes, A. M., I. Palacios, D. Ramia, R. West, M. Valencia, N. Ramia, D. Egas, P. Rodas, M. Bahamonde, and M. Grunauer. "Natural Disaster Management: Experience of an Academic Institution After a 7.8 Magnitude Earthquake in Ecuador." Public Health (London) 144, (2017): 134-141.

Cerna-Turoff, Ilan, Hanna-Tina Fischer, Hani Mansourian, and Susannah Mayhew. “The Pathways between Natural Disasters and Violence Against Children: A Systematic Review.” BMC Public Health 21, no. 1 (July 12, 2021). https://doi.org/10.1186/s12889-021-11252-3.

“Development of a First-Generation Community Resilience Assessment Methodology.” NIST, May 4, 2021. https://www.nist.gov/programs-projects/development-first-generation-community-resilience-assessment-methodology.

“Emergency Management: Definition, Vision, Mission, ...” Emergency Management Definition, Vision, Mission, Principles. Accessed March 25, 2024. https://emilms.fema.gov/is_0908/media/63.pdf.

“Emergency Shelter Solutions and Standards.” UNHCR. Accessed March 24, 2024. https://emergency.unhcr.org/emergency-assistance/shelter-camp-and-settlement/shelter-and-housing/emergency-shelter-solutions-and-standards.

Environmental health disaster shelter assessment guide. Accessed March 17, 2024. https://emergency.cdc.gov/shelterassessment/pdf/Shelter_Assessment_instruct_508.pdf.

“Earthquake-Resistant Building Technology.” IEEE Public Safety Technology Initiative. Accessed March 19, 2024. https://publicsafety.ieee.org/topics/earthquake-resistant-building-technology.

“FEMA.” Unit Four Emergency Management in the United States, 2002. https://training.fema.gov/emiweb/downloads/is111_unit%204.pdf.

Floods in Bangladesh : A Comparative Hydrological Investigation on Two Catastrophic Events. / Komatsu, Mitsuru.In: Journal of The Faculty of Environmental Science and Technology, Okayama university, Vol. Vol.8, No. No.1, 2003, p. 53-62.

Garcia, Emilio Jose, and Brenda Vale. Unravelling sustainability and resilience in the built environment. Florence: Taylor and Francis, 2017.

Gold, Scott. “Trapped in the Superdome: Refuge Becomes a Hellhole.” The Seattle Times, September 2, 2005. https://www.seattletimes.com/nation-world/trapped-in-the-superdome-refuge-becomes-a-hellhole/.

Guide to expanding mitigation making the connection to ... Accessed March 24, 2024. https://www.fema.gov/sites/default/files/documents/fema_mitigation-guide_older-adults.pdf.

Haque, Ubydul, Masahiro Hashizume, Korine N. Kolivras, Hans J. Overgaard, Bivash Das, and Taro Yamamoto. "Reduced Death Rates from Cyclones in Bangladesh: What More Needs to be done?" Bulletin of the World Health Organization 90, no. 2 (2012): 150-156.

Healthy, resilient, and sustainable communities after disasters, September 10, 2015. https://doi.org/10.17226/18996.

Hesson, Robert. “Basic Elements of Architecture - Analysing Architecture.” Northern Architecture, January 28, 2024. https://www.northernarchitecture.us/analysing-architecture/basic-elements-of-architecture.html.

Housing sex offenders in emergency shelters. Accessed March 17, 2024. http://www.iaem.org/portals/25/documents/CHHS-Memo-%20Housing-Sex%20Offender-in-Emergency-Shelters.pdf.

Horner, Mark W., Eren Erman Ozguven, Jean Michael Marcelin, and Ayberk Kocatepe. "Special Needs Hurricane Shelters and the Ageing Population: Development of a Methodology and a Case Study Application." Disasters 42, no. 1 (2018): 169-186.

Huber, Chris. “Hurricane Harvey: Facts, Faqs, and How to Help.” World Vision, November 4, 2023. https://www.worldvision.org/disaster-relief-news-stories/2017-hurricane-harvey-facts.

Hurricane Sandy SRIRC Case Study. Accessed March 16, 2024. https://www.fema.gov/sites/default/files/2020-11/fema_hurricane-sandy-recovery-collaborating-to-build-resilience_case-study.pdf.

Hurricanes Katrina/Rita and Sexual Violence: Report on Database of Sexual Violence Prevalence and Incidence Related to Hurricanes Katrina and Rita.” National Sexual Violence Resource Center. Accessed March 23, 2024. https://www.nsvrc.org/publications/nsvrc-publications/hurricanes-katrinarita-and-sexual-violence-report-database-sexual-vi.

“How Do Floods Create Humanitarian Crises?” The IRC. Accessed March 24, 2024. https://www.rescue.org/article/how-do-floods-create-humanitarian-crises.

(ICC), International Code Council. “2020 ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters: ICC Digital Codes.” 2020 ICC 500 ICC/NSSA STANDARD FOR THE DESIGN AND CONSTRUCTION OF STORM SHELTERS | ICC DIGITAL CODES, 2020. https://codes.iccsafe.org/content/ICC5002020P1/chapter-7-storm-shelter-essential-features-and-accessories.

