Measuring Sustainability and Resilience Qualities across Post-Disaster Temporary Housing

By

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ABSTRACT

This research began with searching for a solution to temporary housing that residents can receive more quickly than current available temporary housing with an easier transition into permanent housing allowing for better overall community recovery. A framework was developed that suggests optimal temporary housing units at the household-level and at the community-level. The framework includes three key inputs that feed into an integrated sustainability and resilience evaluation model that provides tradeoffs between temporary housing options for a household. The three inputs include (1) the disaster scenario which describes the type of hazard and the level of damage to the pre-disaster home, (2) a description of the particular household in need of temporary housing, and (3) the types of temporary housing options to be evaluated. The framework is exemplified through both a wind hazard event and a flood hazard event causing moderate to severe damage to the pre-disaster homes of the households being considered. At the household-level, the tradeoffs for temporary housing are compared for six different households varying substantially based on perceived social and economic vulnerability. Common and innovative temporary housing options are considered in the examples, including manufactured homes, custom built units, hotels, and other government funding programs. A newly developed integrated sustainability and resilience evaluation model measures eight quantitative qualities of the temporary housing units that collectively formulate a quality of life index. The quantities are assigned weights based on priorities and needs of the household occupying the temporary housing unit. The temporary housing option resulting with the highest quality of life index is recommended to the household. The community-level framework uses the household-level analysis for each type of household in the community along with external constraints such as budgetary restrictions to determine an optimal community-wide solution that seeks to maximize the quality of life of all households while reducing cost of temporary housing.

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CHAPTER I. INTRODUCTION

Billion-dollar disasters caused by extreme weather events are occurring at an increasing rate, with this rate expected to continue increasing. The National Oceanic and Atmospheric Association (NOAA) has reported over 207 billion-dollar disasters since 1989, with 130 of those occurring after 2005 (NOAA, 2018). Numbers associated with evacuations, damaged homes, displaced residents, households in need of temporary housing, and dollars in damage continually have been observed to increase throughout recent years. These numbers will continue to increase due to climate change, population growth, urbanization, and aging infrastructure (Theis, 2012). Table 1 provides a few examples of how damage and dislocation numbers are increasing; therefore, the number of people left without their homes post-disaster is increasing as well, driving the need for sufficient emergency planning along with adequate post-disaster housing.

Table 1. Statistics from Recent Disasters

Disaster	Year	Data	Source
Hurricane Katrina	2005	Displaced over one million Gulf Coast residents	Liu et al., 2005
Hurricanes Ike and Dolly	2008	Over 100,000 homes flooded	Smith & Formby, 2017
Hurricane Sandy	2012	Housing assistance to over 174,000 households	Fugate, 2013
Louisiana Floods	2016	Over 100,000 households received some type of temporary housing assistance	FEMA, 2017a
Hurricane Matthew	2016	Nearly $67 million approved for housing assistance	FEMA, 2017b
Hurricane Harvey	2017	Over 563,000 homes damaged	Smith & Formby, 2017
Hurricane Irma	2017	Mandatory evacuation of 6.5 million people	Stanley, 2017

Emergency management occurs in four stages: planning, mitigation, response, and recovery. Planning and mitigations take place before a disaster, and response and recovery occur post-disaster. Post-disaster housing is considered to take place in four, albeit nonlinear and overlapping, stages as well, and span response and recovery. These four stages were first defined by Quarantelli and include emergency shelter, temporary shelter, temporary housing, and permanent housing (1982).

The Federal Emergency Management Agency (FEMA) designs their housing recovery programs around the following timeline and descriptions (U.S. Senate, 2009). Emergency shelter is the phase immediately following the disaster lasting for approximately two weeks. Temporary shelter begins two weeks post-disaster and spans up to three months, when temporary housing can be provided. Temporary housing lasts anywhere from 3 to 18 months and is intended to get displaced households back into their pre-disaster routine. Permanent housing follows temporary housing and becomes the long-term housing solution post-disaster. Throughout recent years, the response phase of emergency management has improved with the development of organizations such as the American Red Cross (Comerio, 2004), but the same issues with recovery and post-disaster housing occur time and time again. One of the main reoccurring post-disaster issues is the time spent in the temporary housing phase. Based on current FEMA housing recovery programs, temporary housing is expected to last up to 18 months. It has, however, lasted significantly longer in many of the billion-dollar disasters that have occurred since 2005. Indeed, after Hurricane Katrina, the final temporary housing unit left New Orleans six years after the storm hit southern Louisiana (Muskal, 2012). Many of the physical structures used during the temporary housing phase are not designed to last these long periods of time, particularly when considering structural integrity of the unit, and well-being of the occupants.

Disparities in timing, quality, and location of temporary housing have been observed after the past decade of disasters (Sutley and Hamideh, 2017). The specific needs of socially vulnerable households are often overlooked in the existing recovery programs: most live in hazard prone areas, have lower quality housing construction, live in poorly built neighborhoods, are renters (and therefore have less control over dislocation decisions, as well as not applicable for recovery funds), have lower incomes, savings, and often do not have insurance, thus further hindering households' abilities to recover (Kamel and Loukaitou-Sideris, 2004; Sutley and Hamideh, 2017). To receive certain types of aid after a disaster, specific criteria must be met, and losses must be proven. Oftentimes, low income, and racial and ethnic minority households do not have enough possessions pre-disaster to demonstrate substantial loss caused by the disaster or the required paperwork demonstrating ownership of their home, thus having those with higher property values receiving more aid by proving greater losses (Van Zandt and Sloan, 2017). Vulnerable populations, specifically low-income households, who experience issues receiving financial aid recover slower as a direct result (Bolin & Stanford, 1991; Kamel & Loukaitou-Sideris, 2004).

Following the disparities in distribution and timing of temporary housing after Hurricane Katrina, and the timeline for temporary housing observed after 2016 and 2017 disasters, particularly the Louisiana floods and Hurricanes Matthew, Harvey, and Irma, further research on temporary housing is a necessity. The present research provides a new integrated sustainability and resilience evaluation model applied to a selection of the existing types of temporary housing units. The model is designed at both the household-level taking into account the individual household's needs and preferences, and the community-level taking into account the needs of the entire community and the funds allocated to house everyone in need. The model includes three inputs specifying the disaster type, the household, and the types of temporary housing available. The model includes a process for measuring sustainability and resilience qualities of temporary housing, including adaptability, customizability, population stability, environmental impacts, health impacts, financial cost, structural integrity, and hazard vulnerability. These qualities are used to formulate a quality of life index. Given a disaster, a particular household, and the available temporary housing options, the integrated model will generate tradeoffs across qualities based on household preferences, and the quality of life index.

In order to describe how the model was formulated, a background of previous work on post-disaster temporary housing will be presented along with summaries of both common and innovative temporary housing accommodations and programs that have been used after recent disasters. Observations, successes, and areas of improvement for all of the types of temporary housing solutions are highlighted from an extensive content-analysis of the literature in order to better understand the temporary housing programs and the experiences of households residing in the units. The formulation of the newly developed framework, its inputs, the integrated model, and the outputs are described. Finally, two analysis examples are presented, one implementing the framework at the household level, and one implementing the framework at the community level.

CHAPTER II. LITERATURE REVIEW

This chapter presents a history of work that has been made with regard to post-disaster temporary housing specifically to better understand the state of temporary housing and how this knowledge can be expanded and developed.

Quarantelli (1982; 1995) first noted the terms “sheltering” and “housing” were being used interchangeably throughout the literature without distinction. In order to close this gap, he specified four distinct shelter and housing phases post-disaster: emergency shelter, temporary shelter, temporary housing, and permanent housing. Emergency sheltering is referred to when disaster victims seek lodging outside of their permanent home for short periods of time, either hours or overnight. Temporary sheltering extends longer than just the emergency period; it can span several days, but the victims do not normally make effort to reestablish their pre-disaster lifestyle. In many cases these two sheltering phases overlap, but some behavioral aspects are distinguishable. For example, emergency shelter is generally not concerned with meeting the immediate needs of the victims residing in the shelter since the expectation is that everyone will return home within hours. Temporary shelter on the other had has more of a roll with regard to immediate needs of the victims such as determining their access to food, water, and a place to sleep.

The housing phases (i.e., temporary and permanent housing) require more of residential structures, and less of mass sheltering units. The housing phase also includes means for the victims to resume their pre-disaster routine and lifestyle. Unlike the two housing phases, the temporary housing to permanent hosing transition is much more concrete. More often than not, the permanent housing phase results in the households returning to their repaired pre-disaster home, or disaster new, but otherwise similar, home. When low-income households, or households without insurance, experience significant damage to their home and loss to their belongings, it can be very difficult for them to acquire permanent housing. In these cases, haphazardly, the temporary housing unit was turned into permanent housing. For example, households were residing in units that were used as temporary housing while their permanent pre-disaster home was being repaired, but the repairs never happened leaving the households to remain in the previously defined "temporary" units (Quarantelli 1982; Quarantelli 1995).

Quarantelli (1982) analyzed three previous disasters to investigate all four housing recovery phases and the components of a disaster from response through recovery. He highlighted the context of the community, threat conditions, warning and impact, behavior patterns of response groups, evacuation, sheltering phase, return to the community, temporary housing, permanent housing, and post disaster recovery. The three disasters considered as case studies were the Wilkes-Barre, Pennsylvania flood, Xenia, Ohio tornado, and the Grand Isle, Nebraska tornado. Based on his observations from these three disasters he found that renters were more likely to apply for assistance over homeowners, not all who would qualify for assistance applied, and often times those who withdrew their application were never followed up with, therefore it is unknown their post-disaster situation. He also observed differences in social classes having different opinions on living in mobile homes, or manufactured housing units, temporarily. For example, it was reported that middle-class families did not seem to like these manufactured housing units, and those with a higher socioeconomic status preferred to receive rental assistance over the actual unit. Group sites tended to have a negative stigma attached to them; most households preferred to have the manufactured housing unit on their property to ensure peace of mind and safety. It was observed that not much progress was made to investigate what would make a group site feel safer and run smoother. A common concern of those in group sites was the impacts of this type of lifestyle on the social pathologies of children residents. Another common observation was that higher-income victims occupied the majority of the available rental units as a form of temporary housing. Finding units for the elderly, lower-income, and minority groups were frequently a problem post-disaster which led to theories of income being a possible factor, but this has not been proven. Quarantelli (1982) pointed out recurring patterns in temporary housing where more research was needed in 1982 (36 years ago), and as uncovered through this thesis research, these gaps largely still exist.

Quarantelli (1995) also discussed the issues with both the sheltering and housing phases post-disaster. He suggested issues with post-disaster sheltering and housing came more from the planning and operational agencies implementing the sheltering and housing programs and less with the disaster victim occupants. Issues were attributed to pre-disaster housing inventories, failure to recognize pre-disaster conflicts and differences in community power; inadequate use of surviving community resources; erratic organizational mobilization; poor inter-organizational co-ordination; difficulties in intergroup information flow; and other organizational and community-level factors which make the problems in preparing for and providing sheltering and housing. He continued to explain that problems would continue to grow in the future with changes to household composition, changes in age distribution, and changes in social expectations about disaster help and relief. These observations pointed out by Quarantelli (1982; 1995) paved the way for much more developed research to be completed in the area of temporary housing.

The Loma Prieta earthquake of 1989 in San Francisco sparked interest in temporary housing observations discussed specifically by Comerio (1997). She noted that those who were renting before the earthquake were able to be re-housed fairly quickly, within two months, due to the number of vacancies in the disaster area at the time. This is not always the case, especially in current times when urban area vacancies are scarce. She also observed that those who were housed quickly for this particular disaster were pre-disaster renters and were low- to moderate-income households. Some groups of people, such as immigrants, generally sought aid through community organizations and charities for fear of repercussions through the federal government assistance. A large number of the homes destroyed in the earthquake housed the rural poor, elderly, indigent, and illegal immigrant which can be related to affordable housing not being always built to the highest standard. In the early 1990s and still today, affordable housing tends to be rundown buildings which are more susceptible to experiencing damage through routine and extreme hazard events. Households residing in these types of circumstances in 1989 relied heavily on the aid of private charities, as opposed to government aid, because disaster assistance was designed to help single-family homeowners.

Olshansky et al (2006) pointed out improving notes on temporary housing based on the outcomes of the Northridge Earthquake of 1994 in Los Angeles and the 1995 Kobe, Japan earthquake. He stated two major findings in order to have a successful temporary housing program: funding should come from an external source, and the unit should be in an ideal location to aid households in the rebuilding process. He also suggested that temporary along with permanent housing are important aspects that should be considered in pre-disaster planning in order for a smoother recovery post-disaster.

El Anwar et al (2008; 2009) presented a newly developed framework for optimal temporary housing arrangements. He defined temporary housing as tent cities, travel trailers, mobile homes, apartments, public housing units, hotels and motels, cruise ships, and military bases. His model developed was designed to minimize four specific qualities: socioeconomic disruptions of the victims, vulnerability of the temporary unit, environmental impacts onto the community from unit construction, and the total public expenditures of the temporary housing facilities. He developed indices to quantify these four qualities and set target values of the indices as optimization objectives. The socioeconomic disruption index aimed for minimal delivery and installation time, but maximum housing quality and safety. The vulnerability index aimed to minimize the vulnerability to other hazards that could occur as a result to the current disaster, such as landslides, aftershocks, and fires. The environmental impact index aimed to minimizing the impacts on the community by measuring the effects on the soil, air quality, water quality, and level of noise during the construction process. Lastly, the public expenditure index sought to reduce either rental cost or total purchase cost of a temporary housing unit. In order to use the indices a set of inputs were developed: number of displaced households; environmental information such as soil, water quality, and air quality involved in measuring environmental impacts; temporary housing facilities available and information regarding their location, cost, size, delivery and installation time; and data involving post-disaster hazards such as safety distances for each hazard, for example the distance from a temporary housing unit to the epicenter of a potential earthquake, and probability of occurrence. The model for temporary housing arrangements also included a normalization module and an optimization module. The normalization module calculated a weighted performance of the temporary housing arrangement considering the four indices to demonstrate the overall performance for each arrangement. The optimization module was used to generate and compare optimal tradeoffs for each of the four objectives. This was used to generate solutions, or arrangements, based on the values of each set of indices. The output of the model was an optimal arrangement of temporary housing facilities that sought to minimize all of the previously described optimization criteria. This model provided decision makers to identify the relative weights, the objective performance and the temporary housing arrangement assignments that are generated from the optimal solution.

The model developed by El Anwar (2009) is the first record of any system developed to quantify seeming unquantifiable qualities of temporary housing units, while considering the effects on the occupants, not just the convenience of the assistance providers. Furthermore, El Anwar (2009) is also the only record of any quantitative study on post-disaster temporary housing. The work presented here provides a significant step forward on post-disaster temporary housing assignment considering household needs and preferences, as well as community-level constraints.

CHAPTER III. CONTENT-ANALYSIS

A content-analysis of the literature was performed to understand what types of temporary housing units and programs were successful or unsuccessful after previous disasters. This analysis consists of two parts: (1) summaries of various types of temporary housing programs that have been implemented in recent disasters and (2) experiences of households going through post-disaster temporary housing in these types of programs and accommodations. The temporary housing program summaries were developed from program websites and information sheets for obtaining post-disaster assistance, along with other pilot program reports, and manufacturer websites and details; little to no information was found through the peer-reviewed academic literature. The following subsection details temporary housing programs that have been available to households through all or some of the U.S. disaster since 2005 Hurricane Katrina. These programs provide support for temporary housing units, including manufactured housing units, hotel stays, apartment buildings, custom built units, and those utilizing the pre-disaster home.

Current Temporary Housing Programs

FEMA developed a program, Individuals and Households Program (IHP) that provides assistance in wake of disaster. IHP can provide financial assistance, or direct assistance to those victims of disaster who may be underinsured, or not insured at all (FEMA, 2017c). Financial housing assistance can take four forms: rental assistance, home repair assistance, home replacement assistance, and lodging expense reimbursement. Rental assistance includes aid given while repairs are made to pre-disaster homes or other circumstances leading to the transition to permanent housing and may come to aid in renting a home, apartment, manufactured home, recreational vehicle, and the like. Home repair assistance is finance given to homeowners to aid with the repairs, utilities, and private access routes for the home. Financial assistance, in some circumstances, may be given to help replace a homeowner's pre-disaster uninsured, or underinsured, home that was completely destroyed by the particular disaster (FEMA, 2017c). Lodging expense reimbursement can be used for more short-term stays such as those at hotels. Hotels are used as post-disaster housing between the temporary shelter and temporary housing phases. Because of the abundance of hotels and the limited vacancies in other rental properties, hotel stays have become a common form of temporary housing. Hotels accept the FEMA-provided vouchers on a volunteer basis and allow victims to reside throughout the duration of time as specified by FEMA (Hardman, 2016).

Direct housing assistance is used mostly when vacancies in rental properties are high, therefore reducing the number of households that can receive rental assistance. Direct housing takes three different forms: manufactured housing units, Multi-Family Lease and Repair, and permanent of semi-permanent housing construction (FEMA, 2017c). Manufactured housing units (MHUs) are generally the type unit that comes to mind when thinking of common types of temporary housing thought of as the most commonly use temporary housing unit, but these are actually use only as a last resort option (FEMA, 2016a). While millions of Americans live and own their own MHU, and in some cases, in wake of disaster, some households have sufficient funds to purchase their own MHU as part of their own individual housing recovery, but for the duration of this paper manufactured housing units will refer to the specific FEMA-issued manufactured housing units as a temporary housing unit as part of the post-disaster direct housing assistance.

The second form of direct housing assistance is Multi-Family Lease and Repair. This program is designed to aid multi-family residential property owners in repairing their property while allowing displaced households to reside in the units during the allotted temporary housing phase (FEMA, 2013). In order for a property to be eligible for this assistance program, the property must have previously been a multi-family housing property and must be located within the disaster area. A lease agreement value is made based on the fair market rent in the area, the number of units on the property, and the number of months remaining in the specified temporary housing phase. If the total cost of repairs falls in under this lease agreement value, then it is feasible to use the property for the Multi-Family Lease and Repair program, and FEMA will pay the remainder of funds in the form of monthly rent per unit to the landlord. If the cost to repair is the same as the lease agreement value, then FEMA will not pay additional monthly rent to the landlord. If the repair cost exceeds the lease agreement value, then a 25% increase in the fair market rate may be considered, and the property can be re-evaluated for implementation (FEMA, 2013). Other stipulations for this program are that the property must be repaired in two months; it must be in close proximity to everyday community needs such as local schools, grocery stores, and hospitals; and the property must provide all management services as they would have pre-disaster such as building maintenance (FEMA, 2013).

The third form of direct housing assistance is permanent or semi-permanent housing construction. This involves home repairs when other types of financial or direct housing assistance is not feasible or not cost effective (FEMA, 2017c). One particular program that falls in this category is FEMA's Shelter at Home program. The Shelter at Home program is a home repair program that allows homeowner households to reside in their own pre-disaster home as a form of temporary housing (FEMA, 2016b). If repairs can be made to the home to create a safe shelter under the price point of $15,000, then the home can be eligible for this program. An inspector is sent to the home to determine if the home's repairs falls within the allotted funds, and if so, repairs are made by contractors hired by the state. The repairs are supposed to be temporary in nature, creating a safe place to reside while the household takes care of their permanent repairs on their own. Some of these “bare minimum” repairs include mucking out the home, basic restoration and installation of electricity and water heater, removing wet dry-wall and insulation, ensuring one properly working bathroom in the home, and can also include up to $500 in basic cooking and refrigeration appliances (FEMA, 2016b). Some examples of these repairs can be found in figure 1. The Shelter at Home program was implement in Louisiana after the floods throughout the southern part of the state in August 2016. Each home eligible for the program averaged $10,500 in repairs and 3 weeks for repair work to be completed (Crisp, 2017).

Figure 1. Shelter at Home Temporary Repairs (FEMA, 2016b): (a) Exterior Door Replacement; (b) Outlet Replacement; (c) Bathroom Vanity; (d) Kitchen Sink

Two other types of temporary housing programs, independent of FEMA housing assistance, involve custom built units and were developed as a result of previous disasters, Hurricane Katrina and Hurricanes Dolly and Ike, respectively. First, the Katrina Cottage which was created in wake of Hurricane Katrina in 2005. The Katrina Cottage was designed by Marianne Cusato in an effort to develop an alternative to the commonly stigmatized manufactured housing unit. The magnitude of destruction and displacement following Hurricane Katrina gave insight to the short comings of current temporary housing programs and procedures, which lead Cusato to develop a solution that provided a unit that was fast, affordable, and safe while simultaneously providing an attractive place to live with the desired permanency needed to feel comfortable to return back to normal life (Cusato, 2018). Katrina Cottages can be installed temporarily on pre-disaster private property or permanently, to remain on the property after the temporary housing phase (Levine et al., 2007). These units range from 308 ft^2 up to 1807 ft^2 and are built with hurricane resistant materials to withstand winds up to 150 mph (Katrina Cottages, 2006). When implemented along the Gulf Coast after Hurricane Katrina, several variations of the cottage were created with the aid of local architects based on the location of the unit (Miller, 2006). Figure 2 shows the exterior view of a typical Katrina Cottage.

Figure 2. Katrina Cottage (Cusato, 2018)

The second custom built temporary housing unit was designed specifically for the RAPIDO program. This RAPIDO program, along with its RAPIDO units, was developed after Hurricanes Dolly and Ike destroyed a significant portion of the Rio Grande Valley in South Texas in 2008. Brownsville was one of the most affected cities by the hurricanes; which also had the highest concentration of low-income neighborhoods called colonias. Colonias were neighborhoods generally inhabited by Hispanic- and Mexican-Americans with a median income of $28,523. The neighborhoods were significantly underdeveloped, lacking standard housing developments and necessities like water, electricity, and paved streets (Binkovitz, 2016). After Hurricanes Dolly and Ike, more than 578,000 colonia residents applied for disaster assistance, but approximately 85% were denied under the clause "deferred maintenance” (Binkovitz, 2016). Since homes were not in proper condition prior to the storm, a damage assessment could not distinguish what damage resulted from the hurricanes versus the previously existing condition of the home (Zandt and Sloan, 2017). Since disaster assistance was denied, many residents of these low-income communities were forced to stay in their damaged and molded homes with no other option (Binkovitz, 2016). The RAPIDO program was developed to help these vulnerable households.

The concept of the RAPIDO program was to develop a solution specific to a certain community that would easily transition from temporary to permanent housing (Morales-Diaz, 2016). The housing program consisted of a temporary housing “CORE” that families moved into shortly after a disaster. The CORE is expandable thereby creating larger, permanent homes. The program was executed as a three-step process. First the family received a CORE equipped with essential living amenities; the family resided in the CORE for four months while resources were allocated for permanent expansions. Second, as soon as the time came to move forward on the expansions, families met one on one with designers to select a floorplan that best supported their needs and lifestyle (e.g., number of bed and bathrooms). Finally, after the design selections were complete, the CORE expansions began. The expansion process took around 60 days to be completed. Thus, displaced households were back in their permanent home just four months after the disaster, with expanded space just six months after the disaster. The developers of the RAPIDO program worked closely with the residents to make sure that their needs were being met in the design of the home and that the home felt as if it was native to the area. RAPIDO wanted to provide a temporary to permanent solution that households safe and comfortable residing in (Morales-Diaz, 2016). Figure 3 depicts the CORE of the RAPIDO and the eventual expansion to a permanent home.

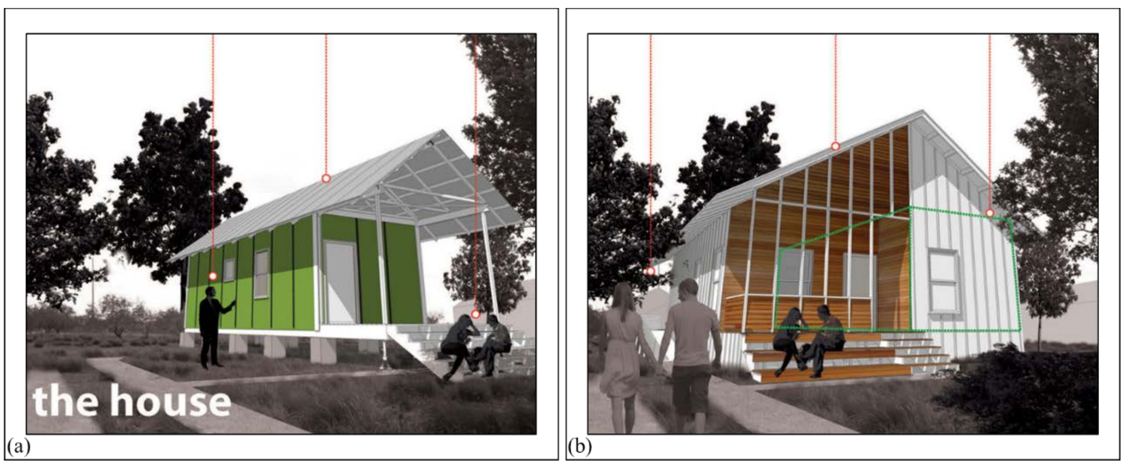

Figure 3. RAPIDO Units (Morales-Diaz, 2016): (a) Temporary CORE; (b) Permanent Home Expansion

Although there are several types of housing assistance provided by FEMA and other new and innovative programs that have been developed, temporary housing accommodations of interest highlighted above are FEMA-issued manufactured housing units, hotel stays, Multi-Family Lease and Repair, Shelter at Home, Katrina Cottages, and RAPIDO. These particular programs have been either used numerous times throughout recent disaster history or have been implemented in great depth allowing for sufficient data collection on household from those residing in these accommodations.

In the next section of the content-analysis, reports, research articles, news articles, and other public records were analyzed to extract qualitative and quantitative experiences of households going through post-disaster temporary housing. Through this analysis, common themes emerged and were consistent across the different types of temporary housing options. In total, seven recurring themes were identified, including ease of transition to permanent housing, location of the unit, economic recovery of the community, job creation for victims, health impacts on victims, customizability of the unit, cost of the unit, and the structural design level of the unit. These themes, or qualities from the household's perspective, inform which temporary housing units were the most or least desirable with respect to different characteristics. This section provides a detailed description of each theme, and anecdotal evidence from the literature and post-disaster reports supporting how each type of temporary housing unit measures against each theme.

Transition to Permanent Housing

The ultimate goal of temporary housing is to provide a temporary place for a household to stay until they can get back into their previous permanent home, or a new permanent home. With this in mind, the development of some temporary housing units has focusing around a smoother transition into permanent housing, including RAPIDO, Katrina Cottages, and FEMA's Shelter at Home and Multi-Family Lease and Repair programs.

RAPIDO has been reported to be the most successful with permanent housing transitions (Morales-Diaz, 2016). Since this program was developed with the thought of creating a temporary to permanent solution, it shines in that regard. As discussed previously, each household receives a “CORE shortly after the disaster and can be expanded to various sizes thereby creating larger, permanent homes. The RAPIDO allows the household to have a smaller, temporary unit equipped with essential living amenities until expansions can be made. As soon as the time came to move forward on the expansions, families do not have to move homes, they can remain in the same home helping their recovery my minimizing resettlement time.

Katrina Cottages also shined with respect to transitioning to permanent housing (Cusato, 2018). These units were installed temporarily or converted to a permanent structure. The units had removable undercarriages in order to be placed on permanent foundations. These units were slightly bigger than the RAPIDO CORE or a typical manufactured housing unit (MHU), either two or three bedrooms which made the permanent installation and acceptance a possibility (ABT Associates, Inc., 2009).

The Federal Emergency Management Agency’s (FEMA) Shelter at Home program also created a smooth temporary to permanent housing transition (FEMA, 2016b). The program was intended for households to come back to a restored house in their familiar community rather than having to move out and resettle in a manufactured housing unit (MHU) (Hardy, 2017a). The temporary repairs included in the program turn a household’s home into a safe place to reside while simultaneously allowing them to start permanent repairs in a timely manner.

FEMA’s Multi-Family Lease and Repair program created a different approach for households to transition from temporary to permanent housing relative to the other programs discussed thus far. This program required the applicant to sign and abide by a FEMA Temporary Housing Agreement which includes the development of a realistic permanent housing plan and requires regular meetings with a FEMA representative to discuss progress towards the pre-established permanent housing plan (FEMA, 2013). Although these households eventually had to move, the program facilitates a permanent solution that made their transition to permanent housing smoother.

FEMA provides two additional temporary housing accommodations, MHUs and hotel stays. These options do not have features that easily transition to permanent housing. They require households to move out of their pre-disaster home into a totally new space, and after some time, move again into a permanent home. This process of moving several times within a single year, or even two years, can increase household and community recovery time, alongside increased distress during the recovery process (Merdjanoff, 2013). The more times a household has to move, the less time they are able to focus their time and energy on reestablishing their everyday routine thereby reaching recovery.

Location

The location of the unit has a direct effect on a household's ability to recover post-disaster because this dictates the access that household will have to employment, childcare, and other essential needs. Some temporary housing units have been developed for specific locations to assist with recovery, for example, a household's pre-disaster property, but some accommodations do not take the ease of access to a household's everyday needs into consideration. Accessibility issues have been made apparent particularly for manufactured homes and hotels. Manufactured housing units can be placed on the household's pre-disaster property or on a newly developed or existing group site where this group site may be in or outside of the disaster-stricken community. Hurricane Katrina demonstrated the recovery setback experienced from using group sites that are far outside of the household's pre-disaster community (Verderber, 2008). Group sites were used after Hurricane Katrina when private property was not available. These group sites heavily affected the transition to permanent housing, especially if the site was isolated from the community and convenient public transportation making everyday tasks, such as grocery shopping, laundry, and commuting to work and school almost impossible (Smith, 2017). Levine et al. (2007) reported one post-Katrina group site was set up in a trailer park in Baker, Louisiana, 91 miles northwest of New Orleans. The site was set up with sewer services, for example, but was completely inaccessible to basic needs due to a lack of transportation made available to the residents (Levine et al., 2007). This remoteness left victims feeling helpless and, in some cases, cost recovery agency employees and volunteer’s money out of pocket to get residents’ basic needs met. In a survey of 47 trailer parks throughout southern Louisiana and Mississippi, only 42% of victims were in close proximity to their original homes (Verderber, 2008), which greatly hindered the ability of residents to return to the city for jobs, schooling and to assist other family members. If manufactured homes were placed on pre-disaster properties, the households were able to begin their damaged home repair process with ease of access to the home. Private-property installation also made it possible to return to the city, one's job, and family (Verderber, 2008).