Kim, Young Ook, Joo Young Kim, Ha Yoon Yum, and Jin Kyoung Lee. 2022. "A Study on Mega-Shelter Layout Planning Based on User Behavior" Buildings 12, no. 10: 1630. https://doi.org/10.3390/buildings12101630

Khaji, Ali, Bagher Larijani, Seyed Mohammad Ghodsi, Mohammad A. Mohagheghi, Hammid R. Khankeh, Soheil Saadat, and Seyed Mahmoud Tabatabaei. "Ethical Considerations for Living in Temporary Shelters (i.e., Camps) Following a Natural Disaster." Archives of Bone and Joint Surgery 7, no. 5 (2019): 445-452.

Koliou, Maria, John W. van de Lindt, Therese P. McAllister, Bruce R. Ellingwood, Maria Dillard, and Harvey Cutler. “State of the Research in Community Resilience: Progress and Challenges.” Sustainable and Resilient Infrastructure 5, no. 3 (January 8, 2018): 131–51. https://doi.org/10.1080/23789689.2017.1418547.

Latka, Jerzy F. 2018. “Emergency and Relief Architecture: Motivation and Guidelines for Temporary Shelters”. A+BE | Architecture and the Built Environment 7 (19):267-330. https://doi.org/10.7480/abe.2017.19.3759.

Leaving millions behind - IFRC. Accessed November 3, 2023. https://www.ifrc.org/sites/default/files/2021-09/B-WDR-2018-EXECSUM-EN.pdf.

Liang, Stephen Y., and Nicole Messenger. “Infectious Diseases after Hydrologic Disasters.” Emergency Medicine Clinics of North America 36, no. 4 (November 2018): 835–51. https://doi.org/10.1016/j.emc.2018.07.002.

Limsaksri, Doungjai and Yanin Rugwongwan. "Thai Temple Area: Facilities Assessment for Emergency Shelter use." IOP Conference Series.Earth and Environmental Science 1217, no. 1 (07, 2023): 012015. doi:https://doi.org/10.1088/1755-1315/1217/1/012015. https://ezproxy.rit.edu/login?url=https://www.proquest.com/scholarly-journals/thai-temple-area-facilities-assessment-emergency/docview/2845191336/se-2.

Manawongcharoen, Pattaramone and Thitirat Panbamrungkij. "A Flood Damage and Shelter Need Assessment: A Case Study of Mueang Sing Buri, Thailand." IOP Conference Series. Earth and Environmental Science 884, no. 1 (2021): 12025.

Marbury, Justice. “Florida Shelters Can Help during Storms. Why Don’t More People Use Them?” Democrat and Chronicle, September 20, 2023. https://www.democratandchronicle.com/story/news/2023/09/20/during-florida-hurricanes-special-needs-shelters-can-aid-caregivers/70897427007/.

Mega-shelter Planning Guide, 2010. https://www.fema.gov/pdf/emergency/disasterhousing/mspg.pdf.

Multi-agency Shelter Plan template - national mass care ... Accessed March 17, 2024. https://nationalmasscarestrategy.org/wp-content/uploads/2014/10/Multi-Agency-Shelterin-Plan-Template-Final_100114.pdf.

Mounaim, Abdel, Naniek Widayati Priyomarsono, and Rudy Trisno. "Emergency Shelter Design for Disaster Preparation." IOP Conference Series. Materials Science and Engineering 852, no. 1 (2020): 12152.Mounaim, Abdel, Naniek Widayati Priyomarsono, and Rudy Trisno. "Emergency Shelter Design for Disaster Preparation." IOP Conference Series. Materials Science and Engineering 852, no. 1 (2020): 12152.

National Disaster Management Research Institute. Accessed March 24, 2024. https://www.ndmi.go.kr/eng/main.do.

Non-traditional shelter concept of operations template. Accessed March 24, 2024. https://www.nationalmasscarestrategy.org/wp-content/uploads/2014/07/non-traditional-shelter-concept-of-operations-template-final-29dec2011.pdf.

Non-Traditional Shelter Case Studies American Red Cross December 31, 2011 https://www.nationalmasscarestrategy.org/wp-content/uploads/2014/07/full-case-studies-final-29dec2011.pdf

Okoli, Chitu and Schabram, Kira, A Guide to Conducting a Systematic Literature Review of Information Systems Research (May 5, 2010). Available at SSRN: https://ssrn.com/abstract=1954824 or http://dx.doi.org/10.2139/ssrn.1954824

Peer, Andrea. “Hurricane Sandy: Facts, Faqs, and How to Help.” World Vision, September 27, 2023. https://www.worldvision.org/disaster-relief-news-stories/2012-hurricane-sandy-facts.

Perry, Michalene. “Natural Disasters, Sexual Violence Create Terrifying Storm with Double Victims • Louisiana Illuminator.” Louisiana Illuminator, September 22, 2022. https://lailluminator.com/2022/09/22/natural-disasters-sexual-violence-create-terrifying-storm-with-double-victims/.

Protecting children post-disasters - world vision. Accessed March 17, 2024. https://www.worldvision.org/wp-content/uploads/child_protection_v3.pdf.

Post-disaster shelter: Ten designs, 2013. https://www.shelterprojects.org/tshelter-8designs/10designs2013/2013-10-28-Post-disaster-shelter-ten-designs-IFRC-lores.pdf.

publisher, Shamim AhmadFollow this. “Boundaries in Architecture: Architectural Dissertation.” Issuu, December 20, 2020. https://issuu.com/shamimahmad1995/docs/boundaries_in_architecture_architectural_dissert.

Rahman, M. Aminur, Fuad H. Mallick, M. Shahjahan Mondal, and Mohammad Rezaur Rahman. “Flood Shelters in Bangladesh.” Hazards, Risks, and Disasters in Society, 2015, 145–59. https://doi.org/10.1016/b978-0-12-396451-9.00009-3.

Rhoads, Jacqueline and Andrea Clayman. "Learning from Katrina: Preparing Long-Term Care Facilities for Disasters." Geriatric Nursing (New York) 29, no. 4 (2008): 253-258

Sarika Tandon, WE ACT for Climate Justice Project Race, Vulnerability and Differential Impacts: Prioritizing Social Justice in Climate Change Adaptation (2013)

Sadri, Arif Mohaimin, Satish V. Ukkusuri, Seungyoon Lee, Rosalee Clawson, Daniel Aldrich, Megan Sapp Nelson, Justin Seipel, and Daniel Kelly. “The Role of Social Capital, Personal Networks, and Emergency Responders in Post-Disaster Recovery and Resilience: A Study of Rural Communities in Indiana.” Natural Hazards 90, no. 3 (November 9, 2017): 1377–1406. https://doi.org/10.1007/s11069-017-3103-0.

Sexual violence in disasters, 2021. https://www.nsvrc.org/sites/default/files/2021-11/sexual_violence_in_disasters_final508_0.pdf.

Shelter Field Guide fema P-785. Accessed March 17, 2024. https://www.nationalmasscarestrategy.org/wp-content/uploads/2015/10/Shelter-Field-Guide-508_f3.pdf.

Shelter guidance aid and shelter staffing matrix – October 2010. Accessed March 17, 2024. https://www.nationalmasscarestrategy.org/wp-content/uploads/2014/07/sheltering_guidance_aid_october_2010.pdf.

Shah, Asim A., Nizete Valles, Sophia Banu, Eric A. Storch, and Wayne Goodman. "Meeting the Mental Health Needs of Hurricane Harvey Evacuees." The American Journal of Psychiatry 175, no. 1 (2018): 13-14.

Shahin, Md, Maruf Billah, Md Mozahidul Islam, Ahmed Parvez, and A. K. M. Mostafa Zaman. "Cyclone Shelters Need Sustainable Development." International Journal of Disaster Resilience in the Built Environment 11, no. 5 (2020): 659-678.

Shariat Alavi, Mahsa, Alireza Fallahi, Zoheir Mottaki, and Fereshteh Aslani. "Post-Disaster Sheltering Process After the 2019 Floods, in Golestan Province, Iran." International Journal of Disaster Resilience in the Built Environment 13, no. 5 (2022): 568-582.

Spearing, Lauryn A., Keri K. Stephens, and Kasey M. Faust. "Shelter Shopping: Where the Built Environment and Social Systems Meet." International Journal of Disaster Risk Reduction 58, (2021): 102161.

"The Sphere Handbook 2018." Sphere. Accessed March 24, 2024. https://spherestandards.org/handbook-2018/.

"Storm Shelter Standards." NSSA National Storm Shelter Association. Accessed March 24, 2024. https://nssa.cc/industry-standards/.

Su, Zhaopin, Guofu Zhang, Yang Liu, Feng Yue, and Jianguo Jiang. "Multiple Emergency Resource Allocation for Concurrent Incidents in Natural Disasters." International Journal of Disaster Risk Reduction 17 (August 2016): 199–212. https://doi.org/10.1016/j.ijdrr.2016.05.003.

Sustainable and resilient design for emergency shelters in ... Accessed March 24, 2024. https://www.researchgate.net/publication/342221342_Sustainable_and_Resilient_design_for_emergency_shelters_in_flood_risk_communities_Case_study_The_informal_settlements_in_the_Bekaa_Valley_Eastern_Lebanon.

UlHaq, Irfan, Sam Whittaker, and Malik M.A. Khalfan. "Developing Community Disaster Resilience through Preparedness." International Journal of Critical Infrastructures 16, no. 1 (2020): 53. https://doi.org/10.1504/ijcis.2020.10027129.

"U.S. Climate Resilience Toolkit." Community Resilience | U.S. Climate Resilience Toolkit, 2019. https://toolkit.climate.gov/topics/built-environment/community-resilience.

US Department of Commerce, NOAA. "Hurricane Sandy." National Weather Service, March 3, 2021. https://www.weather.gov/okx/HurricaneSandy5Year.

Watson, John T., Michelle Gayer, and Maire A. Connolly. "Epidemics after Natural Disasters." Emerging Infectious Diseases 13, no. 1 (January 2007): 1–5. https://doi.org/10.3201/eid1301.060779.