In addition to MHUs, hotels have been used as a common type of temporary housing. Recent details of their shortcomings have been observed following the August 2016 floods in southern Louisiana. Hotels accept FEMA temporary housing vouchers on a voluntary basis. Therefore, the location of voucher-accepting hotels was not always ideal for displaced households (Hardman, 2016). Similar to group MHU sites positioned far away from the city, hotels positioned far away create travel problems (Weiss, 2016), including difficulty in accessing work, school, laundry services, and food (Hardman, 2016). Weiss (2016) shares a story of a mother and her two sons from Baton Rouge, Louisiana, who were asked to check out of their hotel in Baton Rouge. Unfortunately, the closest available hotel was in Houma, Louisiana, 87 miles south, drastically changing their daily commute times (Weiss, 2016).

When a temporary housing accommodation is located far away, it increases the day-to-day stress experienced by the household. Fortunately, not all temporary housing accommodations need to be positioned far away. As previously stated, the RAPIDO units were created specifically for a community. RAPIDO units were installed and expanded on the household's pre-disaster property, or if a household preferred to move out of the floodplain, the program mandated that the unit still be positioned in the community in order to maintain the togetherness of the household with other community members (Zandt and Womeldurf, 2017). The RAPIDO program focused on keeping residents on their property and in the community to help fulfill their everyday needs while building their community back together (Morales-Diaz, 2016). Similarly, Katrina Cottages were designed to be placed on the household's pre-disaster property and can be left as permanent housing if desired (Levine et al., 2007). Also, similarly, FEMA's Multi-Family Lease and Repair program mandated contracts with properties within "reasonable access", e.g., a distance which does not place an undue burden on an applicant to community services such as schools, fire and emergency services, or grocery stores (FEMA, 2013). Most of the newly developed temporary housing programs have taken location into consideration, but with options like hotels and manufactured housing units, some issues still arise that can create a difficult recovery path for households residing in those particular units.

Economic Recovery and Creating Jobs

The location of the temporary housing unit goes hand in hand with the economic recovery of individual household and the community as a whole. The economy of a community can recover faster if their residents are able to stay within their borders keeping funds circulating within rather than circulating in an outside, and otherwise non-recovering community. Utilizing temporary housing accommodations that can keep residents in the community, such as placing units on pre-disaster property, help with that economic recovery (Verderber, 2008).

The developers of the RAPIDO program worked closely with the residents of the targeted neighborhoods to ensure that not only their everyday needs were being met with the design of the unit, but also to ensure that the local economy was stimulated. In order to do this, residents participated in the rebuilding process. Having the residents involved kept the community together, while allowing them to earn income, either through their previous jobs or through participating in the RAPIDO construction if the disaster left them unemployed. Residents were employed as transporters and builders with both skilled and unskilled labor to slowly restore the local construction economy. Purchasing materials from local suppliers also kept funds circulating in the community. Having community programs and procedures in place such as RAPIDO allows for the funds generally spent on federal administration and implementation to be used for community recovery by putting the funds back into the residents' pockets (Morales-Diaz, 2016).

Both the Multi-Family Lease and Repair, and the Shelter at Home programs allowed for employment of local contractors and construction workers. Since these programs are geared towards repairs to properties, rather than prefabricated, factory-built units, local skilled workers who likely are disaster victims as well, have some sort of income to help with their individual recovery. Kaufmann (2017) reports the experience of one property owner in Baton Rouge, LA whose home repairs were expedited by a 70% improvement in completion time (relative to if he had done the repairs on his own) made possible through the Multi-Family Lease and Repair program.

Health Impacts

A major social consequence following disasters is the widespread impact on physical and mental health. While this is often a result of initial physical damage, specific temporary housing accommodations have initiated or exacerbated health conditions. After Hurricane Katrina, many victims residing in manufactured homes experienced decreasing well-being, and mental and physical health problems (Duara, 2008; Verderber, 2008; McIntosh et al., 2009; 2012). In a survey of 47 trailer parks throughout southern Louisiana and Mississippi, 21% confirmed no type of security available on the grounds at night leading to 49% not feeling safe to walk outside after dark. Even during the daylight hours, 45% did not feel comfortable allowing their children to play outside during the day (Verderber 2008). These obstacles faced in group sites hindered the well-being and comfort of the victims, especially the children.

The mental health of FEMA-issued MHU residents were of large concern in the months following Hurricane Katrina as found in a study by Verderber (2008). Victims in all phases of life were affected: children, adults, and the elderly. Domestic violence, divorce rate, depression, anxiety, sleep disorders, hypervigilance, flashbacks, and suicide rates were all observed to increase after living in a MHU. The mental health of children living in MHUs seemed to deteriorate as well: regressive behaviors, nightmares, increased aggression to others and to one's self, social withdrawal and isolation, nutrition decline, and fear of darkness. In the aged, sleep disorders, memory loss, and disorientation increased were all observed through the study. Loss of appetite, overeating, and a lack of concentration was also observed in the elderly community. Of all the victims included in the Verderber (2008) study, 50% of MHU residents met criteria for major depressive disorder with 15 times as many suicides and 70 times as many suicide attempts than the Louisiana state average.

Households residing in hotels experienced similar mental health impacts as those residing in the FEMA-issued MHUs. Again, using the August 2016 south Louisiana floods as an example, over 750 households were still staying in hotels waiting for the next steps six months after the storm (Hardy, 2017b). With households having to stay in hotels for so long, mental health issues begin to arise. Children staying in hotels were having a hard time adjusting to living in only one room as opposed to a house; anxiety in children was observed to increase because they could not process their current living situation (Hardman, 2016).

A study performed by Abramson et al. (2015) explored the physical health conditions of victims after Hurricane Sandy. The victims of Hurricane Sandy included in this survey are households that remained in their damaged home because no other option was available to them. The study included visiting and interviewing a random sample of 1000 people that were residing in one of the nine New Jersey counties affected by Sandy. Poorer physical health and lower mental health was found in lower income households which was directly attributed to staying in damaged homes. Mold growth was very common in damaged homes; those exposed to mold were 2.5 times more likely to develop asthma and 2 times more likely to experience mental health distress than those not exposed (Soo, 2015).

Units such as the RAPIDO programs and Katrina Cottages sought to relieve some of the stress and mental hardships on disaster victims and develop units that had a more “home” feeling and that also allowed for them to continue every-day activities such as having friends and family over (ABT Associates, Inc., 2009). RAPIDO units tried to implement the local culture in their design to ensure the residents still felt connected to their homes and felt like they could resume their lifestyle and did not feel that their living situation was causing unneeded and unwanted stress (Morales-Diaz, 2016).

Customizability

The ability to customize a temporary housing unit and make it feel like a home had a direct relationship to the well-being of occupants. For example, interior and exterior walls cannot be painted, and locations and layouts cannot be specified in FEMA-issued manufactured housing units. Residents can face legal charges if they try to change any part of the MHU (Verderber 2008). In 2006, one year after Hurricane Katrina, a lawsuit was filed stating that the MHUs and the group sites that a number of them were located in were “unsafe and presenting a clear and present danger to the health and well-being of plaintiffs and their families” (Brunker 2006). Other temporary housing programs and units such as the RAPIDO and Katrina Cottages sought to make the units as customizable as possible by allowing the household to feel like they had some type of control over the unit they were given.

During the implementation of the RAPIDO program, households met one on one with designers to select a floorplan that best meet their needs and lifestyles. These selections included the number of bedrooms, and location of the unit, either back onto the pre-disaster property or another property out of the flood plain (Morales-Diaz, 2016). RAPIDO wanted to ensure that these units could be modified to fit cultural, lifestyle, and environmental factors (Zandt and Womeldurf, 2017). Katrina Cottages also geared their units towards customizability. Designer of the Katrina Cottages, Marianne Cusato believed that it was important to give households an attractive place to live with the desired permanency needed to feel comfortable to return back to a normal life (Cusato, 2018). To achieve this, several variations of the cottage were developed with different architects and designers in different locations along the Gulf Coast (Miller, 2006).

Financial Cost

With all the different types of temporary housing units, financial cost becomes a driving factor. Depending on the situation, government agencies such as FEMA and HUD provide funds for temporary housing units, and in other cases, insurance companies may help with finances, or even the individual household takes care of the cost of the unit. This depends on the financial assistance programs, and if the household applies and is approved for assistance. The financial cost of the units can be dependent on the location of the unit, the size of the unit, or the duration of stay in the unit. At the time of the August 2016 floods in south Louisiana, the cost of installing a FEMA mobile unit on private property was reported as $129,000: $62,500 upfront cost for mobile home; $23,000 for installation; $15,400 for maintenance; $5,000 for transportation; and $23,000 for administrative overhead cost (Allen, 2016). The total cost for installation in a pre-existing commercial mobile home park was $149,000 (Allen, 2016). For the same disaster, as of May 31, 2017, which is about nine months after the event, FEMA had paid approximately $42 million in hotel stays which averaged to $103 per night per room (Jones, 2017). If assuming an 18-month temporary housing phase, this nightly average amounts to approximately $55,600, which is approximately 43% cheaper than a pre-disaster property FEMA-issued manufactured home.

The "Shelter at Home Program" makes temporary repairs to homes if it can be made livable for under $15,000 with the state's approval. FEMA funds these temporary repairs leaving the homeowners to fund more permanent repairs. Although the cap is $15,000 when this program was implemented in Louisiana after the 2016 floods, the average for repairs was $10,500 per home (Crisp, 2017). It is stated in the Multi-Family Lease and Repair program outline by FEMA and the US Department of Homeland Security that FEMA shall determine the "value of the lease agreement” by multiplying the monthly fair market rent by the number of units, and then multiplying by the number of months remaining between the date the repairs are completed and the end of the 18 month period of assistance (FEMA, 2013). For example, if this program is implemented in Baton Rouge, Louisiana, the fair market rent for East Baton Rouge Parish for two-bedrooms is $906 (HUD User, 2018), and the full 18 months of temporary housing are needed, the total cost, per household would be about $16,300.

The RAPIDO program, as well as the Katrina Cottages wanted units that would not cause as much of a heavy finance burden as the manufactured units. An estimated cost for a RAPIDO three-bedroom expansion is $69,000 (Simone, 2015). A Katrina Cottage can generally be delivered for approximately $70,000 which includes construction (Katrina Cottage, 2006). Many of these alternative housing units are significantly less in financial cost than the estimated amount for manufactured housing units.

Structural Design Level

One of the most important qualities of temporary housing units is the structural design level of the unit. Some issues were seen with manufactured housing units at the time of Hurricane Katrina. The units, proved to be unsustainable since they were only designed to withstand 40 mph (Verderber, 2008). Although this meets FEMA’s minimum requirement, it falls much shorter than ASCE 7 (2005) and HUD’s Manufactured Home Construction and Safety Standards (1994) wind loads. Thus, the structures put occupants at risk to high winds, making them susceptible to future disasters. This was especially concerning since many residents stayed in these units for six more hurricane seasons. Since the demand for temporary housing was so high in the aftermath of Katrina, the travel trailer units distributed to victims were built using the least expensive materials and methods that were the most readily available which included steel framing, foam-insulated panels, and manufactured wood interiors (McIntosh, 2008). They were constructed very quickly to meet the high demand, but the expedient construction backfired when a number of units were found to be unhealthy for residency and not sustainable (McIntosh et al., 2009).

Structural design level is another quality where Katrina Cottages and RAPIDO units shined by designing their units to be more resistant against higher winds. The creators of the Katrina Cottage wanted to develop a unit that was sustainable to prevent damage from future storms, with the regional and community culture, condition, and climate, while avoiding the issues with past temporary housing options (McIntosh et al., 2009). This was done by designing the units to withstand winds up to 150 mph and built with hurricane resistant materials (Katrina Cottage, 2006). Taking the design one step further, all plans available were reviewed by a professional engineer, and moving forward, should be reviewed by a local professional to make sure the design meets local installation requirements (Cusato, 2018). RAPIDO units were also built to use readily available and standardized materials in an intuitive design that can quickly by built by unskilled labor and can be replicated at various scales (Morales-Diaz, 2016). After the additions to the CORE were completed, the families had a permanent home that surpassed the structural integrity and safety of their pre-disaster home, thus preparing for future disasters. Residents had the decision to install the CORE on their pre-disaster property or relocate out of the flood plain to a different location. Homes located in the flood plain were elevated 1.5 to 2 feet above the ground to setback future flooding and damage (Zandt and Womeldurf, 2017). Elevated homes were strapped down and raised on piers along with a simple foundation system. Keeping residents on their property through both temporary and permanent housing phases avoided long spans of displacement and ease of overall community recovery. These households were able to fulfill their everyday needs while building their community back together (Morales-Diaz, 2016).

Table 1 summarizes the seven themes extracted through the content-analysis presented above on post-disaster temporary housing. The information in table 2 is used to suggest an optimal temporary housing unit for a particular household based on their needs and preferences in post-disaster recovery.

Table 2. Household Experiences in Temporary Housing

Temporary Housing Unit	Information	Theme	Source
Shelter at Home Program	These essential emergency cleanup and minor repairs help households get a jumpstart on their full recovery and live in at least a portion of their home, while they continue to finish the big task of making permanent repairs to their home.	Transition to permanent housing	FEMA, 2016b
Shelter at Home Program	Government officials would like the community to be able to come back to a restored house rather than having to move out and resettle in manufactured homes	Transition to permanent housing	Hardy, 2017a
Multi-Family Lease and Repair Program	Applicant eligibility requires the signing and abiding by a FEMA Temporary Housing Agreement which includes a realistic permanent housing plan (PHP) and requires regular meetings with FEMA representatives to discuss progress towards the established PHP	Transition to permanent housing	FEMA, 2013
RAPIDO units	Consists of a temporary housing “CORE” that families move into a disaster that can be expanded to create larger, permanent homes later	Transition to permanent housing	Morales-Diaz, 2016
Katrina Cottage	Can be installed temporarily or converted to be permanent	Transition to permanent housing	ABT Associates, Inc., 2009
Katrina Cottage	Two and three bedroom have a removable undercarriages in order to be placed on permanent foundations if need be	Transition to permanent housing	ABT Associates, Inc., 2009
Manufactured housing units	Group sites inaccessible or isolated from other community sectors made everyday tasks (grocery shopping, laundry, and commuting to work and school) almost impossible	Location	Smith, 2017
Manufactured housing units	One group site was located in Baker, Louisiana 91 miles northwest of New Orleans after Katrina	Location	Levine et al., 2007
Hotels	Staying in hotels significant distances away from home created severe travel problems	Location	Weiss, 2016
Hotels	Issues arose with getting to work and getting children to school, but also smaller inconveniences such as traveling for laundry and for food	Location	Hardman, 2016
Multi-Family Lease and Repair Program	The property must be within reasonable access (A distance which does not place an undue burden on an applicant) to community services such as schools, fire and emergency services, grocery stores, etc.	Location	FEMA, 2013

Katrina Cottage	Can be placed in the household's pre-disaster property and can be left after reconstruction	Location	Levine et al., 2007
Manufactured housing units	The close proximity to permanent residence allow for repairs to begin on the damaged home and also make it possible to return to the city, one's job, and family	Location and economic recovery	Verderber, 2008
RAPIDO units	Keeping residents on their property and in the community help fulfill their everyday needs while building their community back together	Location and economic recovery	Morales-Diaz, 2016
RAPIDO units	Purchasing materials from local suppliers also kept funds circulating in the community	Economic recovery	Morales-Diaz, 2016
RAPIDO units	RAPIDO allows for funds generally spent on federal administration and implementation to be used for community recovery by putting funds back into the residents' pockets	Economic recovery	Morales-Diaz, 2016
Multi-Family Lease and Repair Program	Expedites completion time for multi-family housing owners by about 70%	Creating jobs	Kaufmann, 2017
RAPIDO units	Residents can be employed as transporters and builders with both skilled and unskilled labor to slowly restore the local construction economy	Creating jobs	Morales-Diaz, 2016
Manufactured housing units	Domestic violence, divorce rate, depression, anxiety, sleep disorders, hypervigilance, flashbacks, and suicide rates were all observed to increase	Health impacts	Verderber, 2008
Manufactured housing units	Children showed signs of regressive behaviors, nightmares, increased aggression, social withdrawal and isolation, nutrition decline, and fear of darkness.	Health impacts	Verderber, 2008
Manufactured housing units	Elderly experienced sleep disorders, memory loss, disorientation, loss of appetite, overeating, and inability to concentrate	Health impacts	Verderber, 2008
Manufactured housing units	50% of group site residents met criteria for major depressive disorder	Health impacts	Verderber, 2008
Manufactured housing units	15 times as many suicides and 70 times as many suicide attempts than the Louisiana state average from those living in group sites	Health impacts	Verderber, 2008
Manufactured housing units	47 out of 50 group sites parks in Louisiana and Mississippi participated in a survey: 21% confirmed no type of security on the grounds at night	Health impacts	Verderber, 2008
Manufactured housing units	47 out of 50 group sites in Louisiana and Mississippi participated in a survey: 49% did not feel safe to walk outside at night	Health impacts	Verderber, 2008
Manufactured housing units	47 out of 50 group sites in Louisiana and Mississippi participated in a survey: 45% did not feel safe to allow children to play outside during the day	Health impacts	Verderber, 2008
Hotels	Children staying in hotels were having a hard time adjusting to living in only a room as opposed to a house	Health impacts	Hardman, 2016
Hotels	Anxiety in children was increasing because they could not understand the reason of their current living situation	Health impacts	Hardman, 2016
Damaged Home	If exposed to mold two times more likely to develop moderate to severe mental health distress	Health impacts	Abramson et al., 2015
Damaged Home	15% of residents had asthma during time of survey for Hurricane Sandy and 19% of them were diagnosed after the storm	Health impacts	Abramson et al., 2015

Damaged Home	Some toxins in damaged homes had “double-barreled effects”- exposure to mold was associated with both clinically-diagnosed asthma and with mental health distress	Health impacts	Abramson et al., 2015
Katrina Cottage	Mental health was preserved with the cottages "feeling more like home" as well as being able to continue every-day activities such as having friends and family over	Health impacts	ABT Associates, Inc., 2009
Manufactured housing units	Interior and exterior walls could not be painted; locations and layouts could not be specified	Customizability	Verderber, 2008
Manufactured housing units	Residents could face legal charges if they tried to change any part of the unit	Customizability	Verderber, 2008
RAPIDO units	Households meet one on one with designers to select a floorplan that best meet their needs and lifestyles	Customizability	Morales-Diaz, 2016
RAPIDO units	Residents can install the CORE on pre-disaster property or relocate out of the floodplain	Customizability and location	Zandt and Womeldurf, 2017
RAPIDO units	The home can be modified to fit cultural, lifestyle, and environmental factors	Customizability	Morales-Diaz, 2016
Katrina Cottage	several variations of the cottage were made with different architects and designers in different locations along the Gulf Coast	Customizability	Miller, 2006
Katrina Cottage	Katrina Cottages developed into the design of various options	Customizability	McIntosh et al., 2009
Manufactured housing units	The cost of installing a FEMA mobile unit on private property was reported as $129,000: $62,500 upfront cost for mobile home; $23,000 for installation; $15,400 for maintenance; $5,000 for transportation; and $23,000 for administrative overhead cost	Financial cost	Allen, 2016
Manufactured housing units	Cost estimates in a pre-existing commercial park for mobile homes- $149,000	Financial cost	Allen, 2016
Hotels	As of May 31, 2017, FEMA had paid approximately $42 million in hotel stays which averaged to $103 per night per room	Financial cost	Jones, 2017
Shelter at Home Program	If a home could be made livable for under $15,000 with the state’s approval, then FEMA would fund these temporary repairs leaving the homeowners to fund more permanent repairs	Financial cost	Crisp, 2017
Multi-Family Lease and Repair Program	FEMA shall determine the "value of the lease agreement" by multiplying the monthly Fair Market Rent by the number of units, and then multiplying the number of months remaining between the date the repairs are completed and the end of the 18-month period of assistance	Financial cost	FEMA, 2013
RAPIDO units	$69,000 for a three-bedroom home	Financial cost	Simone, 2015
Katrina Cottage	including construction, Katrina Cottages can be delivered for approximately $70,000	Financial cost	Katrina Cottage, 2006
Manufactured housing units	Built using least expensive materials and methods that are the most readily available; constructed very quickly to meet demand; backfired when found to be unhealthy and not sustainable due to building materials and processes	Structural design level	McIntosh et al., 2009

Manufactured housing units	At the time of Katrina, designed to only withstand 40 mph winds which are FEMA's minimum requirements	Structural design level	Verderber, 2008
Shelter at Home Program	Reliability of shelter in place is dependent on severity of disaster	Structural design level	Zandt and Womeldurf, 2017
RAPIDO	The purpose was to develop an intuitive design that uses readily available and standardized materials, is able to be quickly built by unskilled labor, and can be replicated at various scales	Structural design level	Morales-Diaz, 2016
RAPIDO	Home is designed to construction standards that make the home more resistant to future disasters	Structural design level	Morales-Diaz, 2016
RAPIDO	In most cases the units are going back on pre-disaster property, so any homes that are in the flood plain can be elevated 1.5 to 2 feet off the ground to keep water out of the home	Structural design level	Zandt and Womeldurf, 2017
Katrina Cottages	Built to withstand the remainder of hurricane season with winds up to 150 mph	Structural design level	Katrina Cottage, 2006
Katrina Cottages	Built with hurricane-resistance materials	Structural design level	Katrina Cottage, 2006
Katrina Cottages	All plans have been reviewed by a professional engineer, but should be reviewed by a local professional to make sure it meets local requirements of installation location	Structural design level	Cusato, 2018
Katrina Cottages	The idea was to create something that was sustainable to prevent damage from future storms, with the regional and community culture, condition, and climate, while avoiding the issues with past temporary housing options.	Structural design level	McIntosh et al., 2009

Vulnerable Populations

The literature also presented another vital topic that highlights ongoing issues with temporary housing. Disparities in timing, quality, and location of temporary housing have been observed after the past decade of disasters (Sutley and Hamideh, 2017). The specific needs of socially vulnerable households are often overlooked in the existing recovery programs: most live in hazard prone areas, have lower quality housing construction, live in poorly built neighborhoods, are renters (and therefore have less control over dislocation decisions, as well as not applicable for recovery funds), have lower incomes, savings, and often do not have insurance, thus further hindering households' abilities to recover (Quarantelli, 1995; Sutley and Hamideh, 2017). To receive certain types of aid after a disaster, specific criteria must be met, and losses must be proven. Oftentimes, low income, and racial and ethnic minority households do not have enough possessions pre-disaster to demonstrate substantial loss caused by the disaster or the required paperwork demonstrating ownership of their home, thus those with higher property values receive more aid by proving greater losses (Van Zandt and Sloan, 2017). Vulnerable populations, specifically low-income households, who experience issues receiving financial aid recover slower as a direct result (Bolin, 1991; Kamel and Loukaitou-Sideris, 2004).

The 1994 Northridge earthquake in Los Angeles, California brought one of the first true realizations of recovery issues within a community stemming from inequalities in distribution of temporary housing. Slower recovery rates were observed for socially vulnerable, or otherwise marginalized, households (Comerio, 2006). The temporary housing programs were observed to produce varying recovery processes and rates based on household characteristics such as race, ethnicity, income, tenure status, and residency situation (Kamel and Loukaitou-Sideris, 2004). Of all the units damaged in the Northridge earthquake, 60,000 were severely damaged which consisted mostly of apartment buildings (Comerio, 1997). Although a significant number of the damaged units were multi-family housing, only 16% of funding went to those units while 59% of funding went to single family home owners (Kamel and Loukaitou-Sideris, 2004).

The RAPIDO program was developed for Brownsville, Texas, one of the most heavily impacted cities by both Hurricanes Dolly and Ike in 2008. The program's goal was to aid specific neighborhoods, colonias that were concentrated with low-income, Hispanic- and Mexican-Americans residing in significantly underdeveloped homes. After Hurricanes Dolly and Ike, these households were forced to reside in their damaged and molded home because no funding or housing assistance was available to them due to deferred maintenance (Binkovitz, 2016). The RAPIDO program was developed to help these vulnerable households because the resilience of a community can be undermined when different segments of the population recover at different rates, some are left behind while others return to pre-storm conditions or even leap ahead (Zandt and Sloan, 2017).

Hurricane Sandy presented alarming statistics regarding low income populations. In the same study by Abramson et al. (2015) discussed previously, it was found that those with lower income have the greatest assistance needs, but those with higher income are more likely to apply for assistance. Poorer health was found in households after the storm with income less than $20,000 when race, age, and gender were controlled. In addition, those households in the low-income bracket experienced lower mental health after the storm.

The south Louisiana August 2016 floods presented information on how renters and other vulnerable populations were treated with respect to temporary housing programs. Renters were put in a tough position after disasters because more often than not, landlords make decisions for their rental properties, meaning occupants are often not consulted for their opinions although the decisions affect them directly and leave them without a form of housing (Van Zandt & Womeldurf, 2017). Six months after the flooding a state total of 750 households, most of whom were pre-disaster renters, were still in hotels waiting the next phase of house (Hardy, 2017b). Those still using assistance 9 months after the storm are households headed by elderly, low-income families that were struggling to make ends meet pre-disaster, and those without insurance (Jones, 2017).

Table 3 summarizes these important observations on post-disaster temporary housing experiences of vulnerable populations throughout recent disasters.

Table 3. Vulnerable Populations in Temporary Housing

Disaster, Year	Information	Source
Consistently observed prior to 1995	Differences in social classes govern the differences in acceptability of mobile homes as temporary housing	Quarantelli, 1995
	Renters have a harder time recovering and have a harder time returning post-disaster	Quarantelli, 1995
	Multi-family dwellings are often not a priority post-disaster which are the main form of housing for renters	Quarantelli, 1995
Northridge Earthquake, 1994	Multi-family and rental households have a harder time receiving necessary aid typically because these groups of people tend to include large number of marginalized groups	Kamel & Loukaitou-Sideris, 2004
	Communities isolated from society have a harder time recovering than those that are well integrated	Kamel & Loukaitou-Sideris, 2004
	Those that are considered to be marginalized in some type of way from what a "normal" life looks like tend to be the ones receiving less aid, suffer more losses, having longer recovery time, and having higher recovery costs	Kamel & Loukaitou-Sideris, 2004
	Some examples of those marginalized groups, classified as more vulnerable: live in hazard prone areas, lower quality construction, poorly built neighborhoods, lower finances for recovery	Kamel & Loukaitou-Sideris, 2004
	For multifamily housing owners to receive aid for their properties, business profitability had to be proven which is exceptionally hard to do in run-down, low-income neighborhoods	Kamel & Loukaitou-Sideris, 2004
	Higher value homes and property showed higher losses because of the higher value	Kamel & Loukaitou-Sideris, 2004
	Those with lower value property and contents could not demonstrate high enough losses to qualify for sufficient or prioritized funding	Kamel & Loukaitou-Sideris, 2004
Hurricane Katrina, 2005	Those who lived in mobile homes prior to the flood have no location for a new mobile home because the site was destroyed, and local policies limited possible mobile unit locations	Rumbach et al., 2014
Hurricanes Dolly and Ike, 2008	85% of applicants from impoverished communities were denied financial assistance because of "deferred maintenance" meaning homes were not up to code prior to the storm, so it was hard to distinguish between hurricane damage and the pre-disaster condition	Binkovitz, 2016
	When different segments of the population recover at different rates, some are left behind while others return to pre-storm conditions or even leap ahead, the resilience of a community can be undermined	Van Zandt & Sloan, 2017
	Neighborhoods that are home to socially vulnerable populations are likely to experience the greatest needs in post-disaster recovery.	Van Zandt & Sloan, 2017
	Many households were living in molded and damaged homes post-disaster because they had no other option	Binkovitz, 2016
Hurricane Sandy, 2012	Those with lower income have the greatest assistance needs, but those with higher income are more likely to apply for assistance	Abramson et al., 2015
	Poorer health was found in households after the storm with income less than $20,000 when race, age, and gender is controlled	Abramson et al., 2015
	Low income households experienced lower mental health after the storm	Abramson et al., 2015
LA Floods,	Those still using assistance (9 months after the storm) are households	Jones, 2017

August 2016	headed by elderly or low-income families that were struggling to make ends meet pre-disaster and those without insurance	
	Six months after the flooding a state total of 750 households, most of whom were pre-disaster renters, were still in hotels waiting the next phase of house	Hardy, 2017b
	Landlords make decisions for rental properties, meaning renters are often not consulted for their opinions although the decisions affect them directly	Van Zandt & Womeldurf, 2017

CHAPTER IV. CONCEPTUAL FRAMEWORK

In an effort to close the gap on disparities in temporary housing and to ensure victims of disasters have a temporary housing accommodation that helps their recovery, rather than hurts, a new approach for selecting temporary housing units based on household needs and preferences was developed and is presented here. The approach seeks to incorporate the common themes extracted from the content-analysis and includes two interconnected loops, one at the household-level and one at the community-level as shown in figure 4.

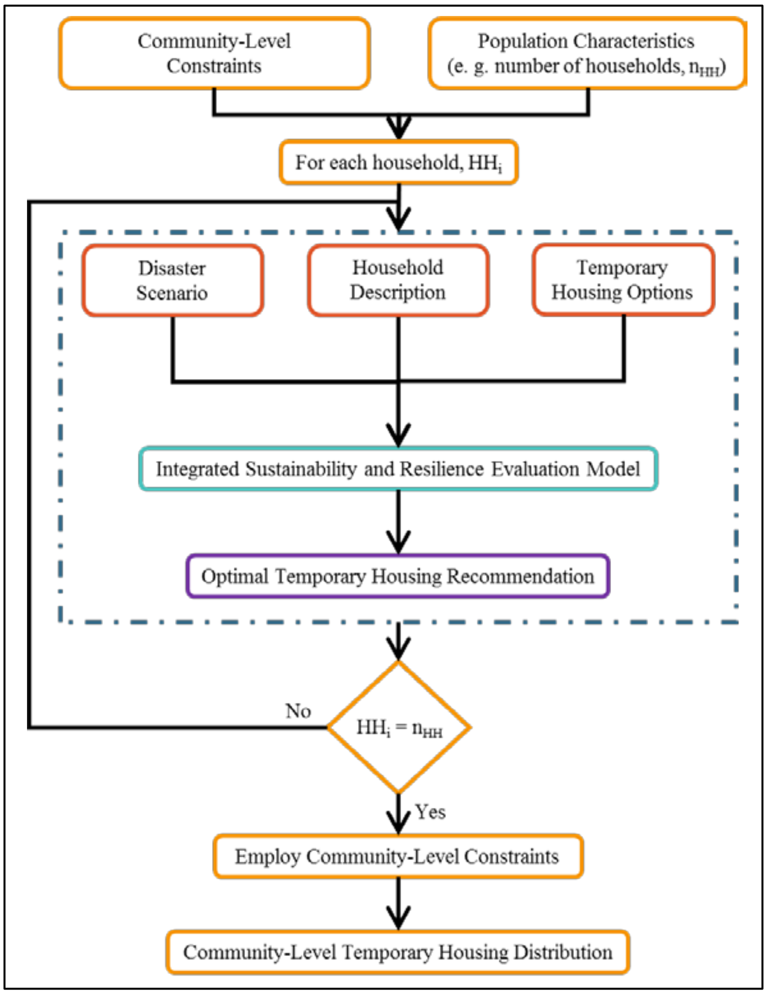

Figure 4. Temporary Housing Evaluation Framework

First, the proposed approach at the household level, shown in figure 5, includes a new integrated sustainability and resilience evaluation model that is applied to the existing types of temporary housing units to recommend an optimal temporary housing solution based on the disaster, household, and the types of units available. The model is designed to take into account the individual household's needs and preferences.