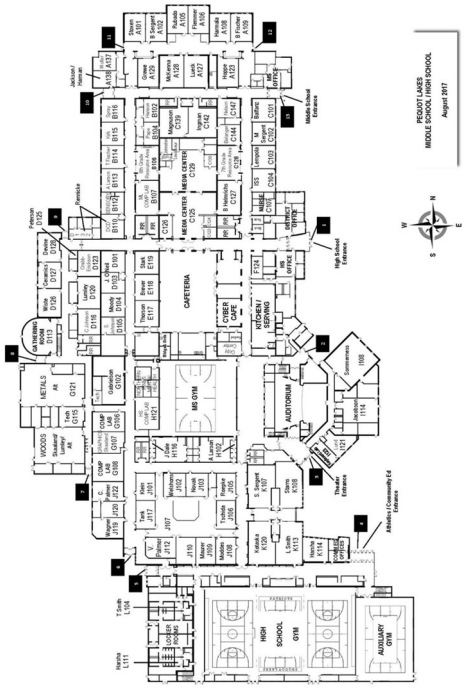
Whittaker, Joshua, Blythe McLennan, and John Handmer. "A Review of Informal Volunteerism in Emergencies and Disasters: Definition, Opportunities and Challenges." International Journal of Disaster Risk Reduction 13, (2015): 358-368.

"World Disasters Report 2018 Leaving No One Behind Executive Summary." World Disasters Report 2018, 2018. https://www.ifrc.org/sites/default/files/2021-09/B-WDR-2018-EXECSUM-EN.pdf.

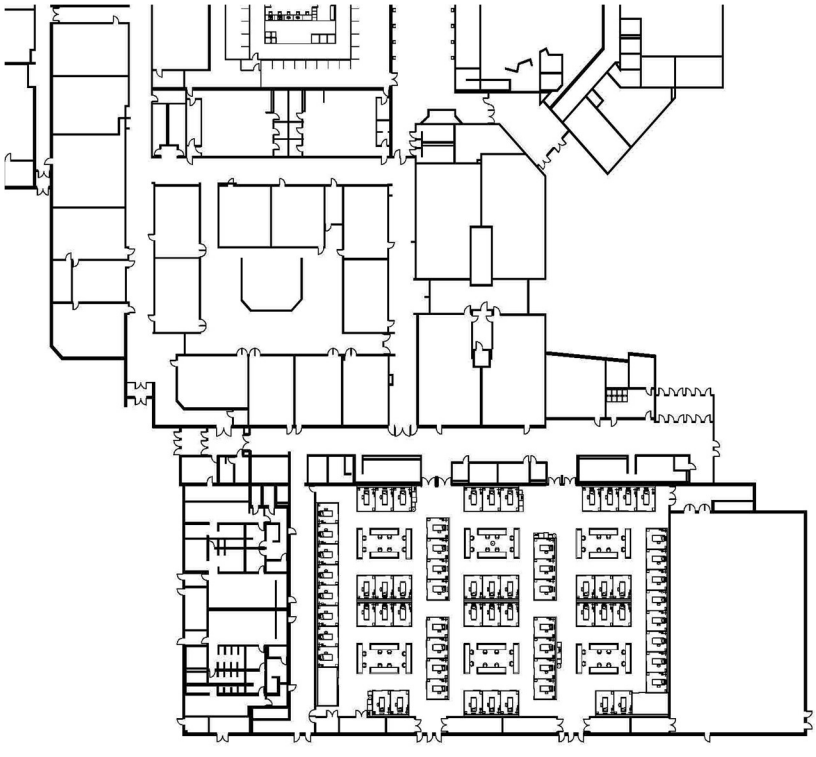
Wyche, Karen Fraser, Rose L Pfefferbaum, Fran H Norris, Deborah Wisnieski, and Hayden Younger. "Exploring Community Resilience in Workforce Communities of First Responders Serving Katrina Survivors." The American journal of orthopsychiatry, 2011. https://pubmed.ncbi.nlm.nih.gov/21219272/.

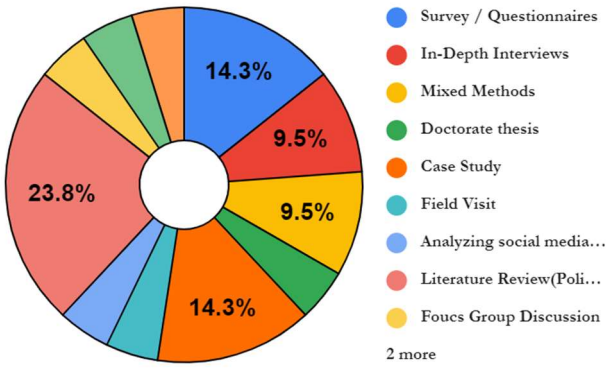
Yen, Muh-Yong, and Fuh-Yuan Shih. "Transforming Schools into Pre-Designed Alternative Care Sites as Part of Preparedness Plan for Pandemic H5N1 Influenza." Journal of the Formosan Medical Association, vol. 107, no. 9, 2008, pp. 673-676.

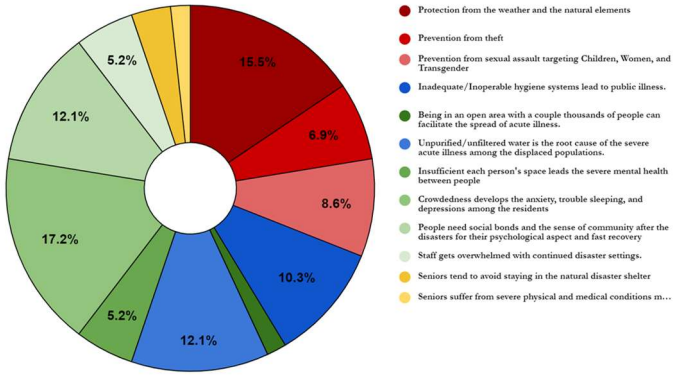
Appendices



[Figure 1] Pequot Lakes High







[Figure 4] The percentage of each problem found in the literature

[Figure 5] 2017 Hurricane Harvey Rowers Civic Center Flooded

[Figure 6] 2018 California Wildfire
Walmart Parking lot

[Figure 7] Hurricane Michael Sexually abused 6 year old child in the

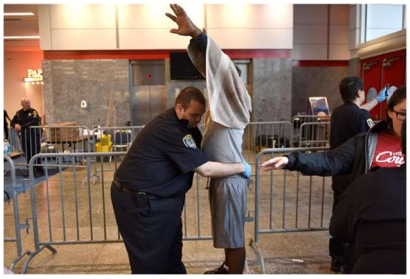
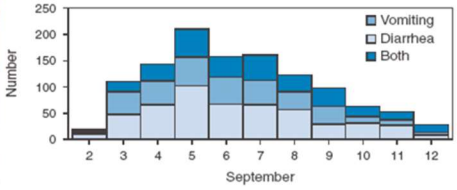


FIGURE. Number of persons reporting symptoms of acute gastroenteritis after Hurricane Katrina at an evacuee medical clinic, by symptom and date — Houston, Texas, September 2–12, 2005



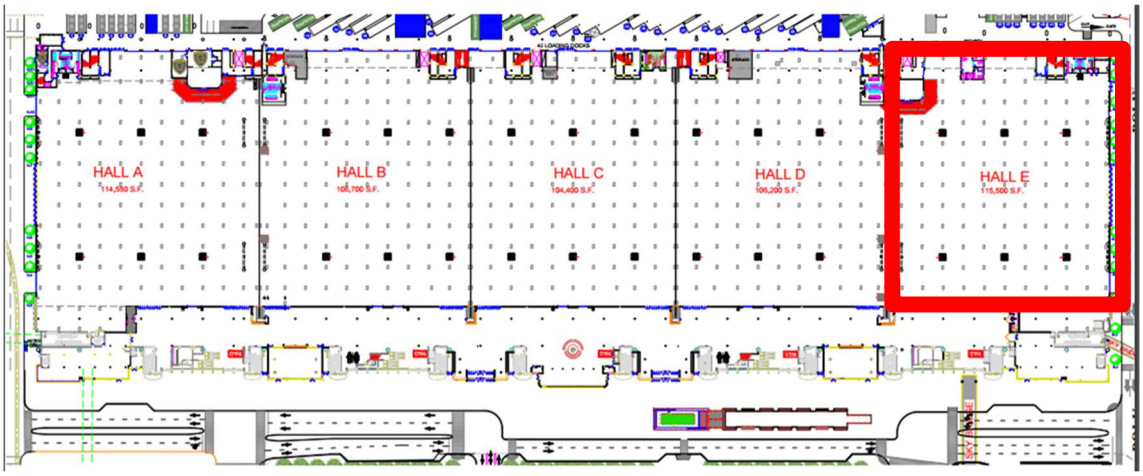
[Figure 9] Outbreak related stomach illness after

[Figure 10] The example of

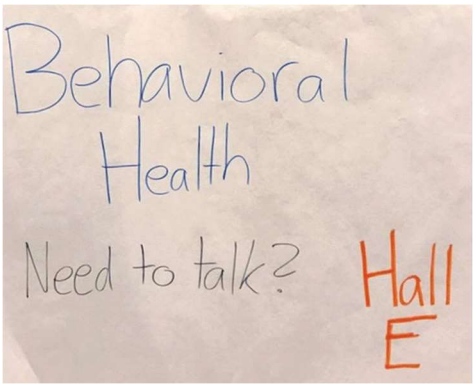
[Figure 11] The example of unhygienic

[Figure 12] Hurricane Katrina Superdome Evacuees (Source : International Business Times - Hurricane Katrina anniversary: 40

[Figure 13] Hurricane Harvey Shelter (Source : Red Cross - Hurricane Harvey: Red Cross Mounts Massive Relief Effort As Thousands Seek Refuge



[Figure 16] George R Brown Convention Center layout with highlighted Hall E, where counseling services were offered after Hurricane Harvey