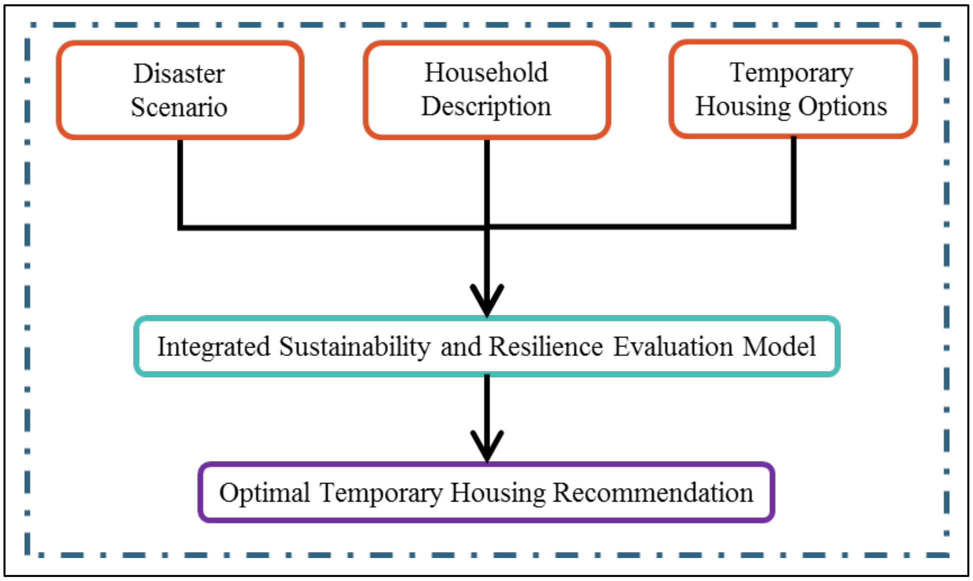

Figure 5. Temporary Housing Evaluation Household-Level Framework

The first input is a disaster scenario that defines the type of hazard and the level of damage to the pre-disaster home. The type of hazard is crucial to understanding what types of damage should be expected. For example, hurricanes and earthquakes have widespan damage impacting entire cities or coastlines, while tornadoes create more localized damage. This helps in anticipating the amount of people who would be in need of temporary housing options and how versatile the units must be to accommodate a large number. The type of hazard also dictates the types of dislocation that can be expected. Hurricanes can be predicted to a certain extent allowing households to evacuate prior to the storm in most cases, while residents are most likely in buildings and in the middle of the hazard for earthquakes and tornadoes. The severity of damage is also a dislocation time estimator. The more damage, the longer the household will be displaced due to longer repair times, and the lower damage the quicker the household can get back into their homes.

Second, the household description details the particular household being considered, including their household size and structure, (i.e., how many people live in the home, whether there are children), economic status, employment stability, and insurance coverage. These characteristics can lead to households having different needs and preferences in temporary housing accommodations based on their pre-disaster status. Some households may need larger units based on household size. Some may need assistance with only minor repairs, while others may need assistance that will provide them a more permanent solution depending on their insurance coverage and financial stability. One other specification in the household description is their tenure status. This specifies whether the household owned a home or rented a property, in which case their needs in temporary housing accommodations would vary. This input also specifies the structural reliability of their pre-disaster home if the home was owned by the household. The structural reliability of the home can be classified as either structurally sound or structurally deficient. Structurally sound means that the building complies with current or more recent building codes, therefore predicted to sustain less damage. Structurally deficient homes are assumed to be made with outdated codes or no codes at all, therefore sustaining much larger amounts of damage. These qualities and descriptions of households can distinguish which households may be considered marginalized and need more assistance in certain aspects in post-disaster recovery from the underlying pre-disaster social vulnerability.

Third, the types of temporary housing to be evaluated are input. This can include any type of temporary housing unit, for example, manufactured homes, custom built cottages and housing units, and other federally and privately funded programs. Temporary housing accommodations that have been found throughout the literature include programs that have been developed by FEMA (i.e., Shelter at Home and Multi-Family Lease and Repair programs), other accommodations provided by FEMA (i.e., manufactured housing units and hotel stays), privately developed programs and units such as RAPIDO and Katrina Cottages, and even staying in a damaged home if no other options are available. In order to evaluate the temporary housing options accurately, enough information must be available to assess the units on each of the sustainability and resilience qualities.

All three input categories feed into the integrated evaluation model which is comprised of two parts: first, the evaluation of temporary housing units using qualities, and second, determining the overall quality of life of a household residing in a particular unit. The first step of the evaluation model includes eight different qualities of temporary housing units. The qualities are shown in figure 6 fall under resilience, sustainability, or both. While there are a number of other qualities and important details that could also be used for assessment, the ones selected here best reflect the common themes found from the content-analysis of the literature presented in Chapter 3. Some themes encompass multiple qualities, and some qualities combine more than one theme, but overall the recurring positive and negative experiences that have been recorded and found in the literature across all types of post-disaster temporary housing are shown through these particular qualities. Transition to permanent housing is implemented as adaptability, meaning how adaptable the structure is. Economic recovery, location, and creation of jobs all feed into population stability. Structural design level breaks down into two qualities, namely, structural integrity and hazard vulnerability. Health impacts, customizability, and financial cost are all mirrored in these qualities. The following sections provide the quantitative formulation for each quality. These formulations are based on specific measurement criteria derived from theoretically-based definitions of the characteristic.

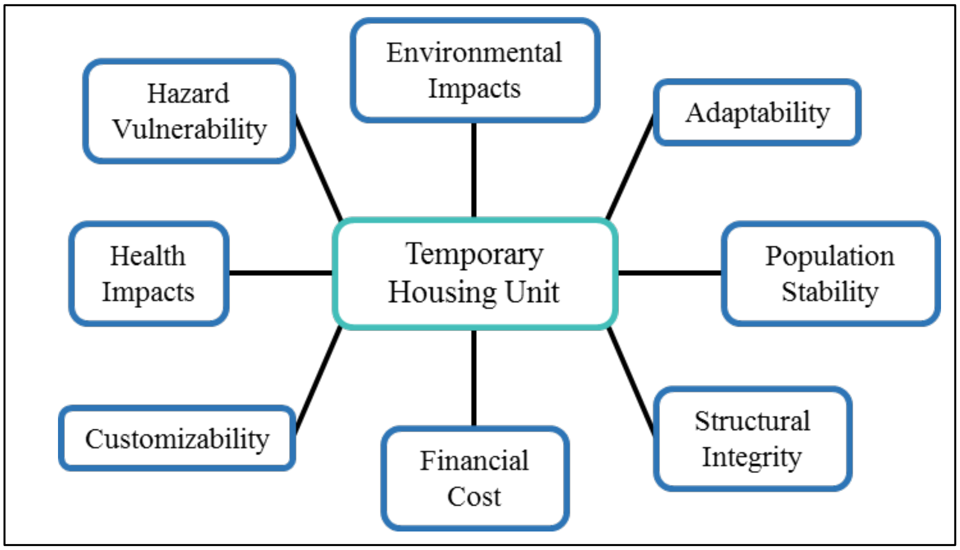

Figure 6. Temporary Housing Qualities

Adaptability

The adaptability, $A(j)$, of a temporary housing unit j is defined in two different ways, with respect to the unit itself, and with respect to the associated program. With respect to the temporary housing unit, adaptability is the ability to transition into permanent housing without having to move into another unit. On the temporary housing program level, adaptability can also mean that the program requires a permanent housing solution before moving into the temporary housing unit. Here, adaptability is measured as a binary quality: the temporary housing accommodation is either adaptable (1), or not (0), expressed as

$$A(j) = \begin{cases} 0 & \textit{not adaptable} \\ 1 & \textit{adaptable} \end{cases} \tag{1}$$

Customizability

The customizability, $C(j)$, of a temporary housing unit j accounts for the number of features that a household can choose or change in order to fit their specific needs. Here, customizability is measured with three possibilities, c_i: customizable interior or exterior appearance and decor, customizable layout or size of the temporary housing unit, and the ability to choose the geographic location of the temporary housing unit. Customizability is measured on a scale of 0 to 3 depending on how many customizable features the unit provides, expressed as

$$C(j) = \sum_{i=0}^{3}(c_i) \tag{2}$$

Population Stability

Population stability, $P(j)$, measures the ability to keep the local economy stimulated after the disaster by keeping the household inside the community. In this study, population stability consists of two scenarios, p_i: (1) the location of the temporary home allows for a circulation of funds within the disaster-stricken community helping to build the economy back; and (2) the temporary housing program creates jobs for those who may be out of work post-disaster. $P(j)$ is measured on a scale of 0 to 2 depending on how the temporary housing unit can stimulate the local economy, expressed as

$$P(j) = \sum_{i=0}^{2}(p_i) \tag{3}$$

Environmental Impacts

Environmental impacts, $E(j)$, are measured here as greenhouse gas emissions for each type of temporary housing j. The total emissions seen during the lifetime of the building is the summation of the greenhouse gas emitted during each of the four life cycle phases, e_i: production, construction, use, and end of life, expressed as

$$E(j) = \sum_{i=0}^{4}(e_i) \tag{4}$$

To measure e_i or $E(j)$, life cycle assessment (LCA) can be performed using a commercially available software, such as ATHENA Impact Estimator for Buildings (ATHENA, 2017).

Health Impacts

Health impacts, $H(j)$, account for potential mental and physical health impacts caused by residing in a temporary housing type j. Mental health impacts could include depression, anxiety, sleep disorders, hyper-vigilance, suicide accounts and attempts, regressive behaviors, social withdrawal and isolation, memory loss, disorientation, and lack of concentration (Verderber, 2008). Physical health impacts could include domestic violence, headaches, nausea, vomiting, asthma diagnosis, and respiratory issues (Verderber, 2008). $H(j)$ is measured as a binary variable: (0) if reports are available on health issues stimulated from residing in the particular type of temporary housing; (1) if no health issues were previously documented, expressed as

$$H(j) = \begin{cases} 0 & higher\ potential\ for\ health\ issues \\ 1 & lower\ potential\ for\ health\ issues \end{cases} \tag{5}$$

Financial Cost

Financial cost, $F(j)$, is estimated here as the dollar price required to fabricate, transport, and install the temporary housing unit or accommodation. The total cost of the unit can include any combination of the fabrication, transportation, and installation phases, f_i, that are applicable to the unit or accommodation in question, therefore $F(j)$ can be expressed as

$$F(j) = \sum_{i=0}^{3}(f_i) \tag{6}$$

Structural Integrity

Structural integrity, $S(j)$, is defined here as the ability of the temporary housing unit to meet full service load and functionality requirements. Damage states categorize physical damage into five levels (0 to 4), namely no damage, minor damage, moderate damage, severe damage, and complete damage, respectively. Table 4 provides brief, general descriptions of typical occupancy statuses and repairs required to buildings at each of these damage states.

Table 4. Damage States and Descriptions

Damage State		Description
0	None	Building is safe for continued occupancy; no repairs required.
1	Minor	Building is safe for continued occupancy; minor repairs required.
2	Moderate	Shelter-in-place allowed; moderate repair and replacement required.
3	Severe	Shelter-in-place prohibited; structural damage or other life-threatening hazards incurred.
4	Complete	Building is not safe for entry and must be reconstructed.

Values between 0 and 3 are assigned to each temporary housing j based on its damage state during occupancy, assuming that no one could still live in a damage state 4. In most cases, $S(j)$ equals zero. When a household decides to shelter in place in their damaged residence instead of dislocating, $S(j)$ exceeds zero, expressed as

$$S(j) = \begin{cases} 0 & No\ Damage \\ 1 & Minor\ Damage \\ 2 & Moderate\ Damage \\ 3 & Severe\ Damage \end{cases} \tag{7}$$

The probability that a particular damage state will occur is conditioned on a hazard intensity measure (e.g., wind speed for wind hazards; spectral acceleration for seismic). Building performance curves provide the probability of not reaching or exceeding a particular damage state given a certain value of the hazard intensity measure (IM), expressed as. Therefore, the probability of not exceeding (PNE) a specific damage state, DS, can be expressed as

$$PNE = P[DS \leq ds | IM = i] \tag{8}$$

The non-exceedance probability expressed in Eq. (8) is referred to as a building performance curve, which are determined through numerical simulations performed on building models to develop a relationship between the appropriate hazard intensity measure (and appropriate range) with physical damage while accounting for epistemic and aleatory uncertainty.

Hazard Vulnerability

Hazard vulnerability, $V(j)$, is defined here as the ability of the temporary housing unit to withstand future disasters. Temporary housing has a FEMA-specified duration of 18 months, but in many cases, it exceeds this time meaning that households may have to endure additional disaster seasons in a temporary housing unit, or additional disasters in the same season (McIntosh, 2008; Muskal, 2012). Building performance curves used for structural integrity can also be used for measuring hazard vulnerability. Using equation 8, the 50^{th} percentile hazard intensity measure at each damage state is recorded for measuring hazard vulnerability. The temporary housing type with the highest 50th percentile IM for a particular damage state has the lowest hazard vulnerability. This means that the unit can experience a greater IM before that particular level of damage is reached. The 50th percentile IMs, w_i, for each temporary housing unit, j, from building performance curves are normalized with respect to the maximum 50th percentile IM for all temporary housing types at that specific damage state, i, expressed as

$$v_i(j) = \frac{w_i(j)}{\max_j w_i(j)} \tag{9}$$

The normalization step is added here to capture how each of the units at a particular damage state perform in comparison to the maximum performing unit at that damage state. The normalized values are summed across damage states for each temporary housing j to determine the hazard vulnerability score, $V(j)$, expressed as

$$V(j) = \sum_{i=1}^{4} v_i(j) \tag{10}$$

Quality of Life Index

The quality of life index, $Q(j)$, measures the overall potential well-being of a household residing in a particular temporary housing unit j based on their self-identified needs. To formulate the quality of life index, the values of each quality for each type of temporary housing unit are summed. Depending on the pre- and post-disaster situation, households may value some qualities higher than others, thus weights, w_i, are applied to each quality measure to account for household preference, expressed as

$$Q(j) = \sum_{i=1}^{8}(w_i * q_i) = w_1 * A(j) + w_2 * C(j) + w_3 * P(j) + w_4 * E(j) + w_5 * H(j) + w_6 * F(j) + w_7 * S(j) + w_8 * V(j) \tag{11}$$

The weights should be set by the household, and not assumed for them. The resulting $Q(j)$ for each type of temporary housing is compared in the evaluation model. The highest quality of life index provides the optimal temporary housing accommodation for that particular household. The developed framework can be implemented in one of two ways, at the household level and at the community level. The procedure described above with the formulation of the quality of life index reflects the implementation at the individual household level. The framework allows for the selection of a particular temporary housing unit based on one specific type of household in consideration.

While ensuring a household's quality of life is important in post-disaster temporary housing, community-level constraints and restrictions tend to drive the selection of temporary housing accommodations. The household level framework discussed above can be scaled back to a community-level analysis, as shown in figure 4. The community-level framework, whether that be at the city-level, county-level, or state-level shows that additional constraints outside of household needs and preferences must be considered. Two inputs are used at the community level, the first being community restraints, and the second population characteristics. Any restrictive details are what must be included in the community-level constraints input. This will, most importantly, include a budget for temporary housing, as well as other limitations such as what units are available, at what quantity are they available, and timing of delivery to the household. The population characteristic input includes information on the various types of households in need of a temporary housing unit. These population characteristics feed directly into the household description of the household-level analysis. The household level analysis is iterated until each household in the community has been recommended a temporary housing accommodation through the quality of life index. While the quality of life for households residing in a temporary housing unit is of high priority in this work, more often than not, it will not be feasible for a community to provide each household with their optimal unit. The next step is to employ the community level constraints, along with the individual households' quality of life in order to develop a temporary housing recommended distribution for the entire community.

CHAPTER V. EXEMPLIFYING FRAMEWORK

With the extensive information pulled from the literature and the quality quantifications formulated, the integrated sustainability and resilience model can be implemented to recommend an optimal temporary housing unit for a household and assignments across a community. Nine types of temporary housing units were used to exemplify the quantitative procedures described above. Once the units have been evaluated, two procedures for using the developed framework are demonstrated, first at the household level and then at the community level. The household level analysis includes a sensitivity analysis which shows how different households drive the selection of temporary housing units. The community level analysis includes a case study of East Baton Rouge Parish after severe flooding in August 2016 and how that community could have distributed temporary housing units based on the needs of households but constrained by the funds available for post-disaster housing recovery. To show the robustness of the framework, the eight temporary housing options were evaluated based on the wind hazard of a hurricane and again with a flooding event. The flooding event was used for the household sensitivity analysis and the community-level case study. For all analyses, the location of the hazards remain the same which is along the Gulf Coast, particularly Baton Rouge, Louisiana.

Temporary housing unit evaluations

Nine types of units were chosen to explicitly depict the quantification of each of the described qualities of temporary housing. The units and programs selected for evaluated are shown in figure 7. While there are many other types of temporary housing options and programs that have been developed after disasters over the years, the ones chosen are units and programs that have extensive and reoccurring information found in the literature. Any type of temporary housing unit can be input into the model as long enough detailing is available for evaluation. The selected temporary housing units and accompanying programs include ones with issues and complications, as well as options that are new and innovative and have been discussed heavily in the preceding chapters. For the purpose of this model, a unit was considered not accessible if a household experiences a half-hour or larger increase in transportation time to everyday needs such as work, schools, or grocery stores, or if the household is unable to use public transportation if it was their means for travel pre-disaster. An example of accessible is having the manufactured housing unit on the household's pre-disaster property or a hotel in the same city as the pre-disaster home. An example of inaccessible is the manufactured home on a commercial group site outside of the disaster area, or a hotel 30 or so miles away.

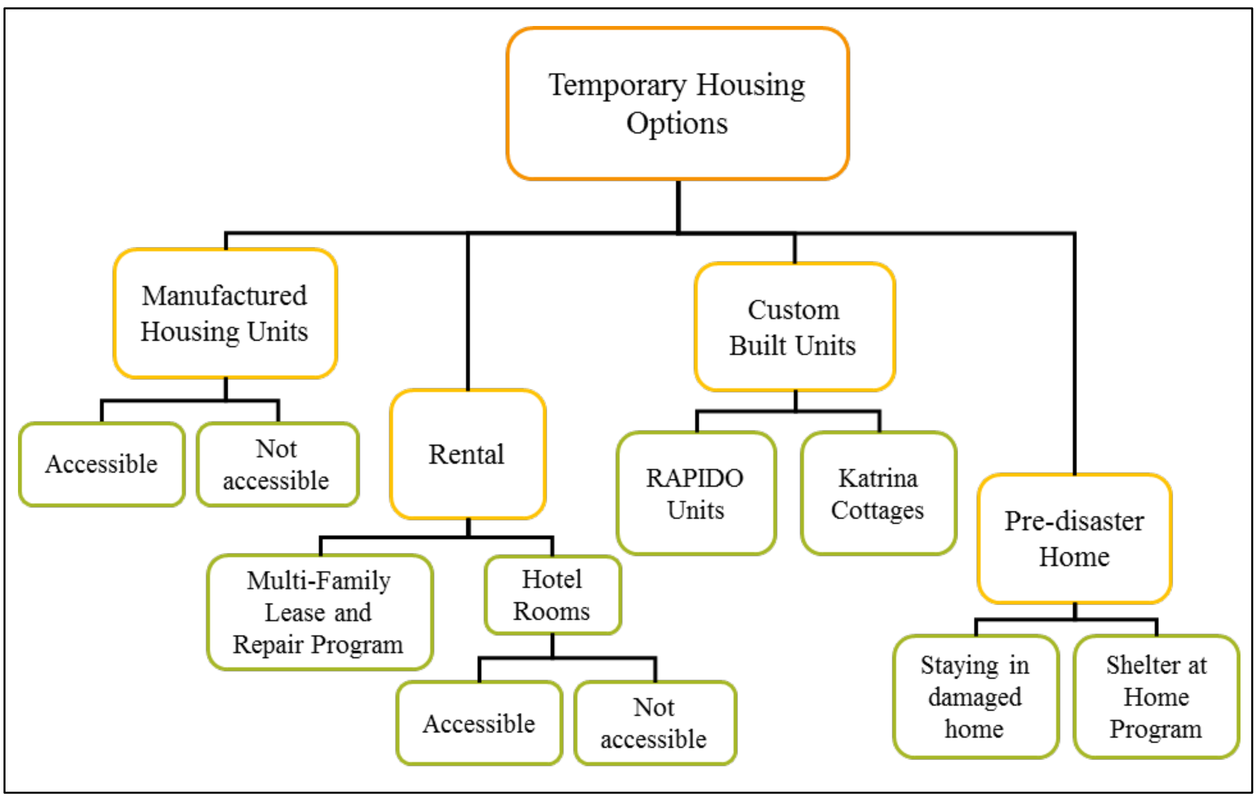

Figure 7. Post-Disaster Temporary Housing Options

All of these unit options are evaluated based on the sustainability and resilience criteria described in the previous chapter. Some of the qualities, namely, adaptability, customizability, population stability, health impacts, and financial cost, are based on the information pulled directly from the literature about each temporary housing units in Chapter 3 using the quantification procedure discussed in Chapter 4. Environmental impacts, structural integrity, and hazard vulnerability involved specific and detailed numerical analysis. The first of the two hazards, wind, is considered in temporary housing accommodation evaluations. Table 5 summarizes the quantification of each of the eight qualities for all nine temporary housing units in consideration with respect to a wind hazard event, and table 6 summarizes the quantifications with respect to a flooding hazard.

Table 5. Temporary Housing Quality Values for Wind Hazard

Qualities/ Units	Adaptability	Customizability	Population Stability	Environmental Impacts (kg CO2eq)	Health Impacts	Financial cost ($)	Structural Integrity	Hazard Vulnerability
Accessible FEMA-Issued Manufactured Housing Unit	0	0	1	8720	1	129,000	0	1
Inaccessible FEMA-Issued Manufactured Housing Unit	0	0	0	8720	1	149,000	0	1
Multi-Family Lease and Repair Program	1	1	2	3367	0	16,308	0	1
Accessible Hotel Stays	0	0	1	2886	1	56,393	0	1
Inaccessible Hotel Stays	0	0	0	2886	1	56,393	0	1
RAPIDO	1	3	2	5670	0	69,000	0	1
Katrina Cottage	1	2	1	9120	0	70,000	0	1
Damaged Home	1	2	1	11,200	1	0	3	1
Shelter at Home Program	1	2	2	11,200	0	15,000	1	1

Table 6. Temporary Housing Quality Values for Flood Hazard

Qualities/ Units	Adaptability	Customizability	Population Stability	Environmental Impacts (kg CO2eq)	Health Impacts	Financial cost ($)	Structural Integrity	Hazard Vulnerability
Accessible FEMA-Issued Manufactured Housing Unit	0	0	1	8720	1	129,000	0	5.000
Inaccessible FEMA-Issued Manufactured Housing Unit	0	0	0	8720	1	149,000	0	5.000
Multi-Family Lease and Repair Program	1	1	2	3367	0	16,308	0	2.072
Accessible Hotel Stays	0	0	1	2886	1	56,393	0	2.072
Inaccessible Hotel Stays	0	0	0	2886	1	56,393	0	2.072
RAPIDO	1	3	2	5670	0	69,000	0	5.000
Katrina Cottage	1	2	1	9120	0	70,000	0	5.000
Damaged Home	1	2	1	11,200	1	0	3	2.072
Shelter at Home Program	1	2	2	11,200	0	15,000	1	2.072

As shown in the two tables above, for most qualities (i.e., adaptability, customizability, population stability, environmental impacts, health impacts, and financial cost) are measured consistently between the two hazard events in question. Structural integrity and hazard vulnerability are derived from separate analysis.

RAPIDO units, Katrina Cottages, a damaged home, and the Shelter at Home programs all prove to be adaptable since a move-in unit is not needed from the temporary to permanent housing phase. The Multi-Family Lease and Repair Program is evaluated as adaptable since it requires a permanent housing plan, as discussed in table 1. The Multi-Family Lease and Repair Program is measured 1 for customizability meaning that the households can modify the interior décor of the unit to fit their needs. Units measuring 2 for customizability include Katrina Cottage, damaged home, and Shelter at Home program, since they all provide the ability to choose or change the layout of the unit in addition to the customizability of the interior and exterior appearance. Katrina cottages have various unit layouts for selection, and the nature of the Shelter at Home program allows the household to make their own permanent repairs or changes to the house as desired. Although those who stay in damaged homes may do so due to limited resources, in theory, they have the (legal) ability to change the unit how they please. RAPIDO units proved to be the most customizable being the only unit where the location of the unit is a decision the household can make on top of the other customizable features.

Population stability in some cases is embedded in the temporary housing program itself. For example, the Multi-Family Lease and Repair Program restricts the apartment selection to the disaster area, and the Shelter at Home program was developed specifically to keep households in their pre-disaster home. Both of these programs center on keeping the local economy stimulated after the disaster rather than having their residents circulate their funds outside the community. The RAPIDO program intends to do the same by having the units placed on the pre-disaster property. RAPIDO also aims specifically to create jobs. They have developed units that can be transported and installed by residents (Morales-Diaz, 2016). Although the Multi-Family Lease and Repair Program and the Shelter at Home program do not explicitly state their ability to create jobs, they must hire out contractors and workers to complete the repairs, thus stimulating the local job force. FEMA trailers and hotels that are accessible keep residents within the community, as well as Katrina Cottages, and staying in damaged home. Therefore, the only units that have no contribution to population stability are the inaccessible FEMA-issued manufactured housing units and hotels since it keeps the residents occupying these units outside of the community.

The environmental impacts of each of the temporary housing units was not a specific quality that was discussed thoroughly throughout the literature but is especially important with respect to sustainability. ATHENA Impact Estimator for Buildings (2017) was used to perform an LCA for each of the temporary housing options. The FEMA-issued manufactured housing units, RAPIDO units, Katrina Cottages, and the two options for a single-family dwelling home (damaged home and Shelter at Home Program) were assumed to be a single family residential building type. The hotels and Multi-Family Lease and Repair Program were assumed to be multi-unit residential-rental building type. For the FEMA-issued manufactured housing units, a typical wood-framed manufactured home was assumed. The same wood-frame, single-story, single family dwelling was assumed for both the damaged home and the Shelter at Home Program. Katrina Cottages and RAPIDO units were also assumed to be single-story wood-frame dwellings with floor plans that matched their individual specifications. For the RAPIDO unit, only the temporary “CORE” was considered to keep the temporary housing phase constant on all units. The Multi-Family Lease and Repair program was modeled with a four-story wood frame apartment building, and the hotel was assumed to be a three-story wood and steel frame building. All buildings were assumed to be in Atlanta, Georgia, the closest location selection to disaster area, Baton Rouge, with a building life expectancy of 50 years, to keep comparisons consistent across types of units. The specific floor plans, necessary assumptions, and total inputs for each temporary housing unit can be found in Appendix A.

ATHENA Impact Estimator (2017) takes specifications of building assemblies (i.e. foundation, walls, columns and beams, roof, and floor) to produce estimated values for fossil fuel consumption, global warming potential, acidification potential, human health criteria, eutrophication potential, ozone depletion potential, and smog potential. The total values for each of these seven LCA measures include the amount emitted during each phase of the project, production, construction process, use, and end of life. For this particular environmental impact evaluation, the total global warming potential from production to end of life is used for comparison, but this is not to say that the remainder of the measures are not of concern. The global warming potential is estimated in kilograms of CO_2 equivalent. After the LCAs were performed the following values were estimated for each unit in kg CO_2 eq: 8720 for the manufactured housing unit; 11,200 for the single-family dwelling; 5670 for the RAPIDO core; 9120 for the Katrina Cottage; 228,000 for the entire hotel; and 20,200 for the entire apartment building. To keep the values per unit, the hotel and apartment global warming potential were divided by the number of units within the respective building. With 79 units for the hotel and 6 units in the apartment building, the global warming potential is reduced to 2890 kg CO_2 eq per unit in the hotel, and 3370 kg CO_2 per unit in the apartment. Therefore, with respect to environmental impacts, the hotel has the highest impact for overall structure, but has the lowest when considering individual occupied units. Figure 8 shows the breakdown in total global warming potential for each life cycle stage for each temporary housing unit.

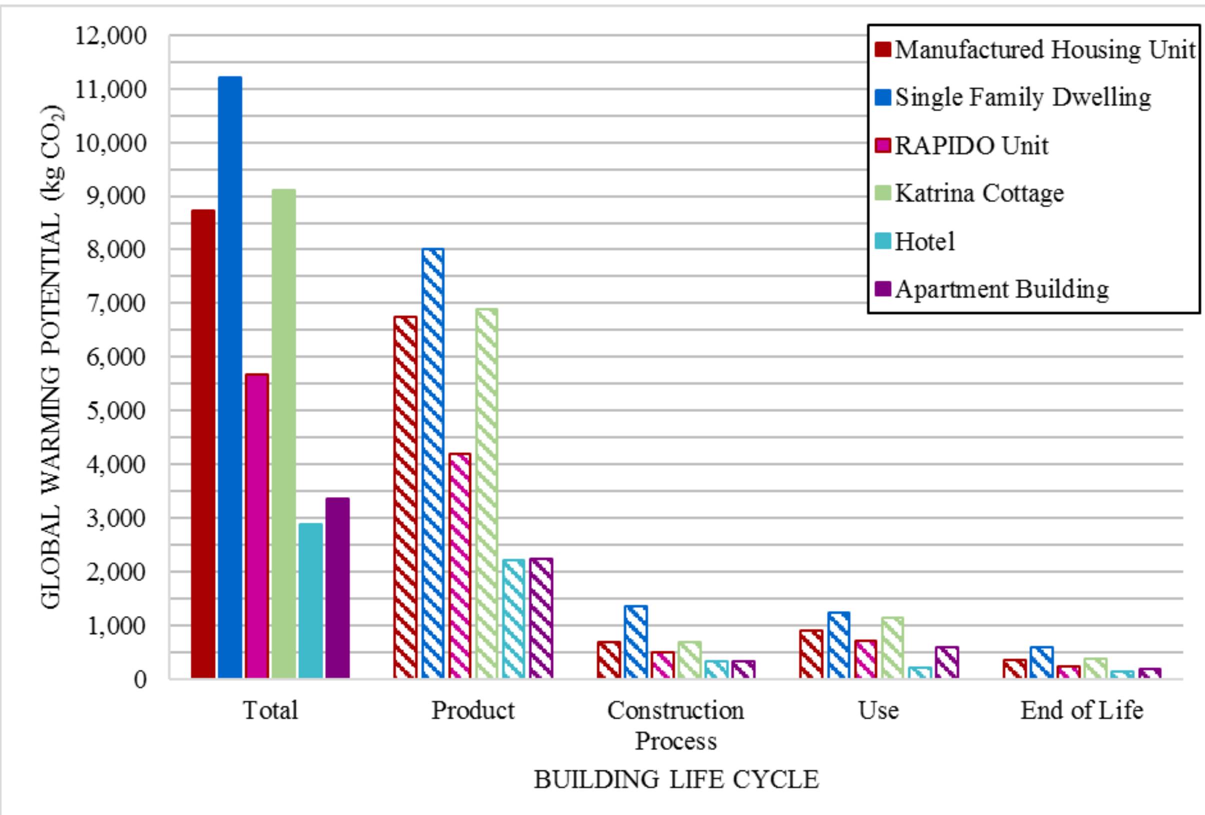

Figure 8. Life Cycle Environmental Impacts

Records on health impacts are extracted directly from the literature based on the measurement criteria discussed in Chapter 4. The values for the financial cost is also based on findings in the literature and can be found in table 2. To keep measurements consistent, a time period of 18 months was assumed for the total time spent in the temporary housing phase. FEMA-issued manufactured housing unit, RAPIDO unit, and the Katrina Cottage are all values explicitly stated in the literature and can also be found in table 2. The total cost for Multi-Family Lease and Repair Program is estimated from their lease agreement value which includes the fair market and the duration of temporary housing (FEMA, 2013). With the assumed disaster in Baton Rouge, specifically, the fair market rent for a two-bedroom is $906, which over 18 months can be totaled to be $16,308 (HUD User, 2018). The hotel stays were also estimated using 18-month time frame. With an average hotel room at $103 a night, over 18 months, the total for one household to remain in a hotel is $56,393 (Jones, 2017).