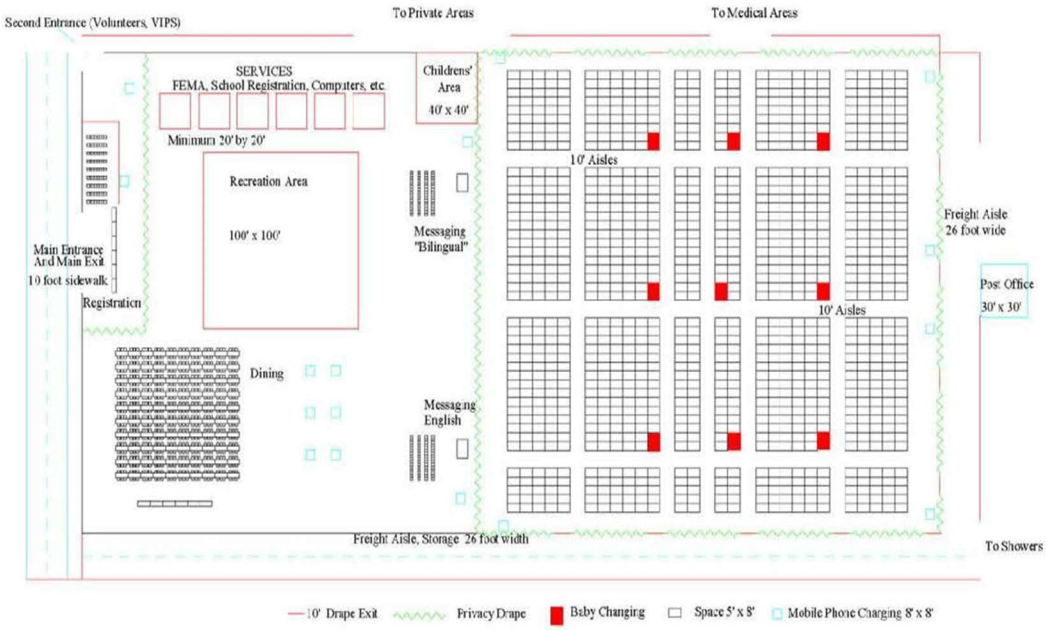
[Figure 17] Sign for counseling service at George R Brown Convention Center after Hurricane Harvey

[Figure 18] Seniors in the natural disaster shelters (Source : Google

[Figure 19] Hurricane Sandy destroyed all the backpacks and toys of

[Figure 20] Children's space in natural disaster shelters (Source : Google Search)

1. **Conceptual Shelter Layout**
   200,000 Square Foot Exhibition Hall
   Example Capacity, 1,126 personal spaces (8 feet x 5 feet)



[Figure 21] The Conceptual Layouts of Mega Shelter (Source : FEMA Mega Shelter Guidelines)

Mega Shelters				
#	The facility name	# of people	Duration	Meals
1	Cajundome, Lafayette LA	18,500 evacuees	58 days	409,000 meals
2	Reliant Park, Houston, TX	27,100 evacuees	37 days	
3	Dallas Convention Center & Reunion Arena, Dallas, TX	25,000 evacuees	39 days	114,200 meals
4	Superdome, New Orleans, LA	9,000 evacuees (550 National Guardsmen.) - Estimated peak population between 15,000 and 20,000	5 days	

[Table 1] Non Traditional Shelters : Hurricane Katrina - American Red Cross [1]

Emergency Shelter	Short-Term Period(A single night - A few days) The most basic kind of shelter support No extensive food preparation and medical services
Temporary Shelter	Short Term Period (A few Weeks) after a disaster
Temporary Housing	Long-Term Periods(6 months to 3 years) : Rental Houses and Prefabricated Unit Purpose : Allow people to return to their normal lives.
Permanent Housing	Long-Term Period(Several Years) Resistant and Resilient to Future Hazards
Alternative Care Sites(ACS)	Short-Term Periods(2 weeks ~ several weeks) & Long Term (Several Months) Purpose : Providing medical services outside of the original medical facilities (hospitals)

[Table 2] Categories of Emergency Post Disasters Relief Shelters and Alternative Care Sites [96]

Long Term / Mega Shelter(Based on 1000 people) :	Short Term / Standard Shetler(Based on 200 people):	Duration of the Shelters Not Defined (Source : CDC Environmental Health Disaster Shelter Assessment)
1 shower per 25 individuals	1 shower per 48 individuals	Adequate number of working showers/bathing facilities = 1 per 15 persons
1 toilet per 20 individuals	1 toilet per 20 individuals	Adequate number of working toilets = minimum 1 per 20 persons.

96 Quarantelli, 1991, Wu and Lindell, 2004, Johnson et al., 2006, Johnson, 2007a, Johnson, 2007b, Félix et al., 2013a

1 Hand Wash Sink per individuals	1 Hand Wash Sink Per 20 individuals	Adequate number of working hand-washing stations = 1 per 15 persons.

[Table 3] Shelter Guidance Aid and Shelter Staffing Matrix Shower, Toilet, Hand Wash Sink Requirements

Community Design Occupant Capacity < 50	Community Design Occupant Capacity > 50
1 Water Closet	1 Water Closet per 250 for the first 500 occupants and 1 additional per 500 occupants or portions thereof > 500 occupants
Lavatories Not Required	1 per 1,000 Occupants

[Table 4] 2020 ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters | Tornado Shelters Required Water Closet and Lavatories(702.3)

Community Design Occupant Capacity < 50	Community Design Occupant Capacity > 50
1 Water Closet	1 per 50 occupants
Lavatories Not Required	1 per 100 Occupants

[Table 5] 2020 ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters | Hurricane Shelters Required Water Closet and Lavatories(703.3) [97]

Standard / Short-Term Shelter	Long Term / Mega Shelter
40 sq. ft. per person in dormitory area	60-80 sq. ft. per person in dormitory area, 40 sq. ft. per person
100 sq. ft. per person in dormitory areas for people with disabilities and others with access and functional needs using mobility devices, service animals or larger DME items.	100 sq. ft. per person in dormitory area for people with disabilities and others with access and functional needs using mobility devices, service animals or larger DME items

[Table 8] Multi-Agency Shelter Plan Template Space Considerations [98]

Adequate Spacing	Minimum 2.5 ft between cots/beds/mats
Adequate space per person in sleeping area (minimums)	Evacuation Shelters = 20 ft2 per person
	General Shelters = 40 ft2 per person

97 (ICC), International Code Council. "2020 ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters: ICC Digital Codes." 2020 ICC 500 ICC/NSSA STANDARD FOR THE DESIGN AND CONSTRUCTION OF STORM SHELTERS | ICC DIGITAL CODES, 2020. https://codes.iccsafe.org/content/ICC5002020P1/chapter-7-storm-shelter-essential-features-and-accessories.

98 Multi-agency Shelter Plan template - national mass care ... Accessed March 17, 2024. https://nationalmasscarestrategy.org/wp-content/uploads/2014/10/Multi-Agency-Shelterin-Plan-Template-Final_100114.pdf.

	Medical Shelters = 60–100 ft2 per person

[Table 9] CDC Environmental Health Disaster Shelter Assessment Required Spacing Per Occupant [99]

Type of Occupants	Minimum Required Usable Floor Area in Square Feet Per Occupant
Tornado	
Occupants who are standing or seated	5
Occupants using a wheelchair	10
Occupants who are relocated in a bed or stretcher	30
Hurricane	
Occupants who are standing or seated	20
Occupants using a wheelchair	20
Occupants who are relocated in a bed or stretcher	40

[Table 10] 2020 ICC 500 UCC/NSSA Standard for the Design and Construction of Storm Shelters - [Table 502.3] Occupant Density - Community Storm Shelters [100]

	Typical					Atypical		Result
	2005 Hurricane Katrina Superdome	2011 Japan Tohoku Earthquake Multiple Temporary Shelters	2010 Earthquake in Haiti Temporary Camp in Champ-de-Mars	2018 Wildfire in California Formal Shelter	2018 Wildfire in California Walmart Parking Lot Spontaneous Outdoor Shelter	2018 Hurricane Michael **Davidson Middle School**	2005 Hurricane Katrina Cajundome	Design Implementation

99 Environmental health disaster shelter assessment guide. Accessed March 17, 2024. https://emergency.cdc.gov/shelterassessment/pdf/Shelter_Assessment_instruct_508.pdf.

100 (ICC), International Code Council. "2020 ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters: ICC Digital Codes." 2020 ICC 500 ICC/NSSA STANDARD FOR THE DESIGN AND CONSTRUCTION OF STORM SHELTERS | ICC DIGITAL CODES. Accessed April 13, 2024. https://codes.iccsafe.org/content/ICC5002020P1/icc-nssa-standard-for-the-design-and-construction-of-storm-shelters.

Sexual Violence	2	82	19	No Report	No Report	1	0	0
Disease Outbreak	Yes	Yes	Yes	10 Reports	1 Report	No Report	No Report	0
Unsanitary Condition	Extensive	100 Shelters	Extensive	0	1 Report	No Report	0	0
Theft	Extensive	Extensive	Extensive	0	5 Reports	No Report	0	0
No Protection from the weather and the natural elements	1 Incident	2 Incidents (Near Nuclear Plant & No heat)	0	1 Report	16 Reports	No Report	0	0
Mental Health Issue	Extensive	Extensive	Extensive	0	1 Report	No Report	Extensive	Counseling Services

[Table 11] Results of Finding

* Hurricane Katrina + Rita (2015)
The number Sexual Assault Reports - 47
30% of the reports were made in the evacuation & temporary shelter (14~15 Reports)
*Extensive = There were so many uncountable incidents

#	Publication Year	Article / Journal / Book	Author	Research Approach
L1	2006	Hurricanes Katrina/Rita and Sexual Violence	National Sexual Violence Resource Center	Internet Survey(Survey Monkey)
L2	2008	Learning from Katrina: Preparing Long-Term Care Facilities for Disasters	Jacqueline Rhoads, PhD, ACNP-BC, ANP-C, GNP, CCRN, and Andrea Clayman, MSN, APRN, GNP-BC, ANP-C	Literature Review