The structural integrity of each of the temporary housing units is the structural state the unit is in at the time of occupancy. HAZUS (DHS, 2015) building performance curves conditioned on maximum wind speed for a hurricane-prone region were adopted for the wind event, and 50th percentile flood depths from van de Lindt et al, (2018) were adopted for the flood event for measuring the structural integrity. Although these separate building performance criteria are based on two different hazard causing different types of damage to the building, one causing wind related damages (i.e., window damage, roof, sheathing, or wall frame failure,) and the other causing water related damages (i.e., drywall and baseboard damage, mold, sewer back up), the damage relative to occupancy status for both hazards remain consistent with those described in table 4. Table 7 shows the damage states and descriptions with respect to wind damage and flood damage.

Table 7. Wind (DHS, 2015) and Flood (van de Lindt et al., 2018) Damage State Descriptions

DS	Wind Description	Flood Description
0	Little or no visible damage from the outside. No broken windows, or failed roof deck. Minimal loss of roof over, with no or very limited water penetration.	No damage; water enters crawlspace or touches foundation (crawlspace or slab on grade). No contact to electrical or plumbing, etc. in crawlspace. No contact with floor joists. No sewer backup into living area.
1	Maximum of one broken window, door or garage door. Moderate roof cover loss that can be covered to prevent additional water entering the building. Marks or dents on walls requiring painting or patching for repair.	Water touches floor joists up to minor water enters house; damage to carpets, pads, baseboards, flooring. Approximately 1” in house but no drywall damage. Could have some mold on subfloor above crawlspace. Could have minor sewer backup and/or minor mold issues.
2	Major roof cover damage, moderate window breakage. Minor roof sheathing failure. Some resulting damage to interior of building from water	Water level approximately 2 feet with associated drywall damage and electrical damage, water heater and furnace and other major equipment on first floor damaged. Lower bathroom and kitchen cabinets damaged. Doors or windows may need replacement. Could have major sewer backup and /or major mold issues.
3	Major window damage or roof sheathing loss. Major roof cover loss. Extensive damage to interior from water.	Water level 2 feet to 8 feet; substantial drywall damage, electrical panel destroyed, bathroom/kitchen cabinets and appliances damaged; lighting fixtures on walls destroyed; ceiling lighting may be ok. Studs reusable; some may be damaged. Could have major sewer backup and/or major mold issues.
4	Complete roof failure and/or, failure of wall frame. Loss of more than 50% of roof sheathing.	Significant structural damage present; all drywall, appliances, cabinets etc. destroyed. Could be floated off foundation. Building must be demolished or potentially replaced.

All of the temporary housing units or accommodations, other than the Shelter at Home Program and the damaged home, should be at damage state 0, unless for some unforeseen reason, the household is provided with a faulty unit. The Shelter at Home program is assumed to be in damage state 1 at occupancy. The original damage to the home may be damage state 1 or 2 depending on the disaster, but assuming the $15,000 capped temporary repairs have been made prior to occupancy, the home would be around damage state 1. The other temporary housing option where the structural integrity exceeds 0, is the option to remain in the damaged home. The damage state would change proportionally to the level of the disaster. For this evaluation, damage state 3 will be used for the structural integrity of the home. Damage state 3 is too heavily damaged to be included in the Shelter at Home program but damaged enough to contract illness from being exposed to the elements without adequate housing.

Several building performance curves conditioned on wind speed were analyzed in order to measure the hazard vulnerability of each temporary housing accommodation with respect to a wind event. Appendix B details the challenges and limitations that stemmed from the process of determining this particular quantification. With hurdles in building performance data, the hazard vulnerability for all the temporary housing options was set to unity until more in-depth data can be collected in this regard. Damage states with respect to flood damage was adopted for the evaluation of a flooding event (van de Lindt et al., 2018). These damage states spell out the 50th percentile flood depth that was used to calculate the hazard vulnerability according to equations 9 and 10. Table 8 specified the 50th percentile depth of flood waters inside the home, known as inundation level, for each particular damage state.

Table 8. Flood Event Damage States

Damage State	50th Percentile Inundation Level (in.)
0	0
1	1
2	24
3	60
4	108

Several temporary housing units, RAPIDO, Katrina Cottages, and FEMA manufactured housing units, are elevated from ground-level to reduce flooding inside the unit which means that a higher flood depth would be required to reach a certain inundation level and therefore a certain damage state. Each of the elevated units, RAPIDO, units, Katrina Cottages, and FEMA MHUs, are all raised 24 inches from ground level, meaning that 24 extra inches of flood depth is required to reach the inundation levels that would cause the same level of damage as the units at ground level. Table 9 summarizes the flood depth required for each unit to reach the 50th percentile inundation level. These values are used as the 50th percentile IM, w_i, in equation 9, furthermore using equation 10, the values found in table 6 are derived for hazard vulnerability.

Table 9. Flood Depth to Reach Damage States

Unit	Elevation from Ground Level (in)	Flood Depth required to reach 50th percentile inundation level (in)				
		DS 0	DS 1	DS 2	DS 3	DS 4
Accessible FEMA-Issued Manufactured Housing Unit	24	24	25	48	84	132
Inaccessible FEMA-Issued Manufactured Housing Unit	24	24	25	48	84	132
Multi-Family Lease and Repair Program	0	0	1	24	60	108
Accessible Hotel Stays	0	0	1	24	60	108
Inaccessible Hotel Stays	0	0	1	24	60	108
RAPIDO	24	24	25	48	84	132
Katrina Cottage	24	24	25	48	84	132
Damaged Home	0	0	1	24	60	108
Shelter at Home Program	0	0	1	24	60	108

In an effort to compare the temporary housing solutions to each other, the values are normalized as percentages of the accommodation that performs the best with respect to that particular quality. This means that the temporary housing option that performs the best has a value of 1.0 for that particular quality, and the other options are between 0 and 1.0, a percentage of the highest performing unit. The normalized quality values for each temporary housing accommodation can be found in table 10 for wind hazard and table 11 for flood.

Table 10. Temporary Housing Quality Normalized Values for Wind Hazard

Qualities/ Units	Adaptability	Customizability	Population Stability	Environmental Impacts (kg CO2eq)	Health Impacts	Financial cost	Structural Integrity	Hazard Vulnerability
Accessible FEMA-Issued Manufactured Housing Unit	0.000	0.000	0.500	0.331	0.000	0.134	1.000	1.000
Inaccessible FEMA-Issued Manufactured Housing Unit	0.000	0.000	0.000	0.331	0.000	0.000	1.000	1.000
Multi-Family Lease and Repair Program	1.000	0.333	1.000	0.857	1.000	0.891	1.000	1.000
Accessible Hotel Stays	0.000	0.000	0.500	1.000	0.000	0.622	1.000	1.000
Inaccessible Hotel Stays	0.000	0.000	0.000	1.000	0.000	0.625	1.000	1.000
RAPIDO	1.000	1.000	1.000	0.509	1.000	0.537	1.000	1.000
Katrina Cottage	1.000	0.667	0.500	0.316	1.000	0.530	1.000	1.000
Damaged Home	1.000	0.667	0.500	0.258	0.000	1.000	0.250	1.000
Shelter at Home Program	1.000	0.667	1.000	0.258	1.000	0.899	0.750	1.000

Table 11. Temporary Housing Quality Normalized Values for Flood Hazard

Qualities/ Units	Adaptability	Customizability	Population Stability	Environmental Impacts (kg CO2eq)	Health Impacts	Financial cost	Structural Integrity	Hazard Vulnerability
Accessible FEMA-Issued Manufactured Housing Unit	0.000	0.000	0.500	0.331	0.000	0.134	1.000	1.000
Inaccessible FEMA-Issued Manufactured Housing Unit	0.000	0.000	0.000	0.331	0.000	0.000	1.000	1.000
Multi-Family Lease and Repair Program	1.000	0.333	1.000	0.857	1.000	0.891	1.000	0.414
Accessible Hotel Stays	0.000	0.000	0.500	1.000	0.000	0.622	1.000	0.414
Inaccessible Hotel Stays	0.000	0.000	0.000	1.000	0.000	0.625	1.000	0.414
RAPIDO	1.000	1.000	1.000	0.509	1.000	0.537	1.000	1.000
Katrina Cottage	1.000	0.667	0.500	0.316	1.000	0.530	1.000	1.000
Damaged Home	1.000	0.667	0.500	0.258	0.000	1.000	0.250	0.414
Shelter at Home Program	1.000	0.667	1.000	0.258	1.000	0.899	0.750	0.414

Another way these results can be communicated are through radar plots, shown in figure 9. Figure 9a-d shows plots for wind and figure 9e-h shows flood. These plots have each temporary housing quality on a different axis. The farther out one temporary housing accommodation is, the better it performs along that particular axis quality. For example, figure 9a depicts both accessible and inaccessible FEMA-issued manufactured housing units. The accessible unit is closer to 1.0 along the population stability axis, so it is considered to perform better in that characteristic. Figure 9b shows the accessible and inaccessible hotel stays, and comparing both 9a and 9b, both the environmental impacts perform significantly better than both the FEMA-issued manufactured housing unit, and slightly better with respect to financial cost. The two custom units, RAPIDO units and Katrina Cottages, are shown in figure 9c. The maximum performance for several qualities, adaptability, health, customizability, and population stability, are shown here along the perimeter of the graph. FEMA’s other two temporary housing programs are shown in figure 9d along with the option of remaining in a damaged home. This radar plot shows the best performance in financial cost with the Shelter at Home program reaching the maximum value of 1.0, but it also shows a fairly low performance by the Multi-Family Lease and Repair program with respect to customizability. The damaged home depicts a high adaptability performance, 1.0, but shows the lowest health impacts at 0. Another way to interpret these radar plots is that the temporary housing option with the largest area performs the overall best. Analyzing the plots in figure 9, RAPIDO, and Shelter at Home program have very large areas for both hazard events, while the Multi-Family Lease and Repair program and Katrina Cottage have notable areas as well. A general conclusion can be drawn that these large area accommodations, (RAPIDO, Shelter at Home, Multi-Family Lease and Repair, and Katrina Cottages) perform overall better than the units with smaller areas, FEMA-issued manufactured housing units, hotels, and damaged home. These radar plots were used to easily depict the temporary housing accommodation evaluations. Not all of the evaluations are measured on the same scale, for example, adaptability and health are binary, whereas financial cost consists of a range of values; however, the radar plots were used here for convenience.

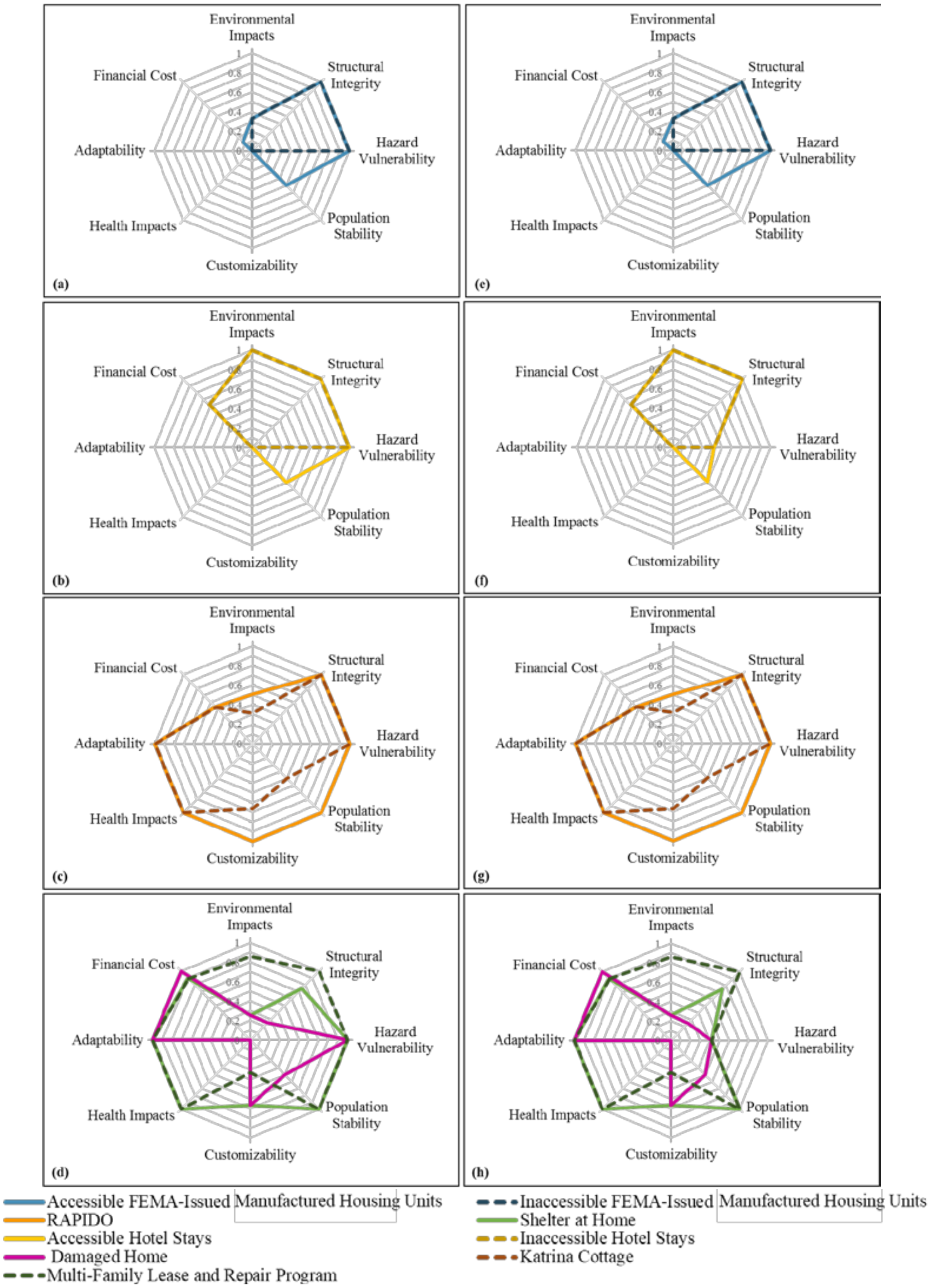

Figure 9. Temporary Housing Normalized Quality Value Radar Plots: (a) Accessible and Inaccessible FEMA-Issued MHUs for Wind Hazard; (b) Accessible and Inaccessible Hotel Stays for Wind Hazard; (c) RAPIDO Program and Katrina Cottage for Wind Hazard; (d) Shelter at Home Program, Multi-Family Lease and Repair, and Damaged Home for Wind Hazard; (e) Accessible and Inaccessible FEMA-Issued MHUs for Flood Hazard; (f) Accessible and Inaccessible Hotel Stays for Flood Hazard; (g) RAPIDO Program and Katrina Cottage for Flood Hazard; (h) Shelter at Home Program, Multi-Family Lease and Repair, and Damaged Home for Flood Hazard

The radar plots for both wind and flood depict the temporary housing units' quality values with the weights considered in equation 11 set to unity. This would be the case if household preferences and needs were not taken into consideration. From the plots, RAPIDO seems to perform the overall best with the largest area; however, not every household would benefit from this particular temporary housing accommodation, nor would the community overall. A household sensitivity analysis follows to demonstrate how the needs of households can govern the selection of post-disaster temporary housing and better support community budgetary constraints.

Household sensitivity analysis

The temporary housing evaluation framework at the household-level, shown in figure 5, can be used for a number of varying situations. For this example, the household description will be manipulated to demonstrate how the model depends on this particular input of the framework and how to select temporary housing units based on different needs. First, the other two inputs will be defined. The disaster scenario input, which will remain constant and based on the temporary housing evaluations, is a wind event along the Gulf of Mexico coast, around Baton Rouge, Louisiana, in particular, as described in the previous section. This hazard and location were selected based on the depth of information that was extracted from the literature. Part of the disaster scenario includes the level of damage which will also stay consistent. In order to show a wide array of temporary housing options, damage levels are specified. The damage assumed to take place as a result of a Gulf Coast wind event is moderate damage to structurally sound homes, and severe damage to structurally deficient homes. Different levels of damage to the pre-disaster home is also explored to show varying needs. Using the damage states defined by HAZUS (2015) the levels of damage are damage state 2 for structurally sound homes and damage state 3 for structurally deficient homes. The level of damage to the pre-disaster home can help guide the selection of the temporary housing accommodation that is adequate for a household. The other consistent input, temporary housing options, consists of all of the units and accommodations that were presented and evaluated in the previous section and shown in figure 7.

The household description input includes 6 hypothetical households articulated for demonstrative purposes. Some temporary housing units may be best for one type of household but may not be the most ideal for another. For example, some households may need an entire new housing unit, and another may need a short-term option while they make manageable repairs to their home. Some households may need different sizes and layout of units based on household size and structure. The different hypothetical households used for comparison are described in table 12.

Table 12. Household Descriptions

Household	Description
1	Middle class income; professional jobs, 2 adults in household without persons under 18 living in household; adequate insurance coverage; home owner; pre-disaster home structurally sound
2	Upper/middle class income, professional jobs; 4 to 5 household members, with 2 adults and persons under 18 living in household; adequate insurance coverage; home owner; pre-disaster home structurally sound
3	Senior couple, both retired, one is handicap, limited insurance; home owner; pre-disaster home structurally sound
4	Low income; service employee; 3 to 4 household members, with 1 adult and multiple persons under 18 living in household; limited insurance; homeowner; pre-disaster home structurally deficient
5	Low income; service employees; 5 to 7 household members, with 2 adults and persons under 18 living in household; no insurance; homeowner; pre-disaster home structurally deficient
6	Low income; service employee; 3 to 4 household members, with 1 adult and persons under 18 living in household; limited insurance; multi-family housing renter

The household descriptions provided in table 12 are used to assign weights to each of the temporary housing qualities, as show in in equation 11. The weights are in place to allow households to rank their preferences in post-disaster temporary housing qualities. The weights assigned to each of these virtual households are by no means correct or based on any specific households; they were assumed based on hypothetical needs of the households often articulated throughout the literature referenced in Chapters 2 and 3 of this thesis. The quality weights for each household can be found in table 13.

Table 13. Household Quality Weights

Quality/Household	Household 1	Household 2	Household 3	Household 4	Household 5	Household 6
w_1, Adaptability	0.5	0.5	1.0	1.0	1.0	1.0
w_2, Customizability	0.0	1.0	0.0	0.0	0.5	0.0
w_3, Population Stability	1.0	0.5	0.0	1.0	1.0	1.0
w_4, Environmental Impacts	0.5	0.0	0.0	0.5	0.0	0.0
w_5, Health Impacts	1.0	1.0	1.0	1.0	1.0	1.0
w_6, Financial Cost	1.0	1.0	0.0	0.0	0.0	0.0
w_7, Structural Integrity	0.0	0.0	1.0	1.0	1.0	1.0
w_8, Hazard Vulnerability	1.0	1.0	1.0	1.0	1.0	1.0

Households 1 and 2 may have less priority on the adaptability of the unit since they both have adequate pre-disaster home and the means to take care of repairs on their own. Household 3 may have emphasis on adaptability to reduce frequent moving due to mobility issues of household members. Households 4 and 5 have older homes, which means they are more susceptible to sustain higher levels damage, so these households may need temporary accommodations that could turn into permanent solutions if their home cannot be repaired or is unfeasible to repair. Household 6 also needs an adaptable solution since they did not have their own home pre-disaster, and since they were in a multi-family unit, post-disaster decisions are made by landlords, possibly leaving the household without their previous unit. Customizability of the unit may be important to households with children in order to make them feel more comfortable living out of their pre-disaster home such as households 2 and 5. Population stability may be important to those households who have working adults that want to stay close to their jobs. It can also be important to those who may have lost their jobs as a result of the disaster and have large families to rely on a temporary housing program that create a way to earn income during recovery[1]. Environmental impacts may be of concern to some, but others may consider other qualities of higher importance. The health impacts are of major concern to everyone, most people do not want their health to be in jeopardy by residing in temporary housing, and so all households have been given heath as a priority. Financial cost can be a challenging quality to weigh because most of the time finance comes into play with a particular agency, governmental or private, that is providing the temporary housing accommodations. The cost of the post-disaster housing can also come right out of the household's pocket as well; either they have the means to do so, or they do not have other options for assistance. For the purpose of this sensitivity analysis, households 1 and 2 have a weight of 1 assuming they have large enough savings and sufficient insurance coverage allowing them to fund their own repair and housing needs. Households 3, 4, 5, and 6 are assigned a weight of 0 assuming that these households would not be able to repair their homes without receiving temporary housing accommodations with the assistance of recovery programs. Structural integrity is high priority for those who foresee spending an extended period of time in their temporary housing unit. Households 4 and 5 are assumed to spend a longer amount of time in their temporary accommodations sine it is assumed that their pre-disaster home will experience more damage, while households 1 and 2 may spend less time with less damage to their pre-disaster home. This also goes hand in hand with adaptability; if a household is expecting a temporary turned permanent solution, the need for structural safety of the unit is higher than those who are residing in the unit temporarily. Finally, since all those in temporary housing units are susceptible to additional disasters, regardless of the duration of stay, hazard vulnerability has been weighted as 1 for each of the households.

[1] Previous disasters have shown people with service jobs are more likely to lose those jobs during a disaster leaving households that rely on their paycheck to lose their income (Masozera et al., 2007; Mueller et al, 2011; Van Zandt and Sloan, 2017).

With the temporary housing units evaluated for a wind event based on the specified sustainability and resilience qualities, and the household weights specified, equation 11 can be implemented. Each temporary housing unit will produce a different quality of life index for a household, and the unit that creates the highest quality of life index is the optimal unit for that particular household. Table 14 shows the summed quality of life of each temporary housing accommodation for each household. Figure 10 also shows these indices in a graphical form.

Table 14. Quality of Life Indices

Unit/Household	Household 1	Household 2	Household 3	Household 4	Household 5	Household 6
Accessible FEMA-Issued Manufactured Housing Unit	1.80	1.38	2.00	2.67	2.50	2.50
Inaccessible FEMA-Issued Manufactured Housing Unit	1.17	1.00	2.00	2.17	2.00	2.00
Multi-Family Lease and Repair Program	4.82	4.22	4.00	5.43	5.17	5.00
Accessible Hotel Stays	2.62	1.87	2.00	3.00	2.50	2.50
Inaccessible Hotel Stays	2.12	1.62	2.00	2.50	2.00	2.00
RAPIDO	4.29	4.54	4.00	5.25	5.50	5.00
Katrina Cottage	3.69	3.95	4.00	4.66	4.83	4.50
Damaged Home	3.13	3.42	2.25	2.88	3.08	2.75
Shelter at Home Program	4.53	4.57	3.75	4.88	5.08	4.75

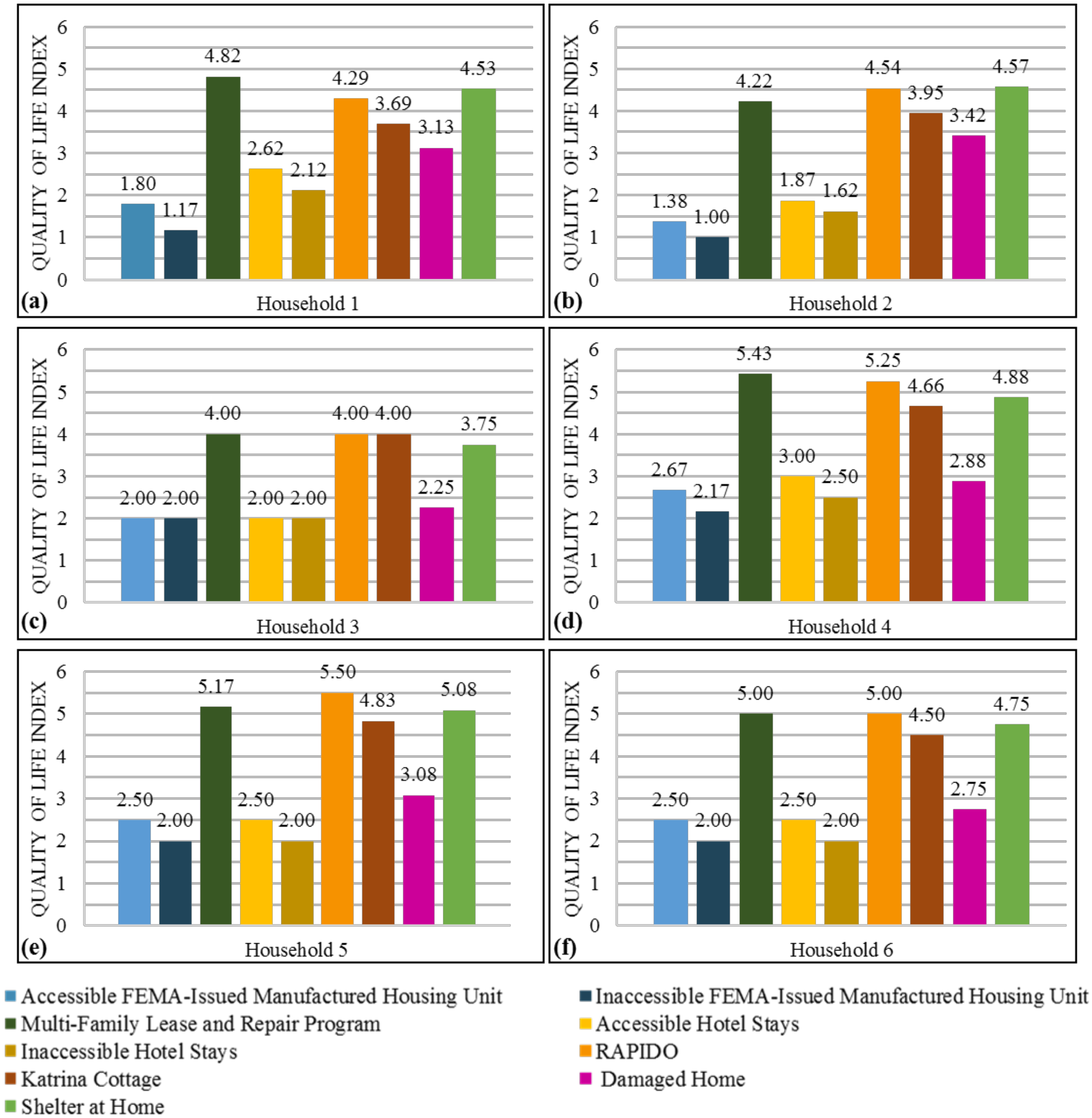

Figure 10. Quality of Life Indices for Households: (a) Household 1; (b) Household 2; (c) Household 3; (d) Household 4; (e) Household 5; (f) Household 6

Some households have one clear temporary housing accommodation that provides the highest quality of life, while others have multiple recommendations. Households 1, 2, 4, and 5 have a single highest quality of life, all of which follow reasonable suit with their housing needs. Households 1 and 2 are expected to not experience as much damage to their pre-disaster home as some of the other households since they are assumed to have more structurally sound homes, meaning reasonable repairs for damage are assumed rather than major repairs or total destruction. Therefore, the recommendations of Multi-Family Lease and Repair program for household 1 and the Shelter at Home program for household 2 seem intuitive. Multi-Family Lease and Repair allow the couple in household 1 have a temporary place to reside while they complete the repairs to their home on their own. Since only two people need to be taken care of, the adaptability and customizability of the unit are not of major concern. This particular program also allows household 1 to remain inside the community making access to their jobs easy and safe further assisting their recovery. Household 2 is slightly different with adding the concern of children. Having multiple children make living in smaller spaces difficult such as a hotel or an apartment building. The recommended Shelter at Home program offers a larger space since the pre-disaster home is being occupied. With children also comes the need for adaptability. The smoother the transition to permanent housing and community recovery, the more stable the children are in their own individual recovery (Abramson et al., 2015). The high emphasis on customizability and adaptability are focused here, mostly for the recovery of the children. This program narrows the time taken to move from temporary to permeant housing while offering the comfort and size of the pre-disaster home to accommodate a large household. This program, as with the Multi-Family Lease and Repair program, keeps the household in the community allowing for an easy return to school and jobs. Household 4 is also recommended the Multi-Family Lease and Repair program. While this household has children as well, the household a whole is not as large as household 2 therefore making smaller units more reasonable. Regardless if their pre-disaster home can be repairs or if they have to find a new home, this particular program gives the household a substantial place to live, inside the community, while working with them to establish a permanent housing plan. All of these aspects can be beneficial, especially to a single parent with a single income post-disaster. The RAPIDO program is suggested for household 5. This program provides a totally new temporary turned permanent housing unit on the pre-disaster property. Since this household will experience severe damage to an already structurally deficient building, without outside financial resources other than assistance programs, it may be in their best interest to have a new housing unit that can serve as a temporary housing unit following the disaster and can eventually expand to a large permanent home that can accommodate their entire family. The RAPIDO program would also allow this household to have a better home, with respect to structural performance than if they would try to repair the pre-disaster home.