L3	2012	Reduced death rates from cyclones in Bangladesh: what more needs to be done?	Ubydul Haque,a Masahiro Hashizume,a Korine N Kolivras,b Hans J Overgaard,c Bivash Das,d and Taro Yamamotoa	Policy & Data Review
L4	2014	AN OVERVIEW OF THE DESIGN OF DISASTER RELIEF SHELTERS	Abdulrahman Bashawria, Stephen Garritya and Krisen Moodleya	A review of the literature, case studies, guidance, and reports
L5	2015	Flood Shelters in Bangladesh: Some Issues From the User's Perspective	M. Aminur Rahman, Fuad H. Mallick, M. Shahjahan Mondal and Mohammad Rezaur Rahman	Field Visits(Shelters of 3 different locations)
L6	2017	Natural disaster management: experience of an academic institution after a 7.8 magnitude earthquake in Ecuador	A M Cordero-Reyes, I Palacios, D Ramia, R West, M Valencia, N Ramia, D Egas, P Rodas, M Bahamonde, M Grunauer	Case study
L7	2018	Meeting the Mental Health Needs of Hurricane Harvey Evacuees	Asim A. Shah, M.D., Nizete Valles, Ph.D., Sophia Banu, M.D., Eric A. Storch, Ph.D., Wayne Goodman, M.D.	Patient Medical Record
L8	2018	Emergency and reilef architecture - Chapter.5 Emergency and relief architecture. Motivation and guidelines for temporary shelters.	Jerzy F. Latka	Literature Review
L9	2019	Ethical Considerations for Living in Temporary Shelters (i.e., camps) Following a Natural Disaster	Ali Khaji, MD, PhD, Bagher Larijani, MD, Seyed Mohammad Ghodsi, MD, Mohammad A. Mohagheghi, MD, Hammid R. Khankeh, PhD, Soheil Saadat, MD, PhD, and Seyed Mahmoud Tabatabaei, MD	Focus Group Discussions (FGDs) - qualitative content analysis approach(Graham content analysis)
L10	2019	Choice of emergency shelter: valuing key attributes of emergency shelters	Ali Asgary, Nooreddin Azimi	Survey
L11	2019	A planning guide for temporary disaster shelters focusing on habitability	Yu Ra Choi, Eun Jeong Kim, and Mi Kyung Kim	Interview

L12	2019	EMERGENCY SHELTER DESIGN FOR DISASTER PREPARATION	Abdel Mounaim , Naniek Widayati Priyomarsono , Rudy Trisno	Qualitative Analysis, Design, Case Study
L13	2019	Evaluating the Role of Mosque as Emergency Shelter During Natural Disasters	Nayeem Asif and Nangkula Utaberta	Case Study
L14	2019	Architecture of emergencies in the Middle East: Proposed shelter design criteria	Alshawawreh, Lara	Thesis (Only for the background information regarding the temporary disaster shelter not for the transitional shetler)
L15	2020	Cyclone shelters need sustainable development	Shahin, Md; Billah, Maruf; Islam, Md Mozahidul; Parvez, Ahmed; AKM Mostafa Zaman. I	A questionnaire survey
L16	2020	Disaster relief shelter experience during Hurricane Sandy: A preliminary phenomenological inquiry	Alyssa L. Basile	Interview
L17	2021	Post-disaster sheltering process after the 2019 floods, in Golestan province, Iran	Mahsa Shariat Alavi, Fallahi, Alireza, Mottaki, Zoheir, Aslani, Fereshteh	Observations Field Survey Activities Questionairres In-depth Interviews
L18	2021	A Flood Damage and Shelter Need Assessment: A Case Study of Mueang Sing Buri, Thailand	Pattaramone Manawongcharoen and Thitirat Panbamrungkij	Case Study
L19	2021	Shelter shopping: Where the built environment and social systems meet	Lauryn A. Spearing, Keri K. Stephens, Kasey M. Faust	Qualitative Analysis of News Reports and Social Media(Tweets)
L20	2022	Improving Resilience Capacity of the Policies and Planning for Temporary Shelters in Crises and Disasters	Nilgün Okay, Ebru Inal, Gül Yücel & Oya Açıkalın Rashem	Examine the international and national policies

L21	2022	A Study on Mega-Shelter Layout Planning Based on User Behavior	Young Ook Kim ,Joo Young Kim ,Ha Yoon Yum andJin Kyoung Lee	'Axial Line Analysis' and 'VGA' by depthmap X software

[Table 12] The list of literature found in the study

No.	Type	Published Year	Organizations Name	Title
C1	Code	2020	International Code Council	2020 ICC 500 ICC/NSSA Standard for the Design and Construction of Storm Shelters
G1	Guidelines	2010	American Red Cross, Dallas Convention Center, Federal Emergency Management Agency, International Association of Venue, Managers State of California State of Florida	Shelter Guidance Aid and Shelter Staffing Matrix 2010
G2	Guidelines	2018	CDC	Environment Health Disaster Shelter Assessment Guide(CDC)
G3	Guidelines		UN Environment Programme	Flood shelters(Climate Change Adaptation Technologies for Water)
G4	Guidelines	2022	Commonly Used Sheltering Items Catalog	FEMA
G5	Guidelines	2015	Shelter Field Guide	FEMA
G6	Guidelines	2014	National Mass Care Strategy	MULTI-AGENCY SHELTERING/SHELTERING SUPPORT PLAN TEMPLATE
G7	Guidelines	2012	American Red Cross	Sheltering Handbook Disaster Services

G8	Guidelines	2022	FEMA	Guide to Expanding Mitigation Making the Connection to Older Adults
G9	Guidelines	Unknown	World Vision	Protecting Children Post-Disasters
G10	Guidelines	2015	University of Maryland Center For Health & Homeland Security	HOUSING SEX OFFENDERS IN EMERGENCY SHELTERS
G11	Guidelines	2011	the American Red Cross at the request of the City of Los Angeles.	Non-Traditional Shelter Concept of Operations Template
G13	Guidelines	2007	ADA Checklist for Emergency Shelters	Americans with Disabilities Act

[Table 13] Code and Guidelines that were used in the study