When multiple housing options are recommended, considering the household's lifestyle, can help with the selection. For example, household 3 has three suggested optimal housing solutions: Multi-Family Lease and Repair program, RAPIDO, and Katrina Cottage. Considering the needs of household 3, the Multi-Family Lease and Repair program, which utilizes an apartment building, may not be the best solution with the mobility issues this household may experience. Here, both RAPIDO and Katrina Cottages would make moving in and around the unit easier. RAPIDO could be an ideal solution if the household wanted an entire new home, but since the pre-disaster home may not sustain enough damage to make this option feasible, a Katrina Cottage could be considered the optimal unit. The Katrina Cottage would provide the accessibility and feel of a home, while allowing the household to reside on their pre-disaster property while taking care of their home repairs. This also keeps the household in the community allowing the circulation of funds to remain in borders. Household 6 also has two suggested optimal units: Multi-Family Lease and Repair program and RAPIDO. This household does not have pre-disaster property in which to place a totally new unit. In this case, the Multi-Family

Lease and Repair program is a better option for this household, giving them a temporary place to live while helping them develop a permanent housing plan in the meantime. Table 15 summarizes the recommended optimal temporary housing for each household.

Table 15. Recommended Temporary Housing Accommodations

Household	Recommended Temporary Housing Accommodation
Household 1	Multi-Family Lease and Repair Program
Household 2	Shelter at Home Program
Household 3	Katrina Cottage
Household 4	Multi-Family Lease and Repair Program
Household 5	RAPIDO
Household 6	Multi-Family Lease and Repair Program

No two households are alike, and therefore no two households have the same needs in post-disaster temporary housing. The type of household in need of housing accommodations is the driving component of this developed framework in selecting temporary housing units. The differences in households and their needs stem from the social vulnerability of the pre-disaster community, meaning some households are subject to a longer road to recovery based on their income level, insurance coverage, the structural reliability of their pre-disaster home, and the number of household members. If household preferences are not taken into consideration, based on the method of the framework, each household would be assigned the same unit which would not be feasible for the recovery of either the household or the community.

Exemplified in this example are temporary housing accommodation selections made without any regard to the community-level and logistical constraints, which can include how fast the household would receive their temporary housing accommodation, what funds are available to pay for the accommodation, and how the quantities of each unit are available and desired by households. The following example uses a community-level case study to exemplify other external factors in temporary housing accommodation selection.

Community-level case study

While ensuring that all households are housed in temporary housing accommodations that maximize their quality of life is a key point in post-disaster recovery, there are underlying factors that ultimately govern temporary housing selections. These factors can include budgetary restrictions, temporary housing unit quantities, time needed to receive the units, and other logistical constraints associated with the nature of the specific hazard and community, such as debris removal and the availability of land to place temporary housing units. This case study aims to exemplify the framework shown in figure 4 that takes into consideration external limitations of community-wide disaster housing recovery. Information was used from reports published after the Louisiana floods of August 2016 (HUD, 2017). The information gained from the reports was used as baseline information, other assumptions were made in order to complete the community-level analysis at the depth it is intended. Those assumptions are discussed throughout.

For this example, East Baton Rouge Parish in Louisiana is the community used for evaluation. The community-level restraint in consideration is the budget available for temporary housing. Based on the Department of Housing and Urban Development report from the floods (HUD, 2017), 36,938 units in East Baton Rouge Parish sustained some type of damage (minor-low, minor-high, major-low, major-high, and severe) from the floods, including 24,255 owner-occupied units and 12,683 rental units. The report continues to give statistics on those housing units that sustained major-low, major-high, and severe damage for the entire state. For owner-occupied units, 79.98% of the total state-wide damaged units falls in the major-low major-high, and severe categories, and 80.62% of the state-wide total for renter-occupied. Major-low, major-high, and severe damages are assumed to be directly related to damage states 2, 3, and 4 as described in van de Lindt et al (2018). Assuming the residents of only these damage level units need some form of temporary housing and assuming the owner and renter damage level distribution across East Baton Rouge Parish mirrors the distribution of the entire state, the total households in consideration for temporary housing accommodations are 19,399 owners and 10,225 renters. At the time of publication, $776,923,661.88 has been approved in the State of Louisiana for FEMA's Individual and Household Programs (IHP) (FEMA, 2017c). The dollars approved to be used in FEMA's IHP includes both financial and direct housing assistance which covers temporary housing but can also include payouts for personal property repair and replacement assistance, transportation assistance, moving and storage assistance, funeral assistance, medical and dental assistance, and childcare assistance (FEMA, 2016a). For the purpose of this case study, the total amount of IHP dollars approved for the flood is assumed to be for financial and direct housing assistance only. The funds allocated to East Baton Rouge Parish was assumed to be the same percentage as the number of units damaged in the parish compared to the state's totals, which is 40.31% (HUD, 2017). Distributing that total to the owner-occupied households and renter households in need of temporary housing units in East Baton Rouge Parish, the budgetary constraint for this case study is assumed to be $205 million, owner-occupied households and $107 million for renter households.

Census data was pulled to specify the population characteristics of East Baton Rouge Parish. For this evaluation, the population characteristics were broken down by household structure, either family households or nonfamily households. As defined by the United States Census Bureau, a "family household" is a household that has at least one member is related to the householder by marriage, birth, or adoption, and can be broken down into married-couple households; male householder, no wife present; and female householder, no husband present. A “nonfamily household” includes those either living alone or household members living together that are not related to the householder (U. S. Census Bureau, 2016). Each of these categories can be broken down into age categories of householder 15-34, householder 35-64, and householder 65 years and over. The above statistics are given for both owner-occupied units and renter-occupied units. For the purpose of this analysis, single parent households are considered one category rather than two (one led by a male and one led by females). Household age categories of 15-34 and 35-64 are also considered one age category assuming their household needs are relatively similar. Married couple families, single parent families, and those householders living alone were broken down into age categories for this case study, and nonfamily households not living alone were considered one category regardless of age. Other specifications pulled from census data are the percentages of children under the age of 18 that are in owner- and renter-occupied married couple families and single parent families. In this case study, only families in the household age category 15-64 are assumed to have children under 18 living in the home. Poverty statistics were explored as well. Totals were given for the amount of married couple families, married couple families with children, single parent families, and single parent families with children that are below the poverty line in East Baton Rouge parish. These totals are given independent of tenure status, so the percentages are assumed consistent between owner- and renter-occupied units in this case study example. Poverty levels were also looked for those in the age groups 15-34, 35-64, and 65 and older. These statistics were given independent of tenure status, family structure, and children. The distributions were assumed to be for those in poverty in nonfamily living alone, and nonfamily not living alone. Since there are limitations in the census data with regard to providing the exact information needed in this analysis, the following household categories and percentages of each in the population of East Baton Rouge Parish for this example were estimated and simplified based on the statistics discussed above and are shown in table 16.

Table 16. Assumed East Baton Rouge Parish Households

	Household Description	Percentage of Total Owner-Occupied Households	Percentage of Total Renter-Occupied Households
1	Family household, married couple, age 15-64, with children, in poverty	0.80 %	0.11 %
2	Family household, married couple, age 15-64, with children, not in poverty	12.10 %	1.63 %
3	Family household, married couple, age 15-64, without children, in poverty	1.23 %	0.64 %
4	Family household, married couple, age 15-64, without children, not in poverty	26.17 %	13.53 %
5	Family Household, Married Couple, Age 65 and older, in poverty	1.20 %	0.13 %
6	Family Household, Married Couple, Age 65 and older, not in poverty	12.00 %	1.27 %
7	Family household, single parent, age 15-64, with children, in poverty	1.20 %	5.23 %
8	Family household, single parent, age 15-64, with children, not in poverty	1.51 %	6.58 %
9	Family household, single parent, age 15-64, without children, in poverty	3.53 %	4.78 %
10	Family household, single parent, age 15-64, without children, not in poverty	6.95 %	9.41 %
11	Family household, single parent, age 65 and older, in poverty	0.38 %	0.13 %
12	Family household, single parent, age 65 and older, not in poverty	3.82 %	1.27 %
13	Nonfamily household, living alone, age 15-64, in poverty	2.83 %	6.57 %
14	Nonfamily household, living alone, age 15-64, not in poverty	12.07 %	28.03 %
15	Nonfamily household, living alone, age 65 and older, in poverty	0.94 %	0.62 %
16	Nonfamily household, living alone, age 65 and older, not in poverty	9.36 %	6.18 %
17	Nonfamily, not living alone	3.90 %	13.90 %

Each of these households are evaluated at damage states 2, 3, and 4. The percentages of each household in each damage state are assumed to be the same distribution of those state-wide. For each owner-occupied household, 27.39% is assumed to be in damage state 2, 49.41% in damage state 3, and 23.20% in damage state 4. For each renter-occupied household, 33.20%, 45.18%, and 21.62% are in damage states 2, 3, and 4, respectively.

With a $205 million financial budget for owner-occupied households and a $107 million financial budget for renter-occupied households has been specified for community level constraints, and with the assumed and estimated population characteristics for East Baton Rouge shown in table 16, the next step of the community-level framework, the household-level evaluation, is completed for each of these 17 household types. The disaster scenario is a flooding event that replicated the August 2016 Louisiana flood event, the household descriptions are the ones shown above, and the temporary housing options are the ones shown in figure 7. The temporary housing unit evaluations are consistent with the example discussed above, as shown in table 11 and calculated with equations 1 thru 9; however, 17 new sets of household weights, to be used in equation 11 for the quality of life index calculations have been assumed for this community-level analysis. The household weights are not based on any one particular household, nor are they true; they have been estimated based on assumed needs in post-disaster housing. The same weights are assumed for the owner-occupied household and its renter-occupied household counterpart assuming their needs would be the same. What will differ here are not the needs in a post-disaster home, but what accommodations would be available to those who rent versus those who own pre-disaster. Table 17 provides the household weights for each of the 17 households regardless of tenure status and damage level of the pre-disaster home.

Table 17. Assumed East Baton Rouge Parish Household Weights

Qualities/ Household number	w_1, Adaptability	w_2, Customizability	w_3, Population Stability	w_4, Environmental Impacts	w_5, Health Impacts	w_6, Financial Cost	w_7, Structural Integrity	w_8, Hazard Vulnerability
1	1.0	0.5	1.0	0.5	1.0	0.0	1.0	1.0
2	0.5	1.0	0.5	0.0	1.0	0.0	1.0	1.0
3	1.0	0.5	1.0	0.0	1.0	0.0	1.0	1.0
4	0.5	0.0	1.0	0.5	1.0	0.0	0.0	1.0
5	1.0	0.5	0.0	0.0	1.0	0.0	1.0	1.0
6	1.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0
7	1.0	1.0	1.0	0.5	1.0	0.0	1.0	1.0
8	1.0	0.0	1.0	0.5	1.0	0.0	1.0	1.0
9	1.0	0.0	0.5	0.0	1.0	0.0	1.0	1.0
10	0.5	0.0	1.0	0.0	1.0	0.0	0.0	1.0
11	1.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0
12	1.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0
13	1.0	0.0	0.5	0.5	1.0	0.0	1.0	1.0
14	0.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0
15	1.0	0.5	0.0	0.5	1.0	0.0	1.0	1.0
16	1.0	0.5	0.0	0.5	1.0	0.0	1.0	1.0
17	0.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0

The household preferences assumptions follow logic as described in the household-level analysis but has been edited to fit the expected needs of the specified households. An important note is the weight of 0 assigned to each of the households for financial cost. Since this is a community-level analysis, and units with only major-low, major-high, and severe levels of damage are considered, the financial cost of the temporary housing accommodations are assumed to come from an external funding source, rather than be a cost to the household individually, and is considered with the community-level constraints. The weights shown in table 17 were used for the formulation of the quality of life index for each unit for each household. Table 18 below shows the quality of life indices for owner-occupied households.

Table 18. Owner-Occupied Household Quality of Life Indices

Units/ Household	Accessible FEMA-Issued Manufactured Housing Unit	Inaccessible FEMA-Issued Manufactured Housing Unit	Multi-Family Lease and Repair Program	Accessible Hotel Stays	Inaccessible Hotel Stays	RAPIDO	Katrina Cottage	Damaged Home	Shelter at Home Program
1	2.67	2.17	5.01	2.41	1.91	5.75	4.99	2.63	4.63
2	2.25	2.00	3.75	1.66	1.41	5.00	4.42	2.08	3.83
3	2.50	2.00	4.58	1.91	1.41	5.50	4.83	2.50	4.50
4	1.67	1.17	3.34	1.41	0.91	3.75	3.16	1.54	3.04
5	2.00	2.00	3.58	1.41	1.41	4.50	4.33	2.00	3.50
6	2.00	2.00	3.41	1.41	1.41	4.00	4.00	1.66	3.16
7	2.67	2.17	5.18	2.41	1.91	6.25	5.32	2.96	4.96
8	2.67	2.17	4.84	2.41	1.91	5.25	4.66	2.29	4.29
9	2.25	2.00	3.91	1.66	1.41	4.50	4.25	1.91	3.66
10	1.50	1.00	2.91	0.91	0.41	3.50	3.00	1.41	2.91
11	2.00	2.00	3.41	1.41	1.41	4.00	4.00	1.66	3.16
12	2.00	2.00	3.41	1.41	1.41	4.00	4.00	1.66	3.16
13	2.42	2.17	4.34	2.16	1.91	4.75	4.41	2.04	3.79
14	1.50	1.00	2.41	0.91	0.41	3.00	2.50	0.91	2.41
15	2.17	2.17	4.01	1.91	1.91	4.75	4.49	2.13	3.63
16	2.17	2.17	4.01	1.91	1.91	4.75	4.49	2.13	3.63
17	1.50	1.00	2.41	0.91	0.41	3.00	2.50	0.91	2.41

The highest quality of life drives the selection of temporary housing accommodations at the household-level not considering other external factors. If only the quality of life was considered here, most units suggested are RAPIDO units, and a Katrina Cottage for households 6, 11, and 12. If this were the case, 16,257 RAPIDO units would be needed and 3,142 Katrina Cottages for owner-occupied households and the total cost would be about $1.3 billion. Since this is not feasible with the specified budget, the units that produced the three highest qualities of life were considered reasonable options for the household to give more options to reduce spending. The temporary housing accommodations suggested the most one expanded to include options the top three qualities of life are again RAPIDO and Katrina Cottages, but also Multi-Family Lease and Repair and Shelter at Home. In addition to a budget and the quality of life of the household, unit feasibility must be taken into consideration, meaning the accommodation recommended for a particular household needs reflects the level of damage to their pre-disaster home. For example, a RAPIDO unit would not be feasible for a household who can repair their home with a reasonable number of repairs.

In order to maximize the qualities of life and attempt to minimize the spending, RAPIDO units were restricted to only those in damage state 4 category assuming a new home is more financially feasible than repairing the severely damaged home. Katrina Cottages are restricted to those whose pre-disaster home is in damage state 3 assuming the repairs to be completed to the home are extensive and will take time but are reasonable to complete rather than receiving an entire new home. Both Katrina Cottages and RAPIDO units have been restricted to damage states 3 and 4 respectively also because of possible quantity limitations. It is assumed that not enough RAPIDO units or Katrina Cottages would be available, or could be manufactured and transported, to accommodate everyone in the entire community. Multi-Family Lease and Repair programs are also reasonable for some households in damage state 3, as well as damage state 2 allowing households to reside in apartments included in the program while waiting for the completion of repairs. Assuming those whose pre-disaster home is in damage state 3 will remain in the temporary housing phase longer than those with damage state 2 damage, they will not be residing indefinitely, and an apartment inside of the community will allow them to have normalcy with every day activities. Shelter at Home program is a reasonable option for those in damage state 2. Damage state 2 is assumed to be the only damage state where repairs can be made for under $15,000. Temporary repairs can be made in an adequate timeframe getting households back into their pre-disaster home resuming their pre-disaster life style.

Considering these temporary housing accommodations as reasonable options based on the quality of life of those residing in them, and the assumed quantity limitations on RAPIDO units and Katrina Cottages, the following distribution, shown in table 19, can be an adequate solution for community-wide temporary housing assignments.

Table 19. Temporary Housing Accommodation Recommendation 1

Household	Damage State 2	Damage State 3	Damage State 4
1	Multi-Family Lease and Repair	Katrina Cottage	RAPIDO
2	Shelter at Home	Katrina Cottage	RAPIDO
3	Multi-Family Lease and Repair	Katrina Cottage	RAPIDO
4	Multi-Family Lease and Repair	Katrina Cottage	RAPIDO
5	Shelter at Home	Katrina Cottage	RAPIDO
6	Shelter at Home	Katrina Cottage	RAPIDO
7	Multi-Family Lease and Repair	Katrina Cottage	RAPIDO
8	Multi-Family Lease and Repair	Katrina Cottage	RAPIDO
9	Multi-Family Lease and Repair	Katrina Cottage	RAPIDO
10	Shelter at Home	Multi-Family Lease and Repair	RAPIDO
11	Shelter at Home	Katrina Cottage	RAPIDO
12	Shelter at Home	Katrina Cottage	RAPIDO
13	Multi-Family Lease and Repair	Katrina Cottage	RAPIDO
14	Shelter at Home	Multi-Family Lease and Repair	RAPIDO
15	Multi-Family Lease and Repair	Katrina Cottage	RAPIDO
16	Multi-Family Lease and Repair	Katrina Cottage	RAPIDO
17	Shelter at Home	Multi-Family Lease and Repair	RAPIDO

The above temporary housing accommodation distribution results in the use of 4500 RAPIDO units, 7388 Katrina Cottages, 4725 Multi-Family Lease and Repair units occupied, and 2785 Shelter at Home programs amounting to $946 million. The total cost for this recommendation is more than four times the budget specified of $205 million. In an effort to reduce the budget, an additional following community-wide recommendation was developed making finance the governing factor. The two lowest cost accommodations are the Shelter at Home program and Multi-Family Lease and Repair. Coincidently, both of these fall within the top three qualities of life for all 17 owner-occupied households, therefore the quality of life of residents is not forgone completely. Shelter at Home was considered for all household with damage state 2 pre-disaster homes, and Multi-Family Lease and Repair was considered for all households with pre-disaster homes in damage state 3 and 4. The total cost for this recommendation is about $309 million, which is greatly reduced from the first temporary housing distribution option, but still about $100 million over budget.

Rental-occupied households were also considered. The households described in table 16 with preferences as shown in table 17 are the same households evaluated for renter-occupied units as well. Households that were pre-disaster renters differ from owners in the types of temporary housing accommodations available to them. Without considering quality of life of the households, several of the temporary housing programs discussed and researched in this work are eliminated as options for renters. RAPIDO units and Katrina Cottages cannot be used since renters do not own property were the unit could be placed. Shelter at Home is not available to renters because they do not own the home; even remaining in a pre-disaster damaged home is not an option. Most decisions made for rental properties are made by landlords without considering the needs of the occupants (Kamel and Loukaitou-Sideris, 2004).

Location is an issue with FEMA-issued manufactured housing units as well; the units cannot be placed on pre-disaster property, but FEMA-issued MHUs placed in group sites are an option to renters, considered inaccessible units. Along with FEMA-issued MHUs on group sites, hotel and Multi-Family Lease and Repair program are available to renters. Qualities of life were calculated for these four temporary housing accommodation options for renters shown in table 20.

Table 20. Renter-Occupied Household Quality of Life Indices

Units/ Household	Inaccessible FEMA-Issued Manufactured Housing Unit	Multi-Family Lease and Repair Program	Accessible Hotel Stays	Inaccessible Hotel Stays
1	2.17	5.01	2.41	1.91
2	2.00	3.75	1.66	1.41
3	2.00	4.58	1.91	1.41
4	1.17	3.34	1.41	0.91
5	2.00	3.58	1.41	1.41
6	2.00	3.41	1.41	1.41
7	2.17	5.18	2.41	1.91
8	2.17	4.84	2.41	1.91
9	2.00	3.91	1.66	1.41
10	1.00	2.91	0.91	0.41
11	2.00	3.41	1.41	1.41
12	2.00	3.41	1.41	1.41
13	2.17	4.34	2.16	1.91
14	1.00	2.41	0.91	0.41
15	2.17	4.01	1.91	1.91
16	2.17	4.01	1.91	1.91
17	1.00	2.41	0.91	0.41

The Multi-Family Lease and Repair program creates the highest quality of life for all 17 renter-occupied households; this option is also the least costly. Assuming there is no cap to the number of units included in the Multi-Family Lease and Repair program, the cost for all 10,225 households is $167 million. If assuming the number of Multi-Family Lease and Repair units available is limited, an alternative recommendation is to use hotels for those who will need temporary housing accommodations for only a short period, those with a pre-disaster home in damage state 2 with plans for repair. Using hotels for those with damage state 2 homes leaves the Multi-Family Lease and Repair program units for those with damage states 3 and 4 homes. The cost for this alternative is $303 million. Hotel stays could extend to those with pre-disaster homes with plans for repair in damage states 3 and 4; however, since the quality of life in hotels are low so significant time spent in hotels would not be ideal for the household. The cost of increasing hotel stays would also increase. One final option that can be considered are using FEMA MHUs if quantities are limited for both Multi-Family Lease and Repair program units and hotels. Hotels could be used for those with pre-disaster homes with plans for repairs in damage state 2, FEMA MHUs for those in damage state 3, and Multi-Family Lease and Repair program for those with damage state 4. This solution aims to balance quality of life with respect to how long households will reside in units with respect to the level of damage in pre-disaster homes. Hotels are suggested for households in damage state 2 assuming they would not be out of the home for a significant period of time. FEMA MHUs are suggested for damage state 3 assuming households will be in temporary housing long enough to need a solution more permanent than a hotel. Multi-Family Lease and Repair program are suggested for those with a pre-disaster home in damage state 4 assuming these households will be in temporary housing the longest and therefore needed an accommodation that will maximize their quality life. The cost for this distribution, hotels for damage state 2 households, FEMA MHUs for damage state 3 households, and Multi-Family Lease and Repair program units for 4 households, is $916 million. All three of these solutions exceed the specified budget of $107 million. The distribution that minimizes the cost for renter-occupied units is the first solution, with all households using Multi-Family Lease and Repair program as temporary housing, exceeds the budget by about $60 million.

The community-level framework is developed to consider not only the quality of life of households in need of post-disaster temporary housing, but also to consider external community constraints such as budget which was exemplified in this example. For owner-occupied units, the community-level solution that provides adequate qualities of life while minimizing cost is using Shelter at Home program for those with a pre-disaster home in damage state 2 and Multi-Family

Lease and Repair program for those with a pre-disaster homes in damage states 2 and 3. This would require 5314 households using Shelter at Home and 14,085 residing in units included in the Multi-Family Lease and Repair program. For renter-occupied units, the distribution that minimizes cost, while providing the highest qualities of life of the programs available, is having all 10,225 households using the Multi-Family Lease and Repair program. With such a large number using the Multi-Family Lease and Repair program, other solutions were explored as discussed above, but all with increased cost.

The community level example shows that even the recommendations for a community level-solution that minimizes cost still exceeded the given budget which was assumed based on data from the severe Louisiana floods in August 2016 (HUD, 2017). Having the lowest cost solution exceed the budget for both owner- and renter-occupied units solidifies two points. First, funds that are used post-disaster do not help all households in need of temporary housing units. If all households were given temporary housing accommodations, the total dollars spent in IHP programs would have to be much larger. Second, if communities want to be able to provide temporary housing solutions that creates a high quality of life for occupants, either more funds have to be allocated for post-disaster housing, or cheaper yet efficient temporary housing programs must be developed. With the budgetary restrictions specified in this example, it is impossible to provide an adequate unit, or a unit at all, to all households. There are limitations surrounding the costs of the distribution options, such as the cost estimates for the temporary housing accommodations may be based on maximum values rather than mean values, and in reality, not everyone is covered by disaster assistance funds. However, the community-level example demonstrates budget restrictions as a major factor driving the selection of temporary housing units. Another alarming depiction from the community-level analysis is the lack of resources available to those who were pre-disaster renters. Half of the programs that are available and cater to pre-disaster owners are eliminated when considering renters. This lack of programs and resources solidifies the commonly observed vulnerability of renters and why their recovering is generally a harder and longer process compared to pre-disaster owners.

CHAPTER VI. CONCLUSIONS

Temporary housing is a post-disaster topic that has proved to have limited documentation and understanding. This research sought to fill a gap in current post-disaster research by designing an approach for selecting temporary housing options for disaster victims both at the household-level and at the community-level. A content-analysis of the literature was performed, mostly including public news articles, to uncover themes associated with household experiences with temporary housing. The identified themes informed the development of an integrated sustainability and resilience model built on quantifications of mostly qualitative data regarding characteristics of temporary housing units including adaptability, customizability, population stability, health impacts, environmental impacts, financial cost, structural integrity, and hazard vulnerability, which leads to the computation of an overall quality of life index. This wide array of temporary housing qualities are used in the model to show that post-disaster temporary housing is more than just a roof over disaster victims' heads, and temporary housing has a greater meaning to households residing in them. Temporary housing is the transitional phase for households to gain somewhat of their normal pre-disaster lifestyle back. The more efficiently the temporary housing unit can provide this normalcy, the greater impact it will have on the household during recovery as exemplified through the quality of life index. The proposed approach was demonstrated with both common practices and innovative temporary housing solutions. Not only does the temporary housing unit contribute significantly to the quality of life index, but the type of household receiving the temporary housing unit affects it as well. In order to maximize the recovery process after a disaster, a household must be matched with a temporary housing unit that best fits their needs and produces the highest possible quality of life index for them. While aiming to provide the highest quality of life for a household, other external factors typically drive the selection of post-disaster temporary housing accommodations. Budgetary restrictions, quantities of units available, and the time taken to receive the units are all community-level constraints that often times lead to households given temporary housing units that are readily available, and not one that fits their specific needs.

Several conclusions can be drawn from the household-level and community-level analyses illustrated above. Each type of temporary housing unit, whether traditional or modern, has benefits in certain aspect over others. Custom built units, like the RAPIDO units, may seem like a positive solution for everyone, but when considering a particular household's needs, this is not always the case. Households throughout a disaster stricken community do not have the same needs and therefore may not benefit from the exact same type of temporary housing accommodation. Household size, structure, income, insurance coverage, and level of damage to pre-disaster home can cause different households to have different post-disaster needs. Moreover, no two temporary housing solutions perform in the exact same manner for a particular household, and no two types produce the same exact quality of life index. The household-level analysis demonstrated the diversity of needs leading to differing temporary housing accommodation selections to different members of the community.

While the household-level analysis proved that different temporary housing accommodations are recommended to different households, it is important to note that the solutions recommended were newer solutions that have been developed in place of the commonly used FEMA-issued manufactured homes and hotels. Based on the results of the household level analysis, the average quality of life for the commonly used temporary housing accommodations (e.g., manufactured housing units and hotel stays) was only 45.2% of the average quality of life index for newer programs such as Shelter at Home, Multi-Family Lease and Repair, RAPIDO, and Katrina

Cottage, with quality of life values averages of 2.08 and 4.60 respectively. These qualities of life comparisons show the importance of developing temporary housing programs and accommodations that aim to benefit the well-being of the recovering occupants.

The community-level analysis takes the suggested accommodations at the household level and employs them to fit within their particular restraints and limitations. Budget restriction was explored in the community-level case study. Based on the findings from this analysis, the amount of dollars approved for an entire community is often times not enough to supply temporary housing to everyone in the community, much less provide an optimal temporary housing accommodation that will produce an adequate quality of life for the household. For the community-wide temporary housing distribution to owners, the cheapest option is 150% of the specified budget of $207 million. The other two options that maximize qualities of life are 650% and 460% of the budget. For renters, the cheapest option is 155% of the $107 million budget, with the other options at 851% and 281%. While there are limitations associated with the cost estimates, the community level analysis demonstrates the need for cheaper yet efficient temporary housing to accommodate often restricting budgets in housing recovery.

The community-level analysis also shows the limitations of current temporary housing with regard to providing assistance to renters. Renters have less options for temporary housing since they do not own their pre-disaster home and decisions are governed by the landlord. Owners have a wide variety of options that take advantage of the pre-disaster home and property, while renters do not have this luxury. Considering the average quality of life of owners and renters, based on the community-level case study, renters have an average quality of life that is 59.0% of the quality of life of owners, 7.29 and 12.37 respectively. This proves the social vulnerability associated with pre-disaster renters during disaster recovery.

The purpose of this work is to aid community decision makers in either mitigation planning for future disasters, or to aid in response and recovery efforts post-disaster. The proposed approach can help communities develop a distribution that fits their population's needs and their community-level needs and constraints as well. This can be done prior to a disaster to have a distribution plan in place in case of a disaster, or it can be used for hopefully quick deployment of units and accommodation assignments in the wake of disaster if units are readily available. The quicker households can be assigned and using their temporary housing accommodation, the quicker they can focus on rebuilding, finding a new home, or simply starting their everyday routines again. This model seeks to aid community leaders in proper planning and decision making in the wake of disaster to eliminate downtime in the recovery process of households while allowing them to receive a temporary housing accommodation that suits their needs and well-being.

While the proposed framework includes a wide range of inputs that play a part in post-disaster recovery and decision making, there are limitations and room for further development associated with the approach as well. First, the sustainability and resilience criteria should be further developed once more (intentional) data becomes available, and expanded to include other qualities such as the time taken to get households into a unit, the time spent in the unit, cultural appropriateness of the unit, community involvement in the program. Second, the weights applied in the model play the most important role in the major merit of this work: tying temporary housing selection to household preference. All preference weights exemplified in Chapter 5 were assigned based on expert opinion. Additional, intentional, research through field work or other survey mechanisms, is needed to support weight assignments, and ultimately to validate the model.

Model validation is the third limitation to this work, and is a limitation all new community-level and resilience- and recovery-based frameworks are facing. The model developed here is grounded in fundamental social science, and built off of anecdotal evidence found mostly in news articles (i.e., not peer-reviewed literature). Future work is needed to collect the necessary data for model validation. Nevertheless, this thesis serves as an important step forward, and will hopefully help motivate future research on the range of shortcomings identified in this thesis, including (1) systematic documentation of post-disaster temporary housing and household experience that is available to the research community; and (2) comprehensive and consistent development of damage-based fragility models for a suite of building archetypes exposed to wind.

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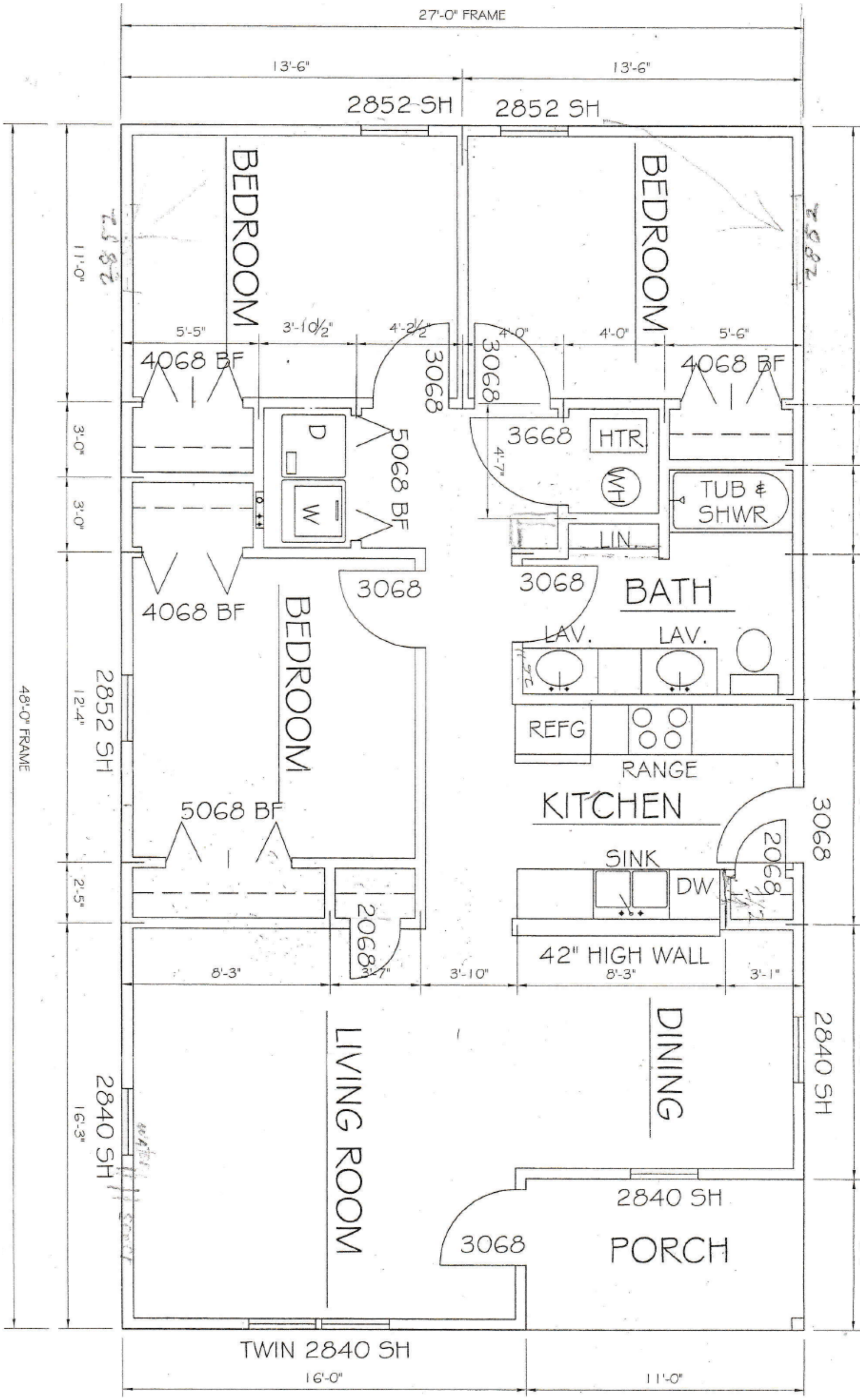
APPENDIX A. ATHENA IMPACT ESTIMATOR FOR BUILDINGS

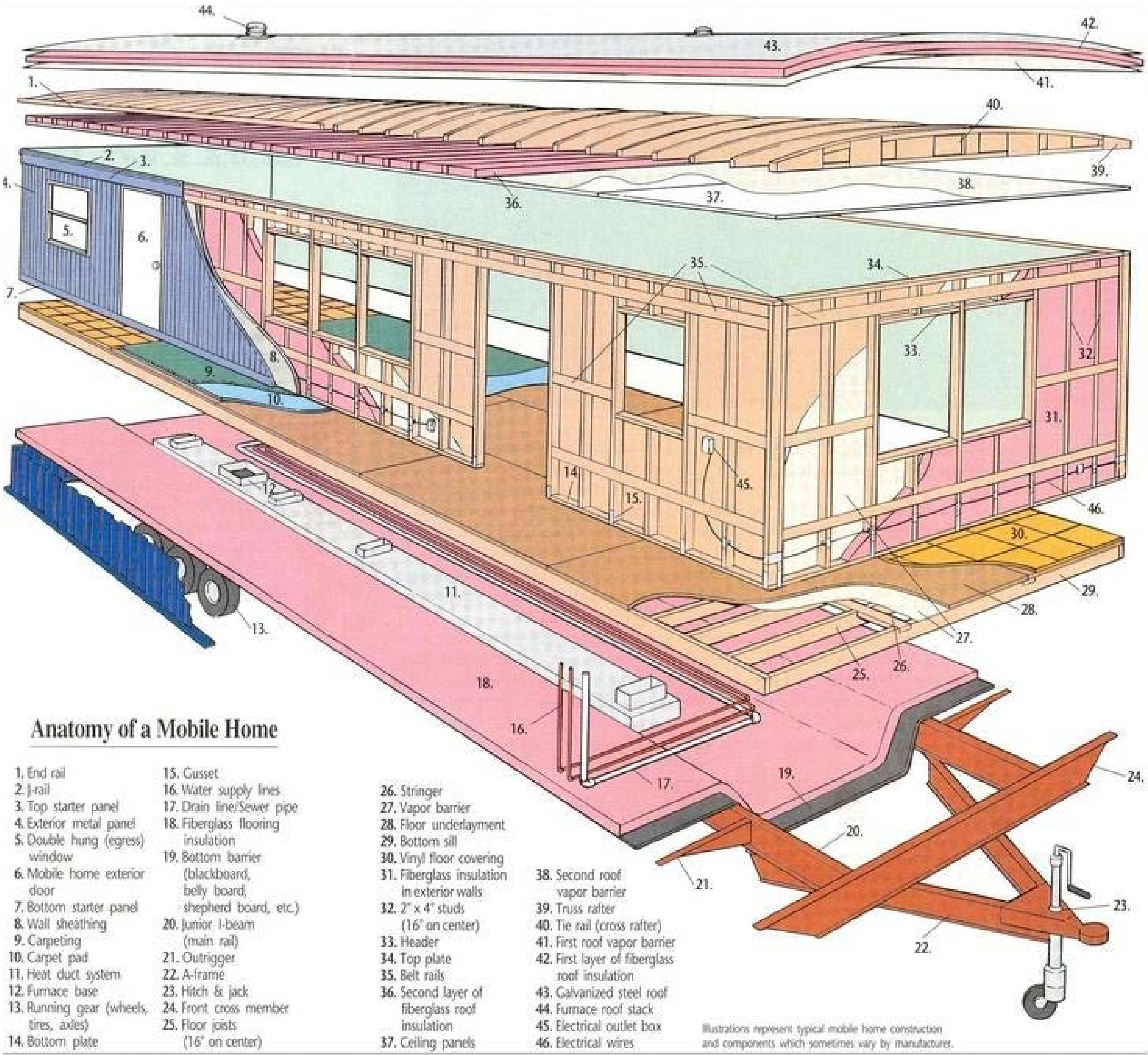
ATHENA Impact Estimator for Buildings (2017) was used to perform to evaluate the environmental impacts of each temporary housing unit for all phases of the building: production, construction, use, and end of life. Found in this appendix are the assumed floor plans for each of the temporary housing unit structures: a single story single family dwelling for shelter at home and damaged home, a four-story apartment building for Multi-Family Lease and Repair program, a three-story hotel for hotel stays, a typical manufactured home floor plan for FEMA-issued manufactured home, a tiny home floorplan for a Katrina Cottage, and the provided floorplan for the RAPIDO core from the program website (Morales-Diaz , 2017). These floor plans aided in the ATHENA modeling of the building to determine the greenhouse gas emissions. In addition to the floor plans are step-by-step inputs used to model the structures and the output bill of materials for each temporary housing unit.

Single Family Dwelling

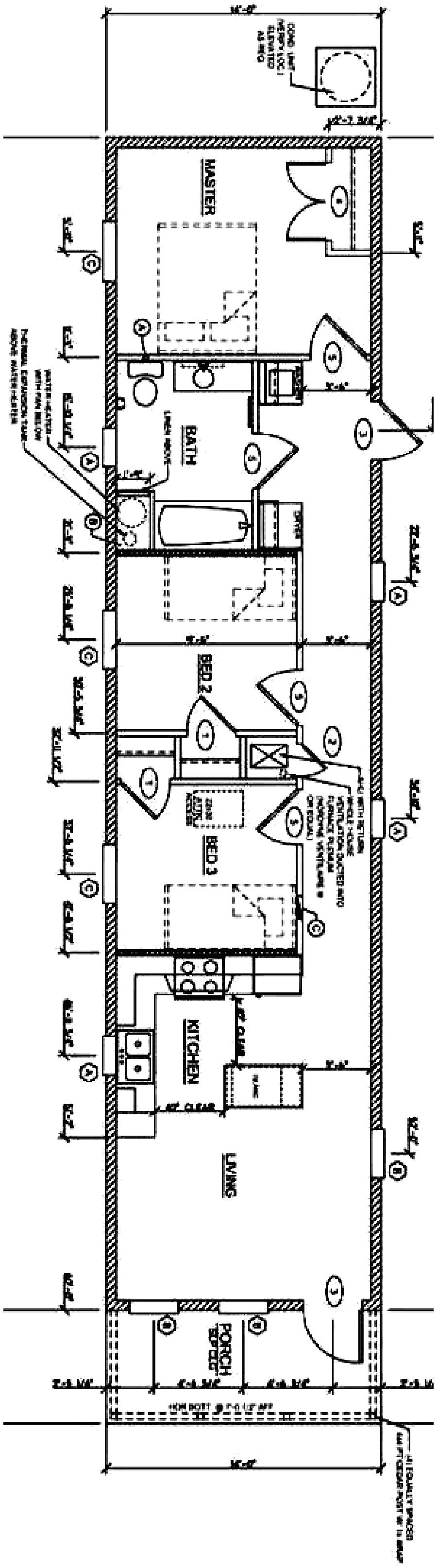


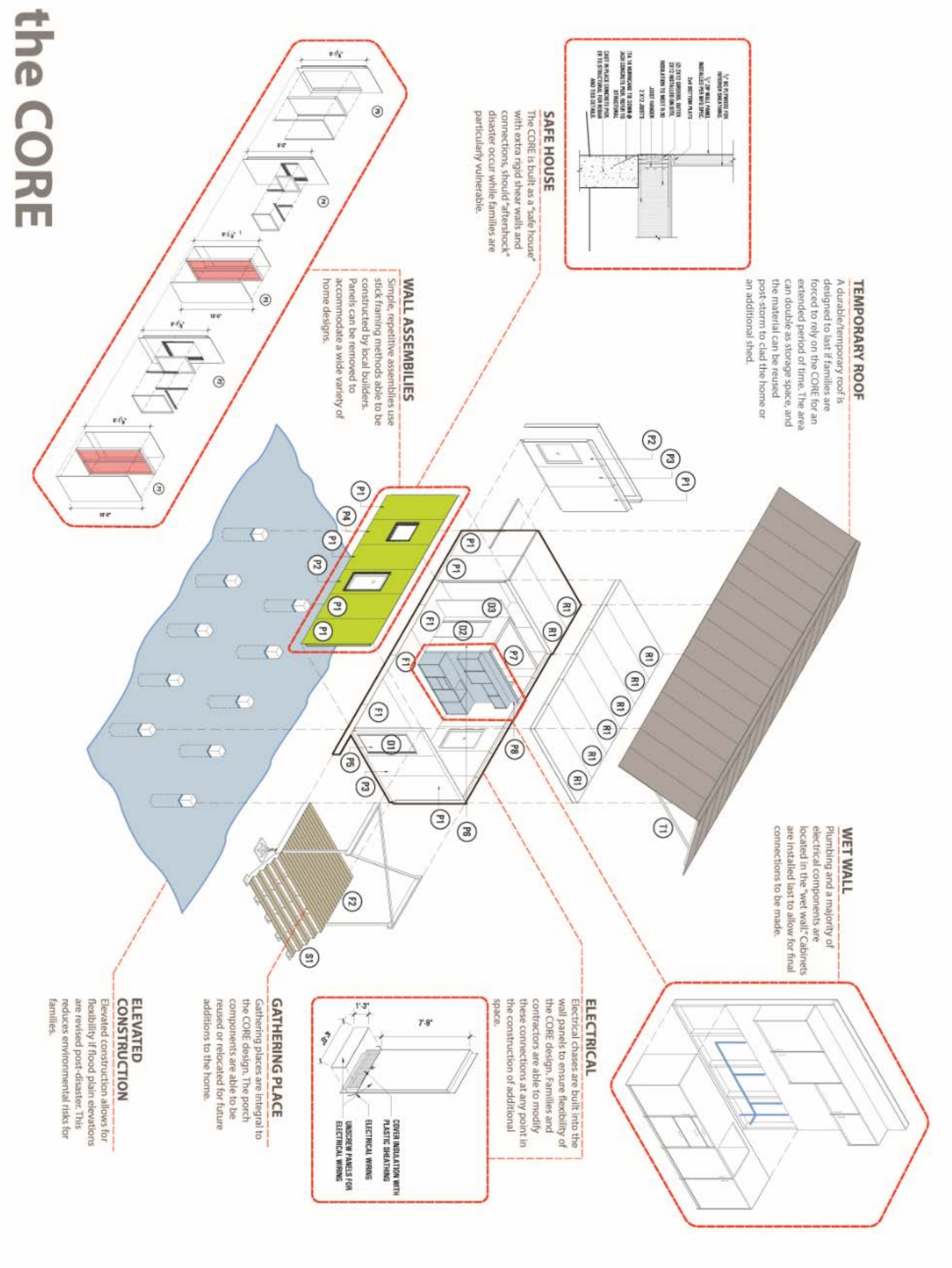
Floor Plans and Assumed Design

Manufactured Home

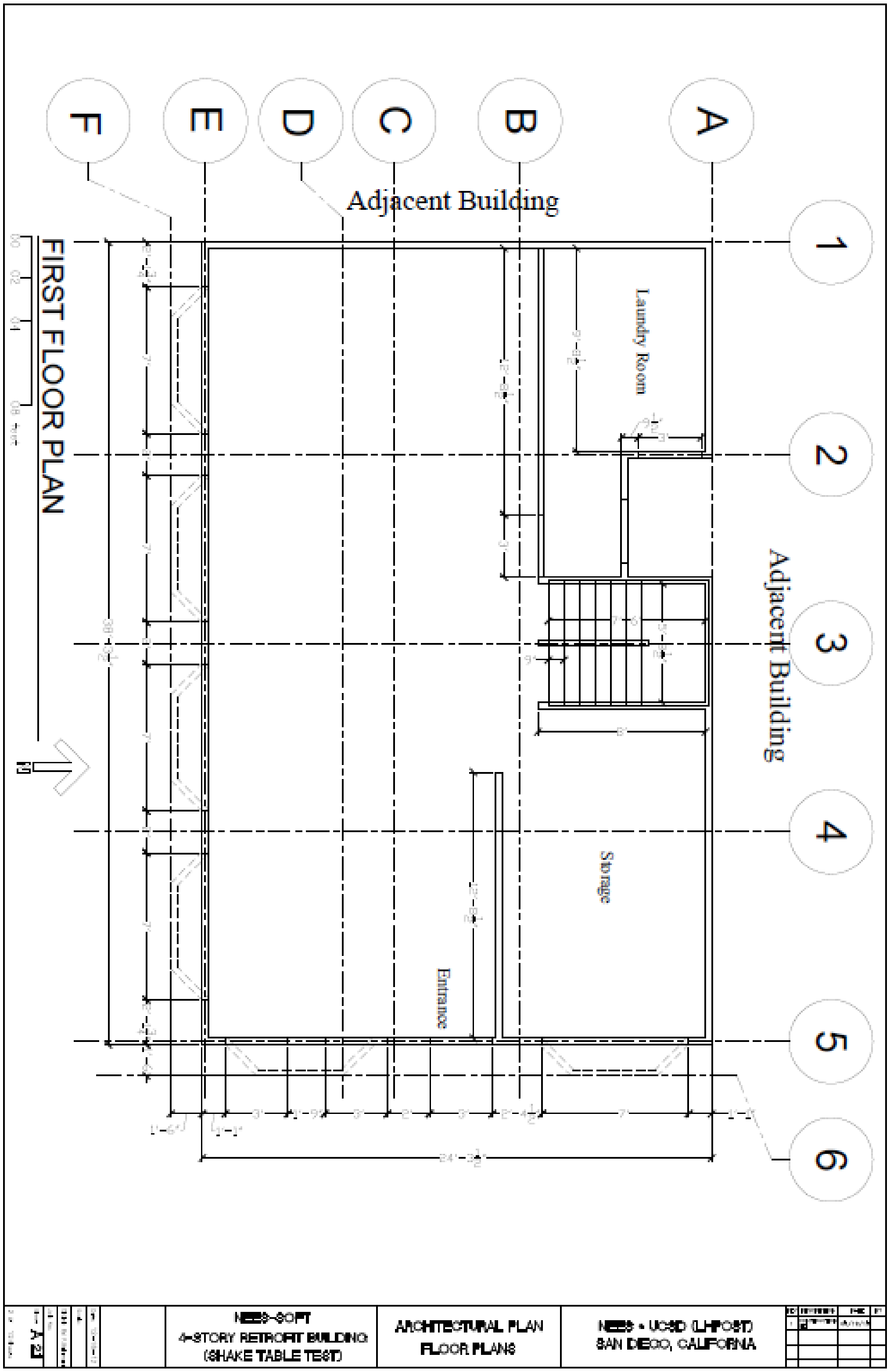

Anatomy of a Mobile Home
1. End rail
2. J-rail
3. Top starter panel
4. Exterior metal panel
5. Double hung (egress) window
6. Mobile home exterior door
7. Bottom starter panel
8. Wall sheathing
9. Carpeting
10. Carpet pad
11. Heat duct system
12. Furnace base
13. Running gear (wheels, tires, axles)
14. Bottom plate
15. Gusset
16. Water supply lines
17. Drain line/Sewer pipe
18. Fiberglass flooring insulation
19. Bottom barrier (blackboard, belly board, shepherd board, etc.)
20. Junior I-beam (main rail)
21. Outrigger
22. A-frame
23. Hitch & jack
24. Front cross member
25. Floor joists (16" on center)
26. Stringer
27. Vapor barrier
28. Floor underlayment
29. Bottom sill
30. Vinyl floor covering
31. Fiberglass insulation in exterior walls
32. 2" x 4" studs (16" on center)
33. Header
34. Top plate
35. Belt rails
36. Second layer of fiberglass roof insulation
37. Ceiling panels
38. Second roof vapor barrier
39. Truss rafter
40. Tie rail (cross rafter)
41. First roof vapor barrier
42. First layer of fiberglass roof insulation
43. Galvanized steel roof
44. Furnace roof stack
45. Electrical outlet box
46. Electrical wires
Illustrations represent typical mobile home construction and components which sometimes vary by manufacturer.

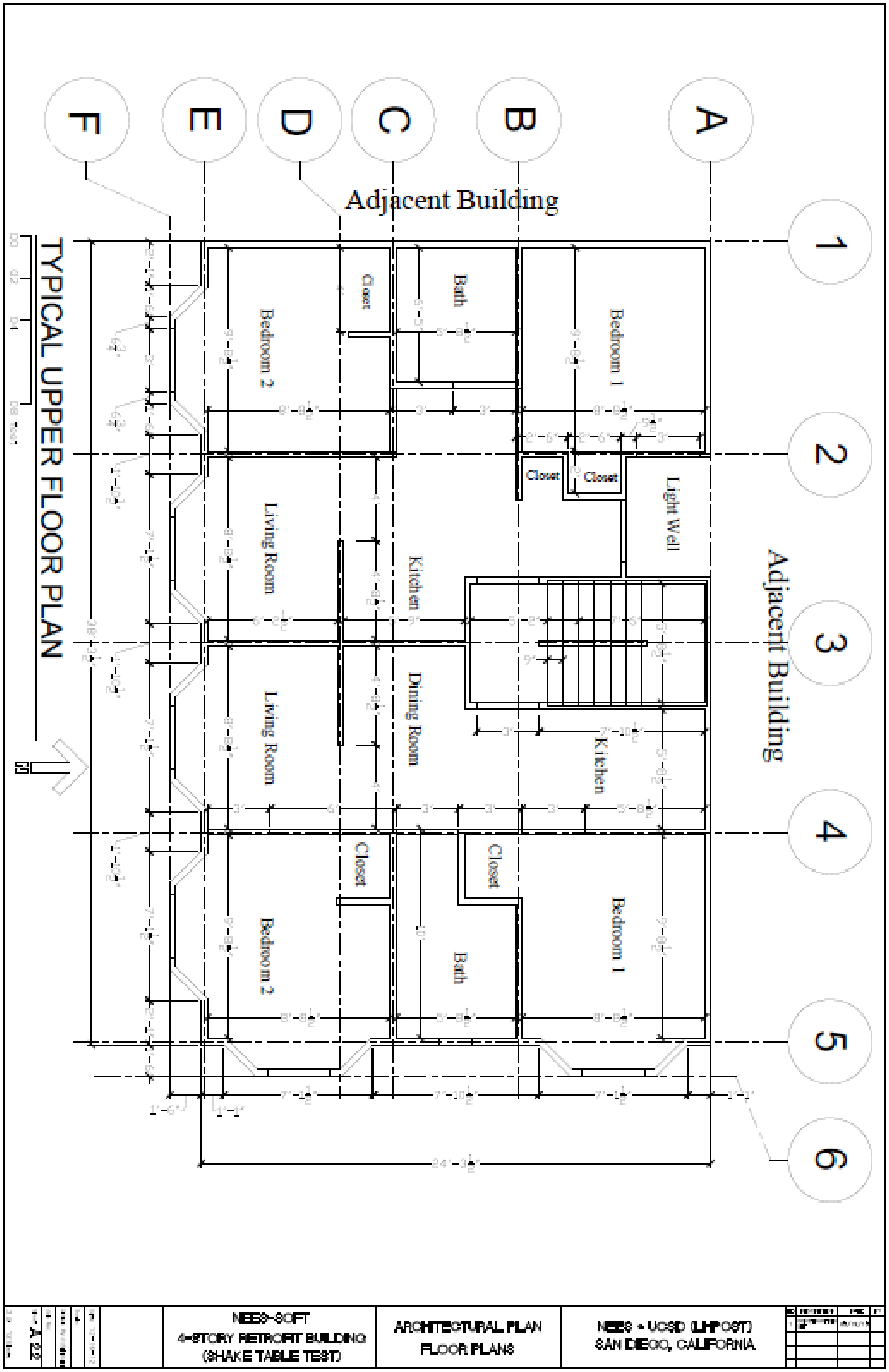
Katrina Cottage

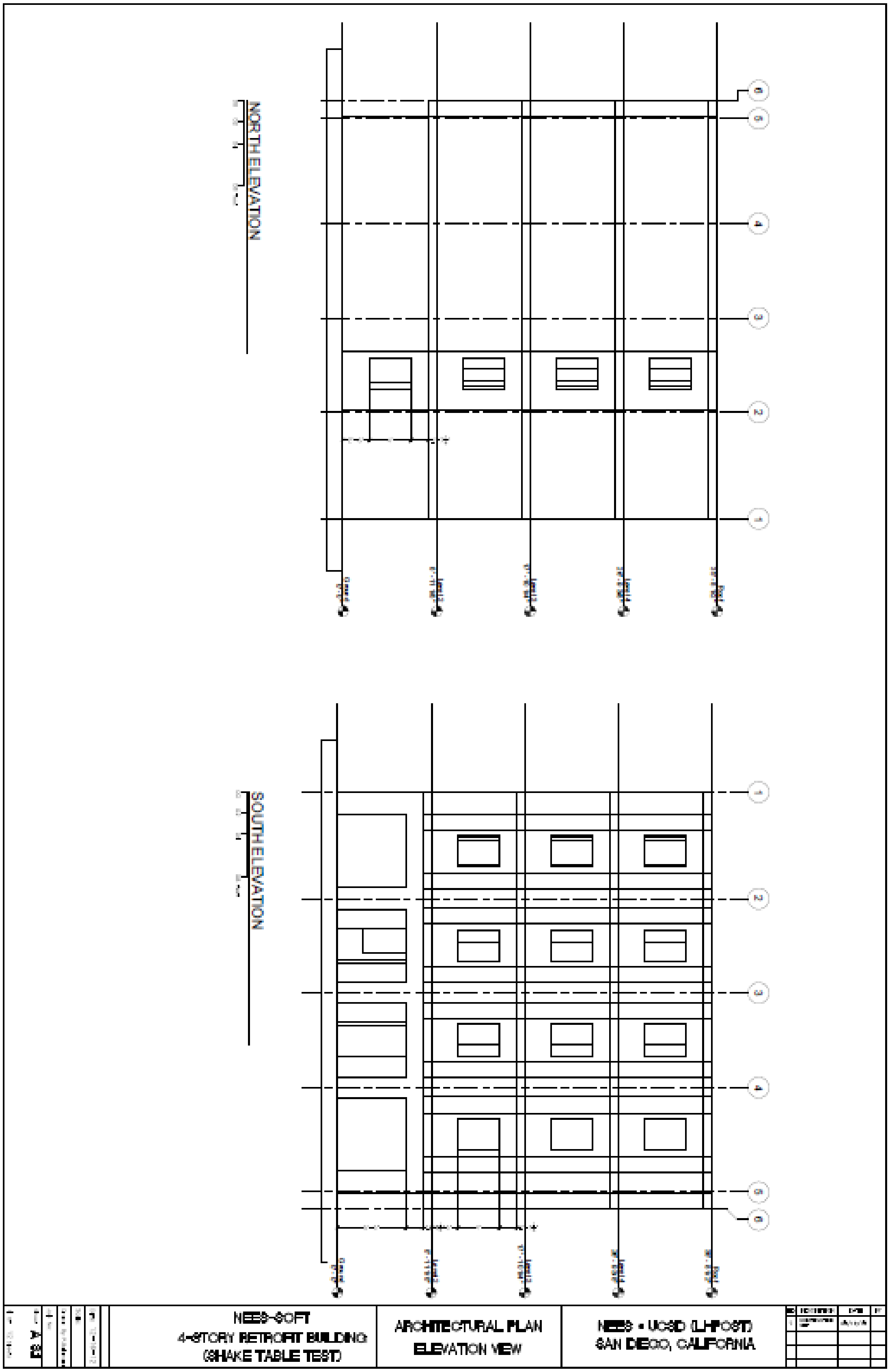


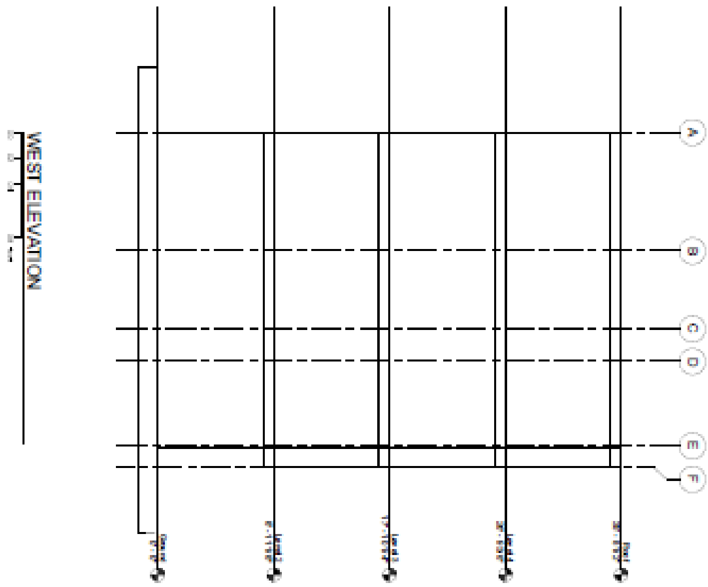

the CORE
TEMPORARY ROOF
A durable/temporary roof is designed to last if families are forced to rely on the CORE for an extended period of time. The area can double as storage space, and the material can be reused post-storm to clad the home or an additional shed.
WET WALL
Plumbing and a majority of electrical components are located in the "wet wall." Cabinets are installed last to allow for final connections to be made.
SAFE HOUSE
The CORE is built as a "safe house" with extra rigid shear walls and connections, should "aftershock" disaster occur while families are particularly vulnerable.
ELECTRICAL
Electrical chases are built into the wall panels to ensure flexibility of the CORE design. Families and contractors are able to modify these connections at any point in the construction of additional space.
COVER INSULATION WITH PLASTIC SHEATHING
ELECTRICAL WIRING
UNSCREW PANELS FOR ELECTRICAL WIRING
WALL ASSEMBLIES
Simple, repetitive assemblies use stick framing methods able to be constructed by local builders. Panels can be removed to accommodate a wide variety of home designs.
GATHERING PLACE
Gathering places are integral to the CORE design. The porch components are able to be reused or relocated for future additions to the home.
ELEVATED CONSTRUCTION
Elevated construction allows for flexibility if flood plain elevations are revised post-disaster. This reduces environmental risks for families.

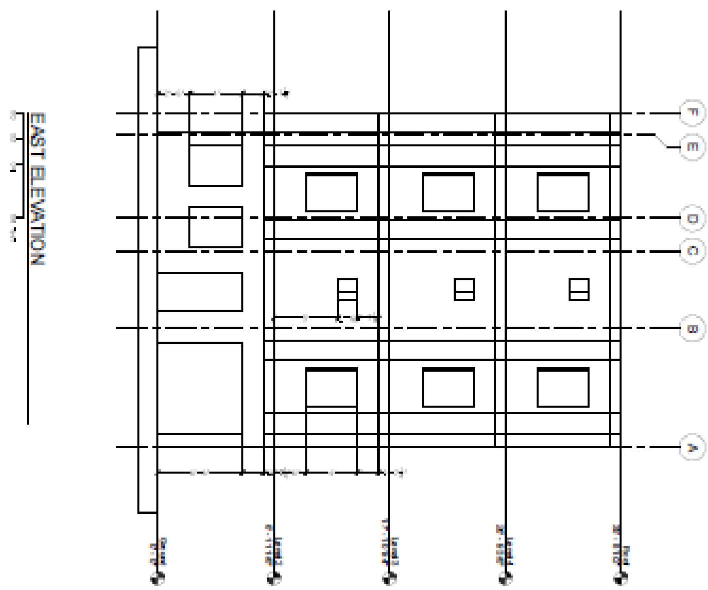
Apartment Building




TYPICAL UPPER FLOOR PLAN
Adjacent Building
Adjacent Building
Bedroom 1
Bath
Closet
Bedroom 2
Closet
Closet
Light Well
Living Room
Kitchen
Living Room
Dining Room
Kitchen
Closet
Closet
Bedroom 1
Bath
Bedroom 2
A
B
C
D
E
F
1
2
3
4
5
6
NEES-SOFT
4-STORY RETROFIT BUILDING
(SHAKE TABLE TEST)
ARCHITECTURAL PLAN
FLOOR PLANS
NEES - UCSD (LHPOST)
SAN DIEGO, CALIFORNIA

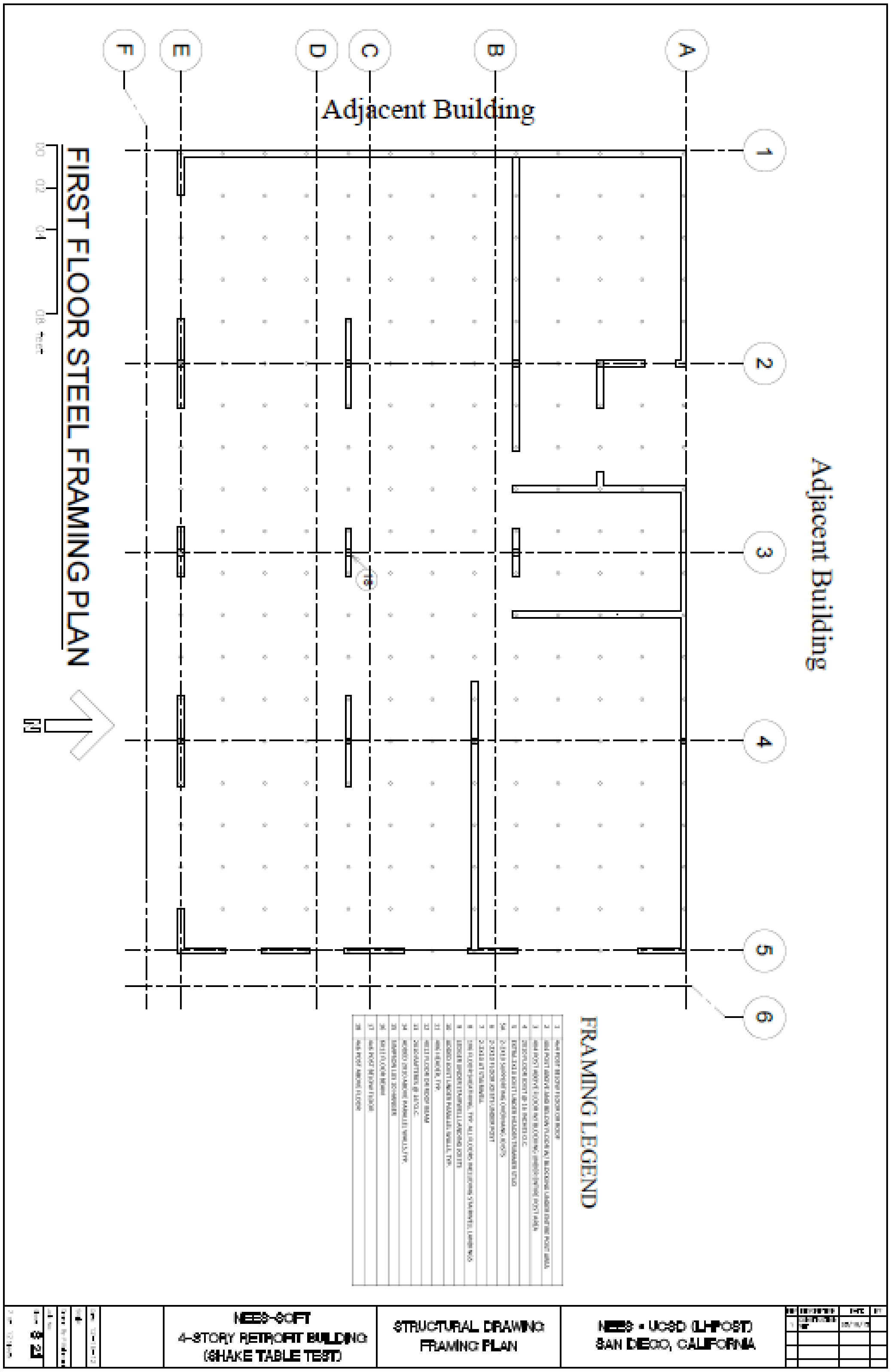

NORTH ELEVATION
SOUTH ELEVATION
NEES-SOFT
4-STORY RETROFIT BUILDING
(SHAKE TABLE TEST)
ARCHITECTURAL PLAN
ELEVATION VIEW
NEES - UCSD (LHPOST)
SAN DIEGO, CALIFORNIA
A 03



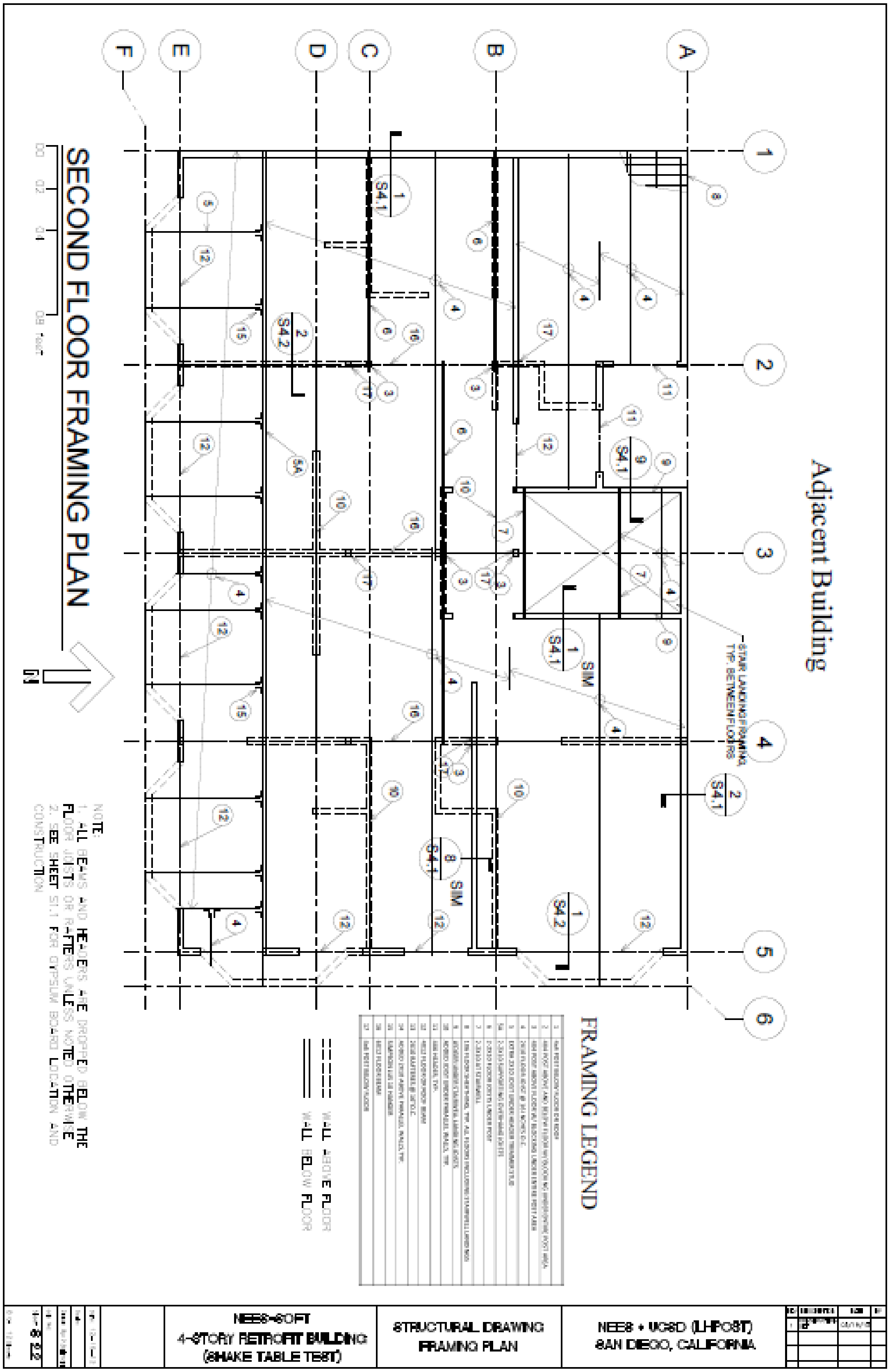


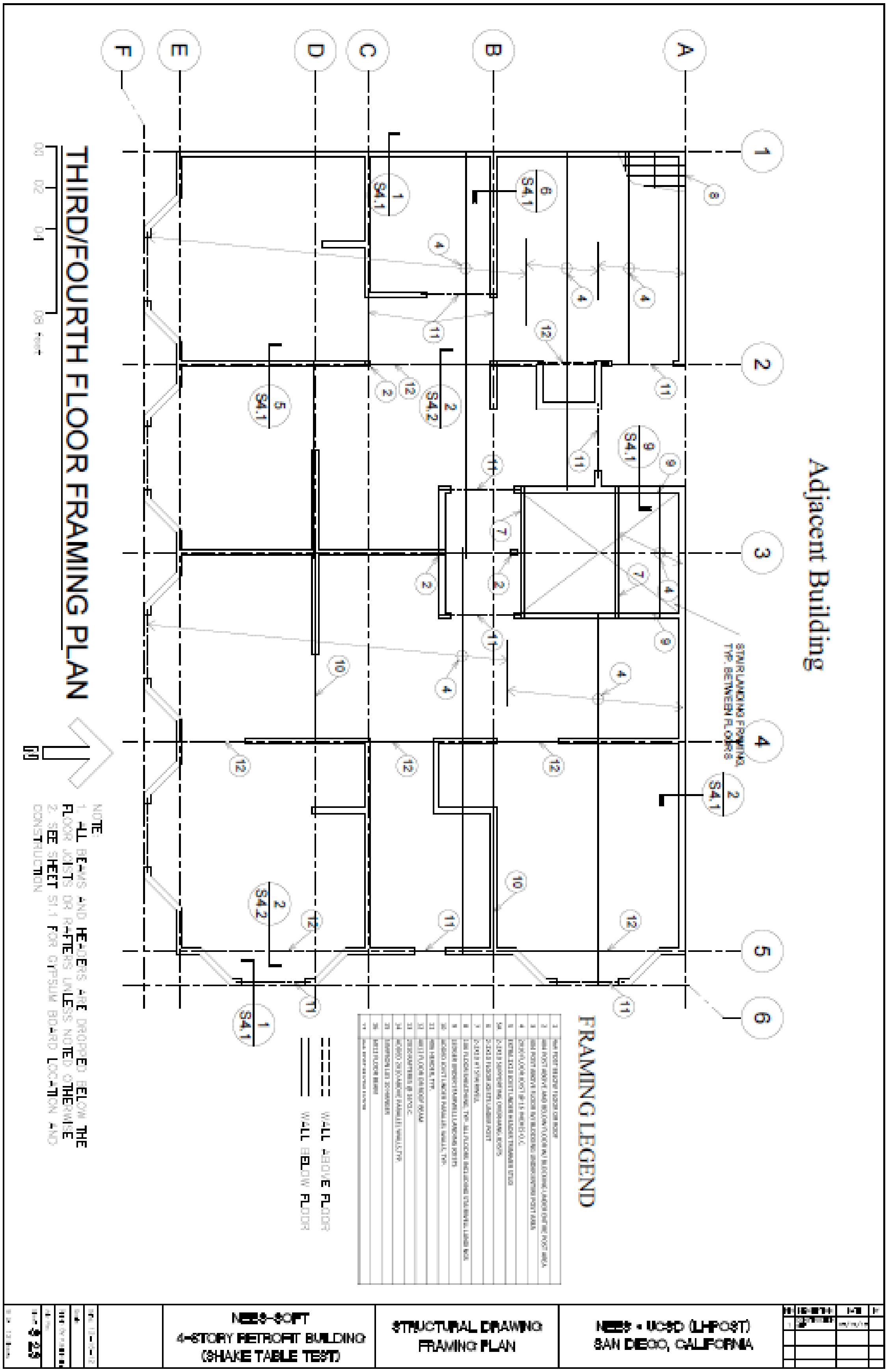
NEES-SOFT 4-STORY RETROFIT BUILDING (SHAKE TABLE TEST)	ARCHITECTURAL PLAN ELEVATION VIEW	NEES + UCSD (LHPOST) SAN DIEGO, CALIFORNIA

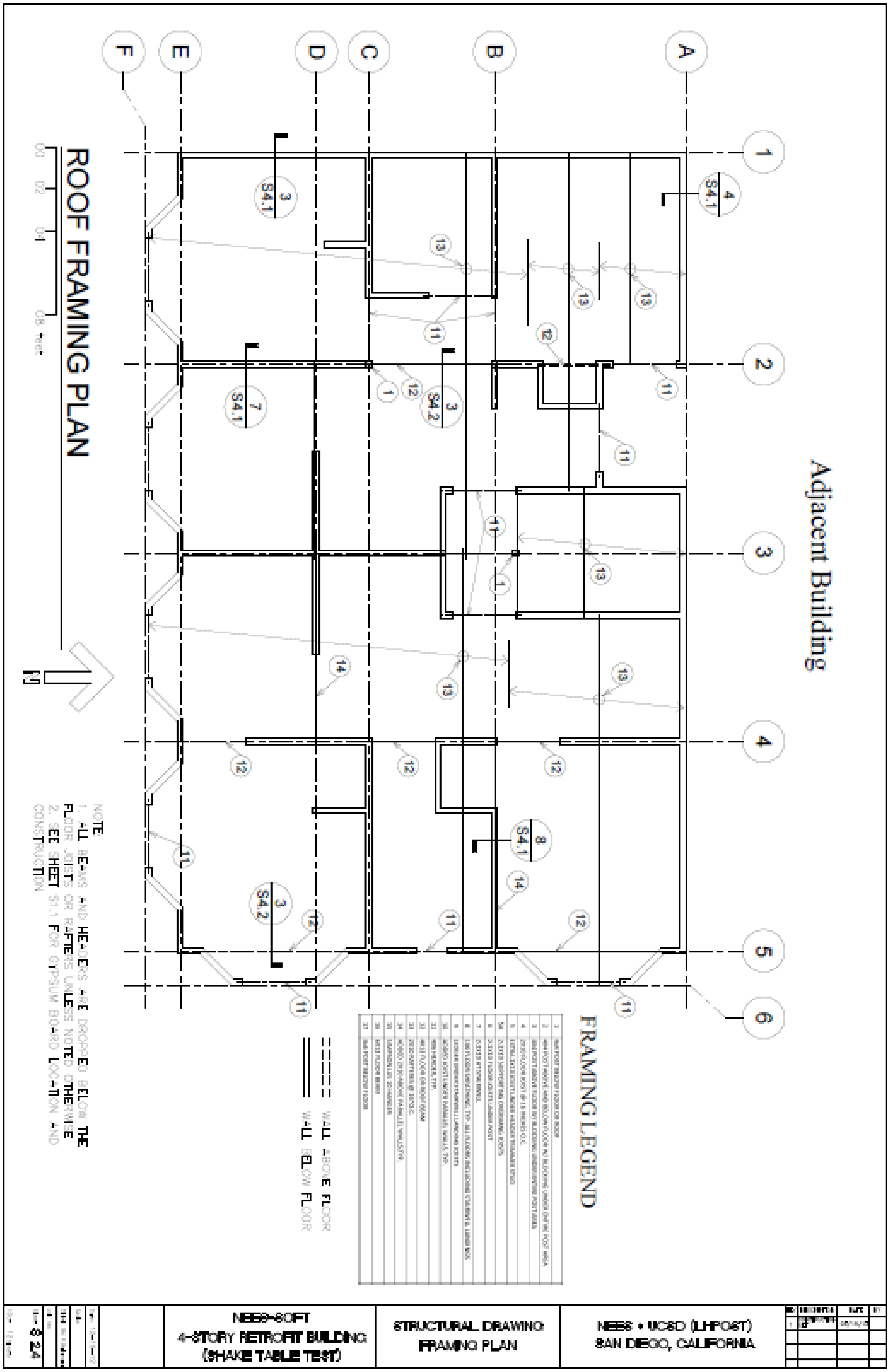
A 02

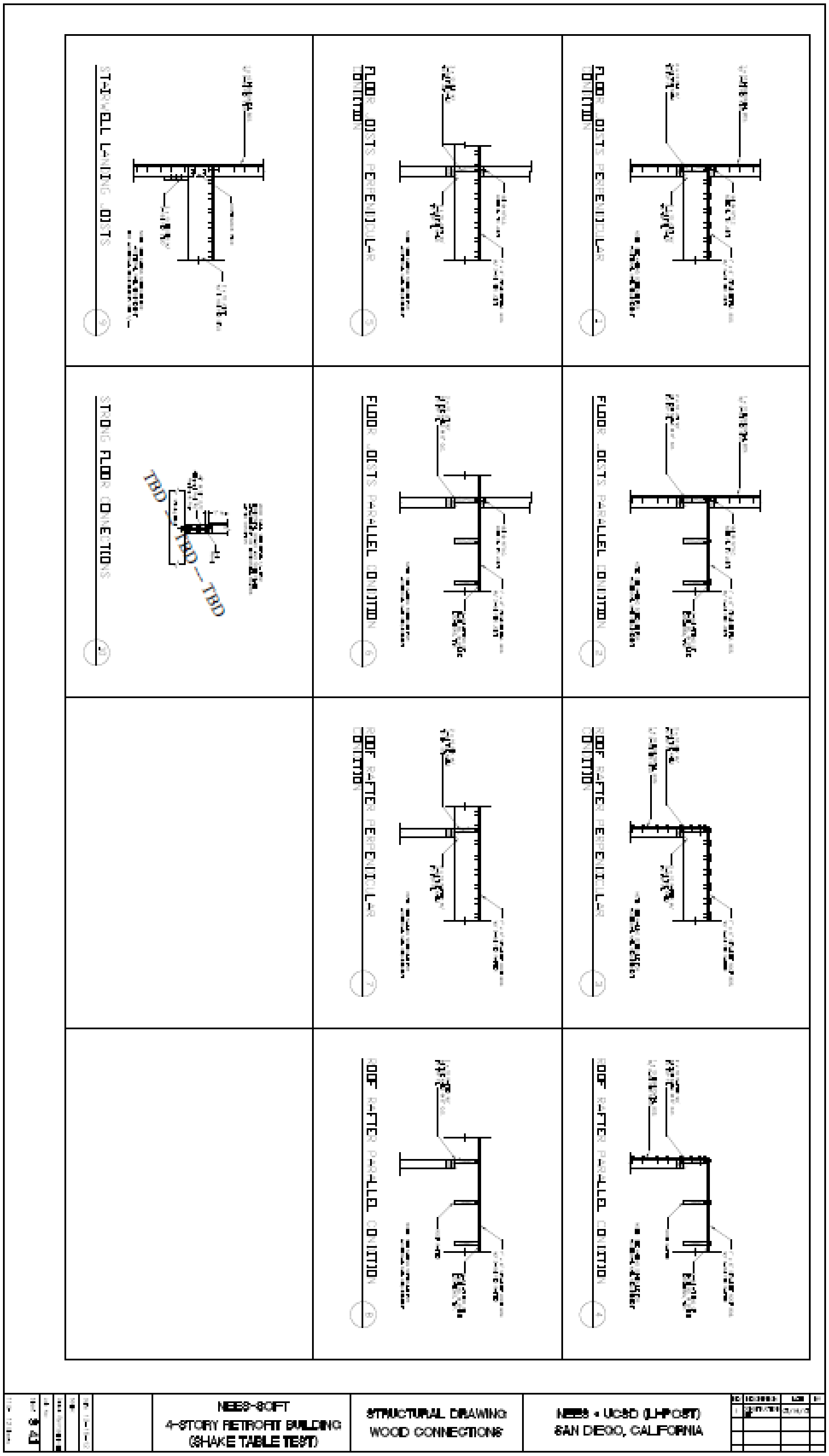


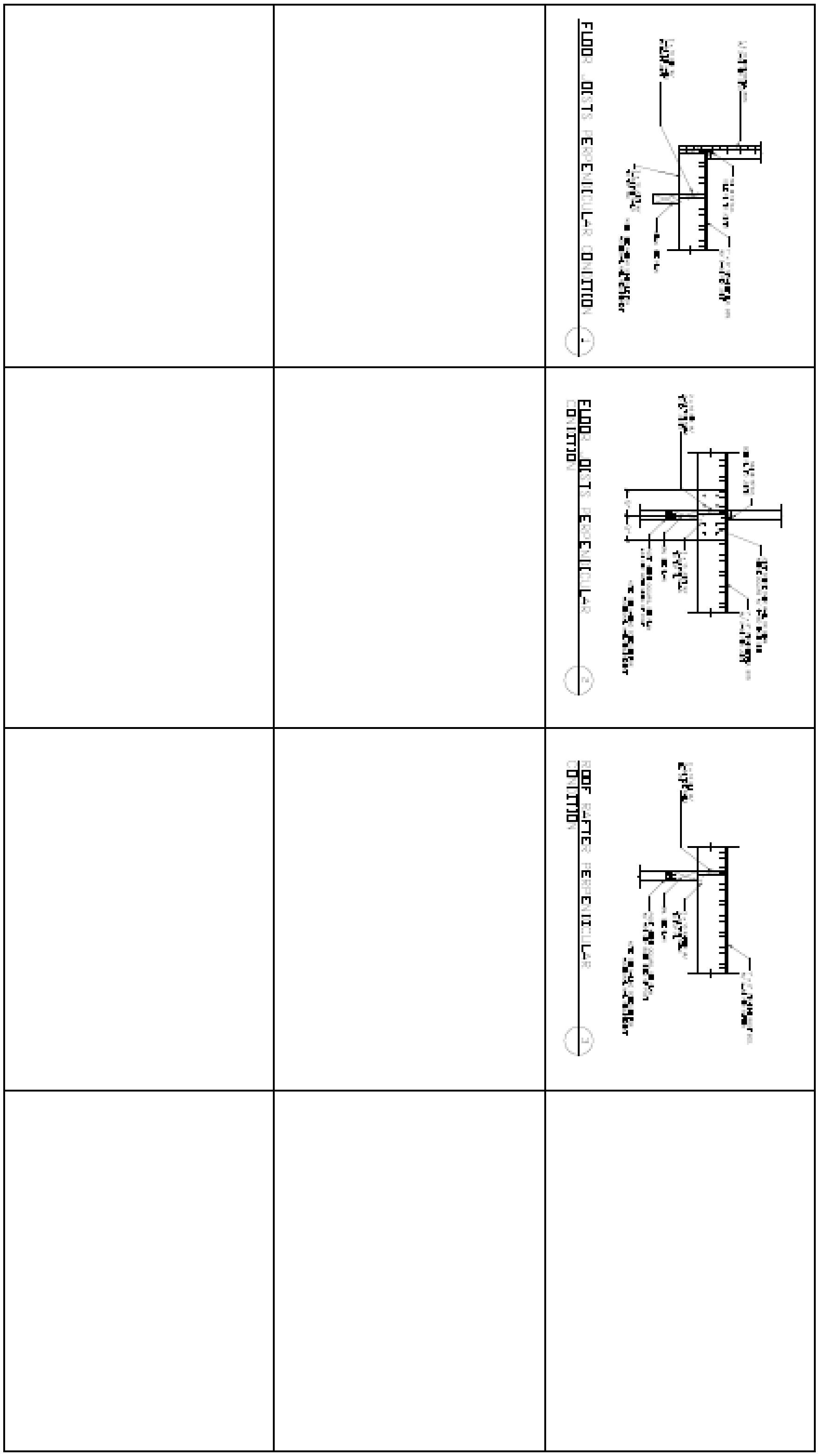
Adjacent Building
Adjacent Building
FIRST FLOOR STEEL FRAMING PLAN
FRAMING LEGEND
A
B
C
D
E
F
1
2
3
4
5
6
NEES-SOFT
4-STORY RETROFIT BUILDING
(SHAKE TABLE TEST)
STRUCTURAL DRAWING
FRAMING PLAN
NEES • UCSD (LHPOST)
SAN DIEGO, CALIFORNIA


Adjacent Building
STAIR LANDING FRAMING TYP. BETWEEN FLOORS
SECOND FLOOR FRAMING PLAN
FRAMING LEGEND
WALL ABOVE FLOOR
WALL BELOW FLOOR
NOTE:
1. ALL BEAMS AND HEADERS ARE DROPPED BELOW THE FLOOR JOISTS OR RAFTERS UNLESS NOTED OTHERWISE
2. SEE SHEET S1.1 FOR GYPSUM BOARD LOCATION AND CONSTRUCTION
A
B
C
D
E
F
1
2
3
4
5
6
SIM
NEES-SOFT
4-STORY RETROFIT BUILDING
(SHAKE TABLE TEST)
STRUCTURAL DRAWING
FRAMING PLAN
NEES + UCSD (LHPOST)
SAN DIEGO, CALIFORNIA


Adjacent Building
STAIR LANDING FRAMING, TYP. BETWEEN FLOORS
FRAMING LEGEND
WALL ABOVE FLOOR
WALL BELOW FLOOR
THIRD/FOURTH FLOOR FRAMING PLAN
NOTE:
1. ALL BEAMS AND HEADERS ARE DROPPED BELOW THE FLOOR JOISTS OR RAFTERS UNLESS NOTED OTHERWISE
2. SEE SHEET S1.1 FOR GYPSUM BOARD LOCATION AND CONSTRUCTION
NEES • UCSD (LHPOST)
SAN DIEGO, CALIFORNIA
STRUCTURAL DRAWING
FRAMING PLAN
NEES-SOFT
4-STORY RETROFIT BUILDING
(SHAKE TABLE TEST)

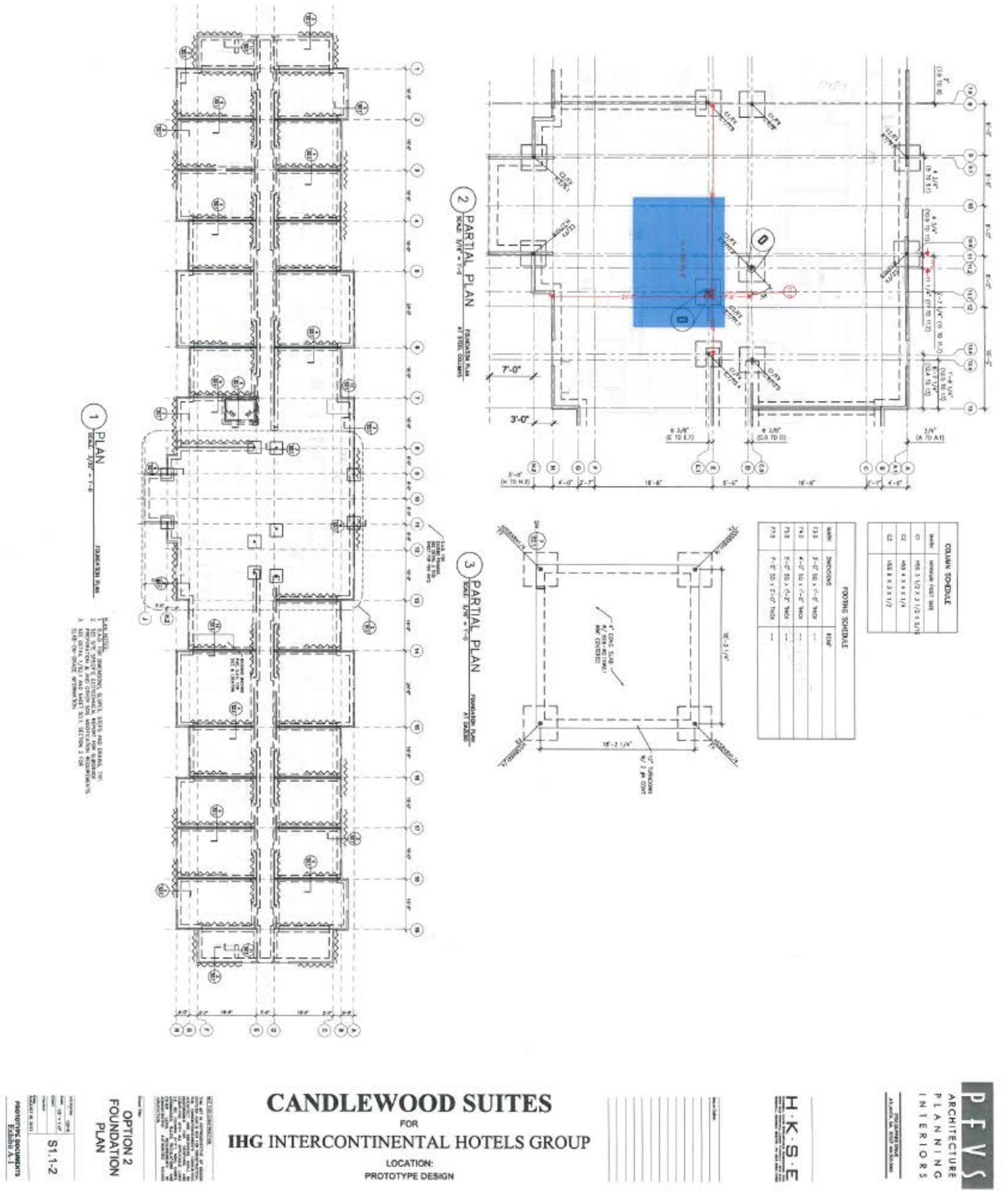

Adjacent Building
ROOF FRAMING PLAN
FRAMING LEGEND
WALL ABOVE FLOOR
WALL BELOW FLOOR
NOTE
1. ALL BEAMS AND HEADERS ARE DROPPED BELOW THE FLOOR JOISTS OR RAFTERS UNLESS NOTED OTHERWISE
2. SEE SHEET S1.1 FOR GYPSUM BOARD LOCATION AND CONSTRUCTION
NEES-SOFT
4-STORY RETROFIT BUILDING
(SHAKE TABLE TEST)
STRUCTURAL DRAWING
FRAMING PLAN
NEES • UCSD (LHPOST)
SAN DIEGO, CALIFORNIA

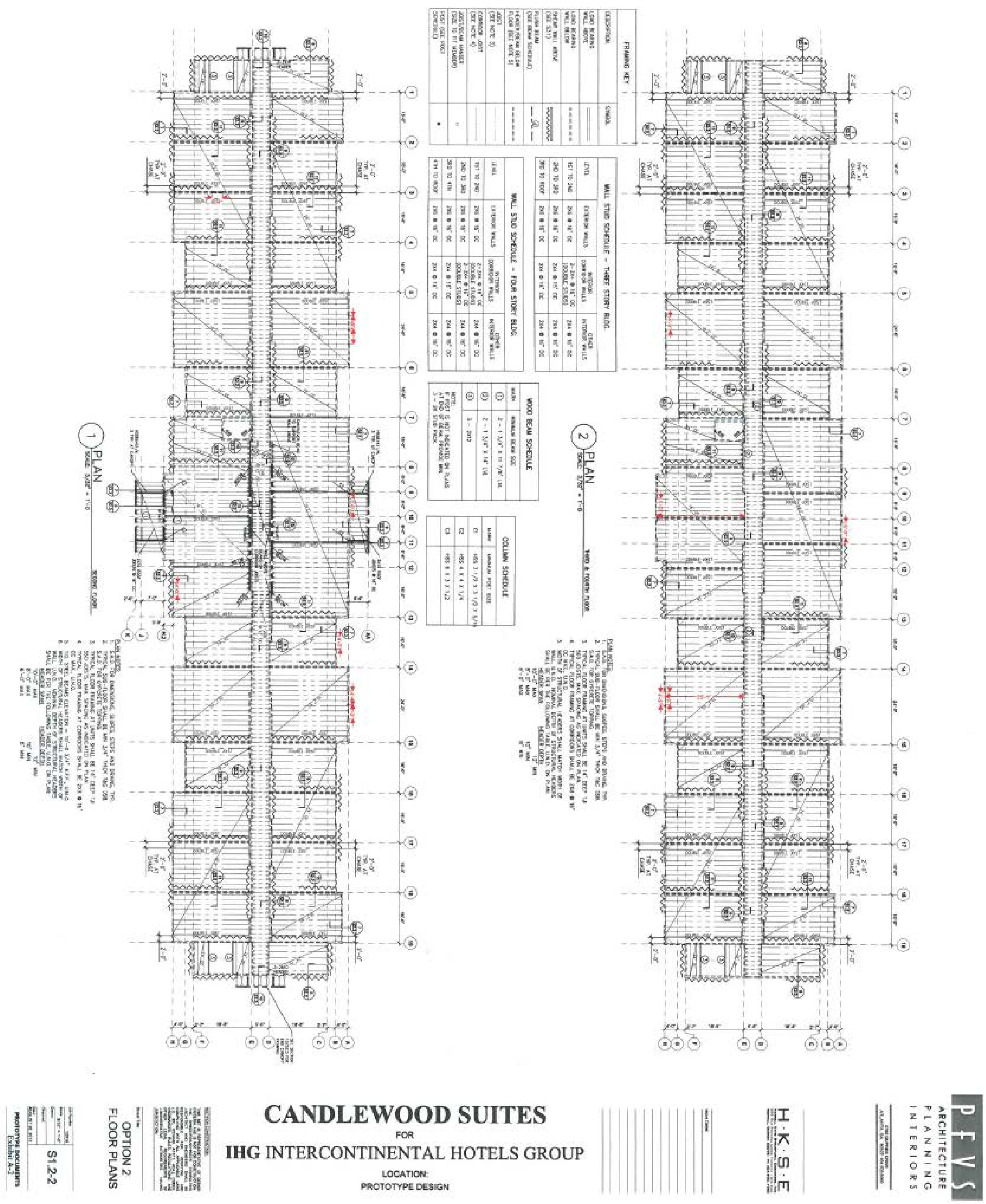

NEES-SOFT
4-STORY RETROFIT BUILDING
(SHAKE TABLE TEST)
STRUCTURAL DRAWING
WOOD CONNECTIONS
NEES + UCSD (LHPOST)
SAN DIEGO, CALIFORNIA
TBD
TBD
TBD

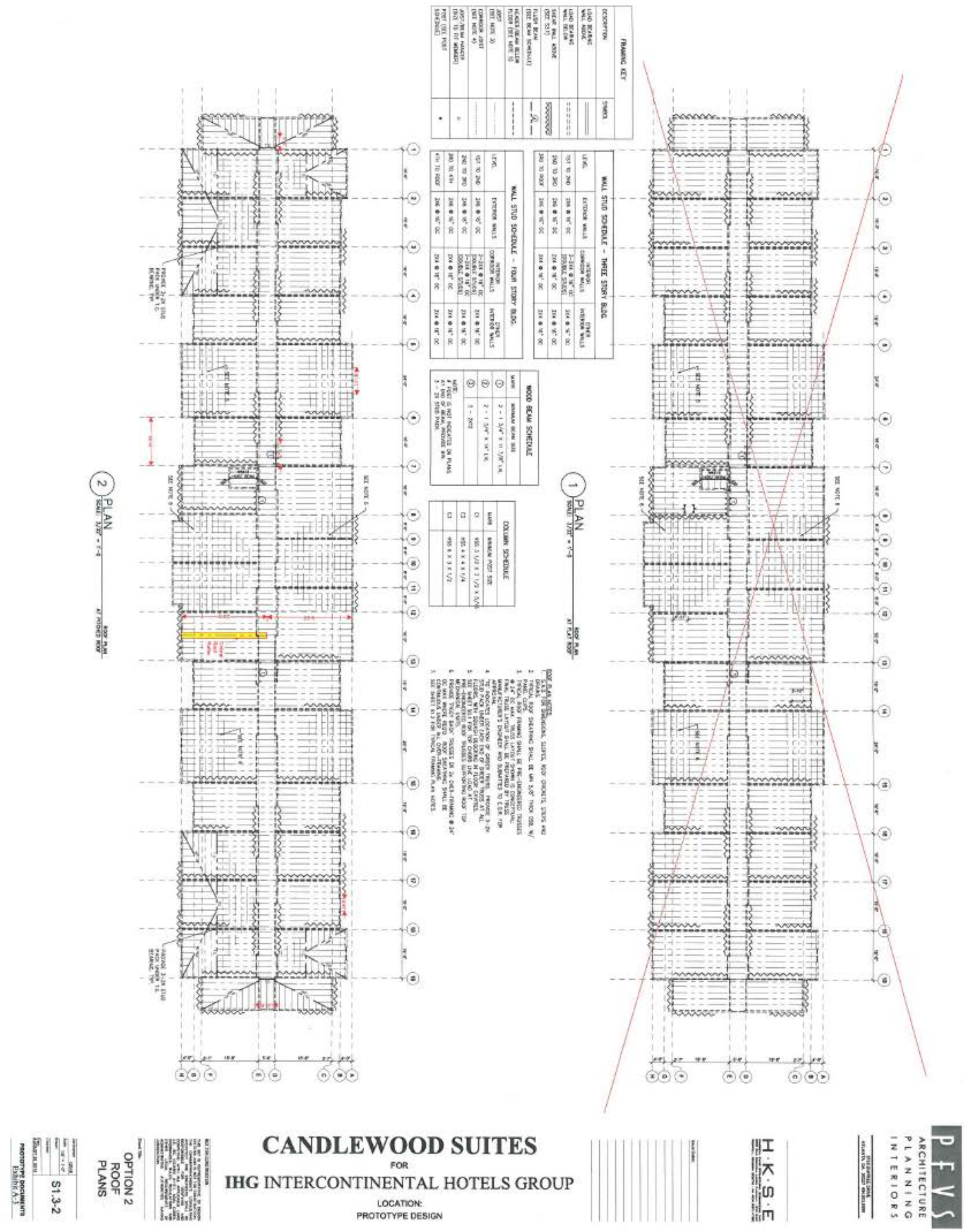


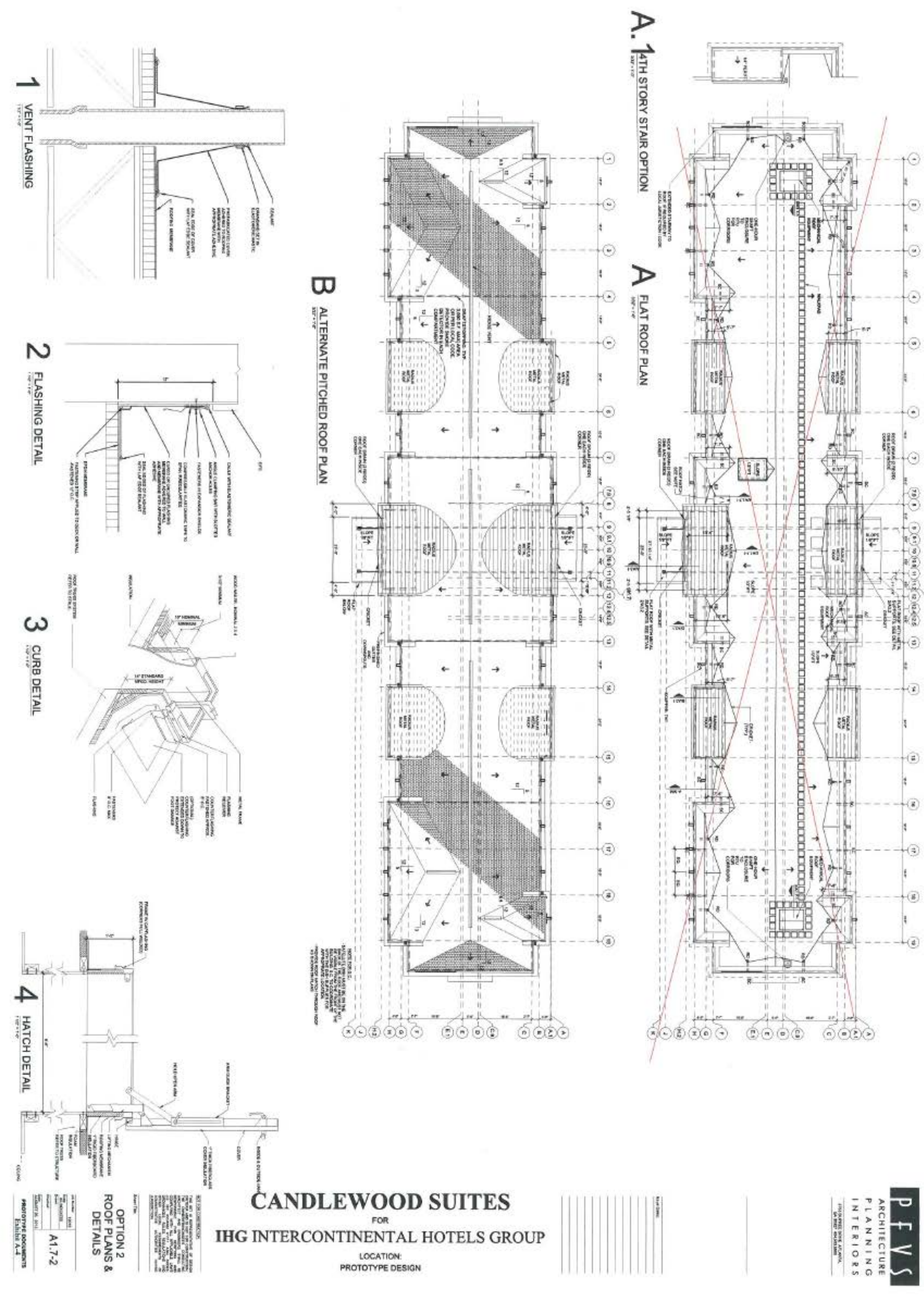
NEES-SOFT 4-STORY RETROFIT BUILDING (SHAKE TABLE TEST)	STRUCTURAL DRAWING WOOD CONNECTIONS	NEES + UCSD (LHPOST) SAN DIEGO, CALIFORNIA

Hotel

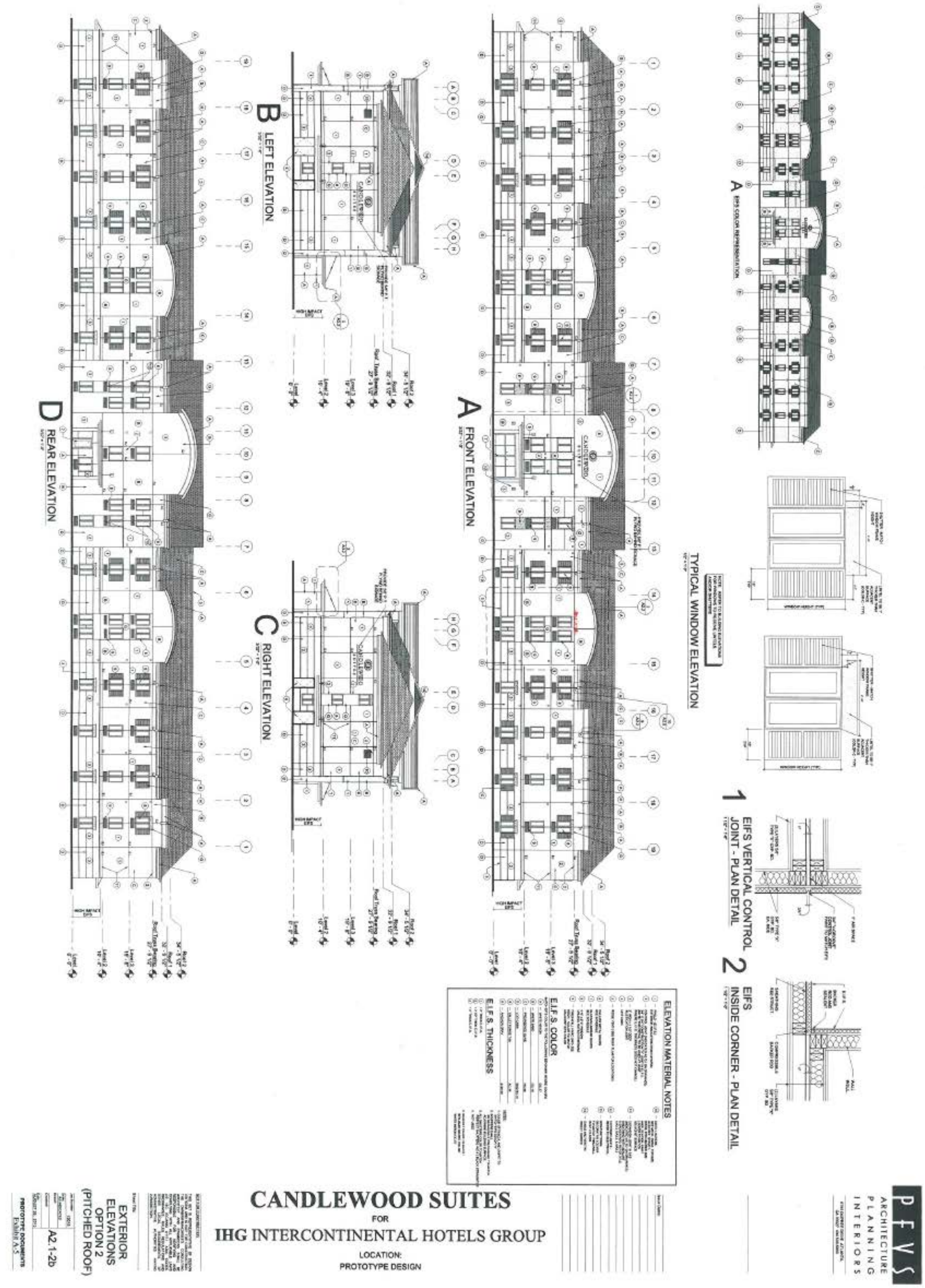

CANDLEWOOD SUITES
FOR
IHG INTERCONTINENTAL HOTELS GROUP
LOCATION:
PROTOTYPE DESIGN
OPTION 2
FOUNDATION
PLAN
S1.1-2
PARTIAL PLAN
PARTIAL PLAN
PLAN
COLUMN SCHEDULE
FOOTING SCHEDULE
H·K·S·E
ARCHITECTURE
PLANNING
INTERIORS

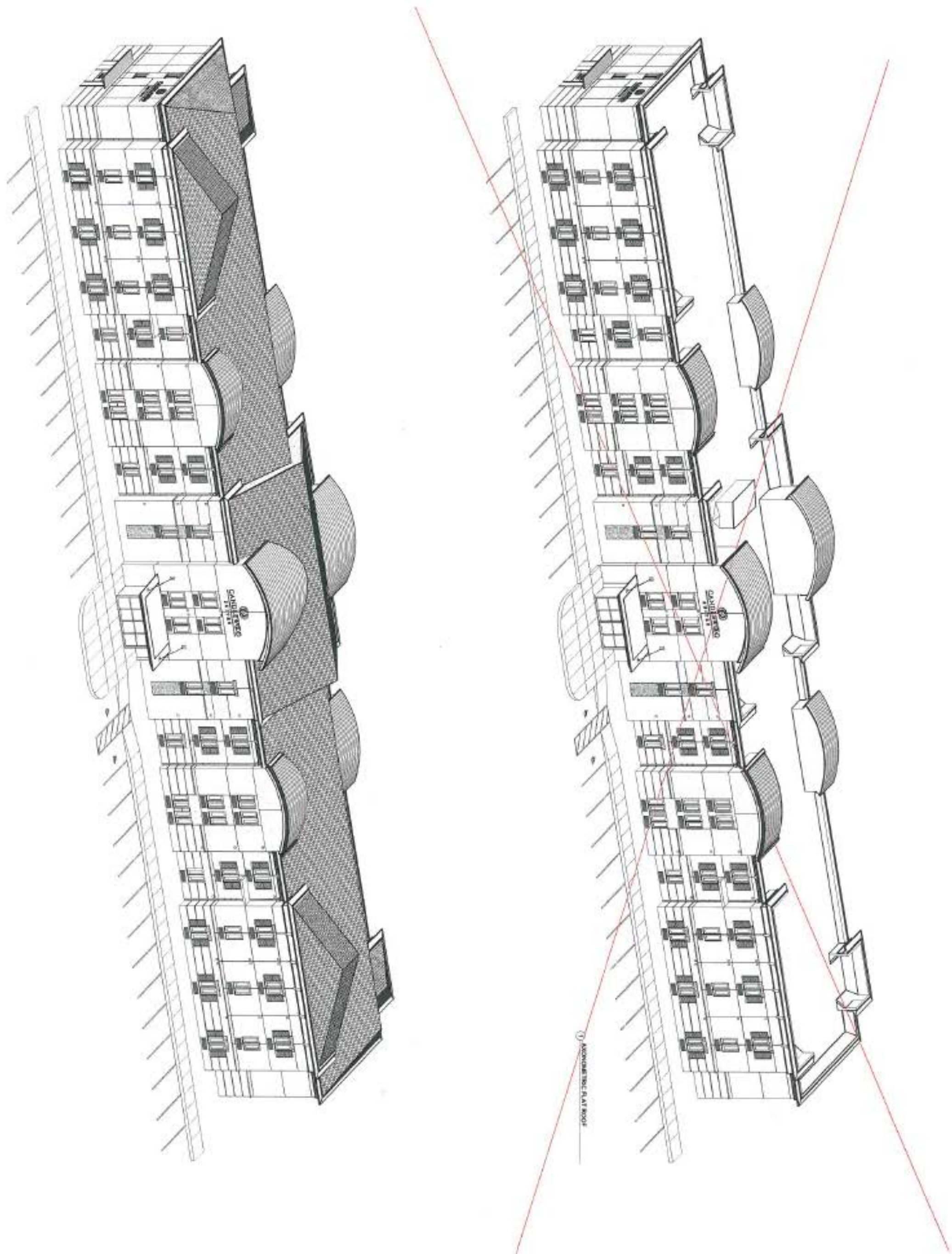

CANDLEWOOD SUITES
FOR
IHG INTERCONTINENTAL HOTELS GROUP
LOCATION:
PROTOTYPE DESIGN
OPTION 2
FLOOR PLANS
S1.2-2
H·K·S·E
PFVS
ARCHITECTURE
PLANNING
INTERIORS


FRAMING KEY
WALL STUD SCHEDULE - THREE STORY BLDG.
WALL STUD SCHEDULE - FOUR STORY BLDG.
WOOD BEAM SCHEDULE
COLUMN SCHEDULE
1 PLAN
2 PLAN
CANDLEWOOD SUITES
FOR
IHG INTERCONTINENTAL HOTELS GROUP
LOCATION:
PROTOTYPE DESIGN
OPTION 2
ROOF
PLANS
S1.3-2
H·K·S·E
ARCHITECTURE
PLANNING
INTERIORS



A.1 4TH STORY STAIR OPTION
A FLAT ROOF PLAN
B ALTERNATE PITCHED ROOF PLAN
1 VENT FLASHING
2 FLASHING DETAIL
3 CURB DETAIL
4 HATCH DETAIL
PFVS
ARCHITECTURE
PLANNING
INTERIORS
CANDLEWOOD SUITES
FOR
IHG INTERCONTINENTAL HOTELS GROUP
LOCATION:
PROTOTYPE DESIGN
OPTION 2
ROOF PLANS &
DETAILS
A1.7-2
PROTOTYPE DOCUMENTS
Exhibit A-4


A EIFS COLOR REPRESENTATION
TYPICAL WINDOW ELEVATION
EIFS VERTICAL CONTROL JOINT - PLAN DETAIL
EIFS INSIDE CORNER - PLAN DETAIL
A FRONT ELEVATION
B LEFT ELEVATION
C RIGHT ELEVATION
D REAR ELEVATION
ELEVATION MATERIAL NOTES
E.I.F.S. COLOR
E.I.F.S. THICKNESS
CANDLEWOOD SUITES
FOR
IHG INTERCONTINENTAL HOTELS GROUP
LOCATION:
PROTOTYPE DESIGN
EXTERIOR ELEVATIONS OPTION 2 (PITCHED ROOF)
A2.1-2b
PROTOTYPE DOCUMENTS
Exhibit A-5
PFVS
ARCHITECTURE
PLANNING
INTERIORS



CANDLEWOOD SUITES

FOR

IHG INTERCONTINENTAL HOTELS GROUP

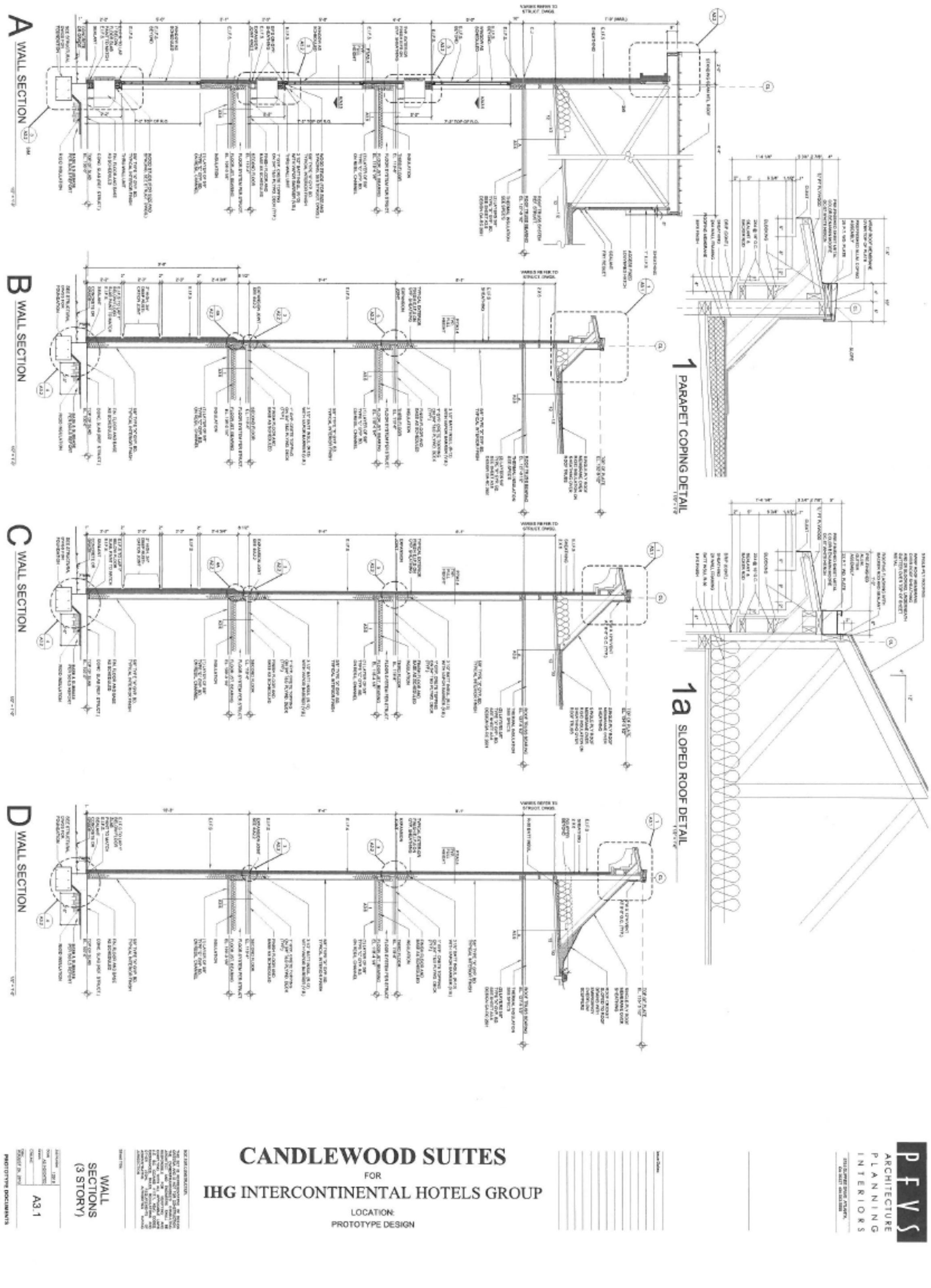
LOCATION:
PROTOTYPE DESIGN

3D VIEWS
OPTION 2

A2.4-2

Exhibit A-6

PFVS
ARCHITECTURE
PLANNING
INTERIORS


A WALL SECTION
B WALL SECTION
C WALL SECTION
D WALL SECTION
1 PARAPET COPING DETAIL
1a SLOPED ROOF DETAIL
CANDLEWOOD SUITES
FOR
IHG INTERCONTINENTAL HOTELS GROUP
LOCATION:
PROTOTYPE DESIGN
WALL SECTIONS (3 STORY)
A3.1
PFVS
ARCHITECTURE
PLANNING
INTERIORS

ATHENA Inputs

		SFD		FEMA Manufactured Home		Katrina Cottege		RAPIDO Core	
Project	Project name	Single Family Dwelling		FEMA MHU		Katrina Cottege		RAPIDO	
	Project location	Atlanta		Atlanta		Atlanta		Atlanta	
	Building type	Single Family Residential		Single Family Residential		Single Family Residential		Single Family Residential	
	Building life expactancy	50	yrs	50	yrs	50	yrs	50	yrs
	Building height	12.5	ft	12.5	ft	12.5	ft	16.875	ft
	Gross floor area	1296	ft^2	896	ft^2	840	ft^2	384	ft^2
Foundation	Type	Concrete Slab on Grade							
	Length	48	ft						
	Width	27	ft						
	Thickness	4	in						
	Concrete	4000	psi						
	Envelope	none							
Interior Walls	Length	165.33	ft	88.6	ft	93.6	ft	93	ft
	Height	8	ft	8	ft	8	ft	9	ft
	Stud type	wood stud		wood stud		wood stud		wood stud	
	Wall type	non-load bearing		non-load bearing		non-load bearing		non-load bearing	
	Sheating type	none		none		none		none	
	Stud spacing	16	in	16	in	16	in	16	in
	Stud thickness	2x4		2x4		2x4		2x4	
	Number of windows	0		0		0		0	
	Window fixed/operable	fixed		fixed		fixed		fixed	
	Window frame type	none		none		none		none	
	Window glazing type	none		none		none		none	
	Number of doors	15		6		8		1	
	Door type	hollow core wood interior door		hollow core wood interior door		hollow core wood interior door		hollow core wood interior door	
	Envelope	(2) gypsum regular 1/2 in. thick		(2) gypsum regular 1/2 in. thick		(2) gypsum regular 1/2 in. thick		(2) gypsum regular 1/2 in. thick	
Exterior Walls	Length	150	ft	156	ft	136.7	ft	88	ft
	Height	8	ft	8	ft	8	ft	9	ft
	Stud type	wood stud		wood stud		wood stud		wood stud	
	Wall type	load bearing		load bearing		load bearing		load bearing	
	Sheating type	OSB		OSB		OSB		OSB	
	Stud spacing	16	in	16	in	16	in	16	in
	Stud thickness	2x4		2x4		2x4		2x4	
	Number of windows	8		7		10		5	
	Total window area	94.67	ft	90.22	ft	137.78	ft	54	ft
	Window fixed/operable	fixed		fixed		fixed		fixed	
	Window frame type	aluminum clad wood window frame double pane		aluminum clad wood window frame double pane		aluminum clad wood window frame double pane		aluminum clad wood window frame double pane	
	Window glazing type	double glazed hard coated air		double glazed hard coated air		double glazed hard coated air		double glazed hard coated air	
	Number of doors	2		2		2		2	
	Door type	solid wood door		aluminum exterior door, 80% glazing		aluminum exterior door, 80% glazing		aluminum exterior door, 80% glazing	
	Envelope	(1) gypsum regular 1/2 in. thick		(1) gypsum regular 1/2 in. thick		(1) gypsum regular 1/2 in. thick		(1) gypsum regular 1/2 in. thick	
	Type	Light frame wood truss		Light frame wood truss		Light frame wood truss		Light frame wood truss	
	Width	48	ft	62	ft	52.5	ft	32	ft
	Span	27	ft	14	ft	16	ft	12	ft

Roof	Live Load	50	psf	50	psf	50	psf	50	psf
	Truss Type	pitched		pitched		pitched		pitched	
	Decking Type	OSB		OSB		OSB		OSB	
	Decking Thickness	0.5	in	0.5	in	0.5	in	0.5	in
	Envelope	(1) gypsum regular 1/2 in. thick		(1) gypsum regular 1/2 in. thick		(1) gypsum regular 1/2 in. thick		(1) gypsum regular 1/2 in. thick	
	Extra Materials	(1796.19) lbs roofing asphalt		(1823.5) sf metal roof cladding-residential		(1745.2) sf metal roof cladding-residential		(918.6) sf metal roof cladding-residential	
Floor	Type			Wood joist		Wood joist		Wood joist	
	Width			64	ft	56.15	ft	32	ft
	Span			14	ft	14.96	ft	12	ft
	Decking Type			OSB		OSB		OSB	
	Live Load			50	psf	50	psf	50	psf
	Decking Thickness			1/2	in	1/2	in	1/2	in
	Envelope			none		none		none	

		4-Story Apartment Building	
Project	Project name	Apartment	
	Project location	Atlanta	
	Building type	Multi Unit Residential - Rental	
	Building life expactancy	50	yrs
	Building height	35.708	ft
	Gross floor area	3748.45	ft^2
Foundation	Type	Concrete Slab on Grade	
	Length	38.29	ft
	Width	24.29	ft
	Thickness	4	in
	Concrete	4000	psi
	Envelope	none	
Interior Walls - Floor 1	Length	44.29	ft
	Height	8.9375	ft
	Stud type	wood stud	
	Wall type	non-load bearing	
	Sheating type	none	
	Stud spacing	16	in
	Stud thickness	2x4	
	Number of windows	0	
	Window fixed/operable	fixed	
	Window frame type	none	
	Window glazing type	none	
	Number of doors	3	
	Door type	hollow core wood interior door	
	Envelope	(2) gypsum regular 1/2 in. thick	
Exterior Walls - Floor 1, GB	Length	56.75	ft
	Height	8.9375	ft
	Stud type	wood stud	
	Wall type	load bearing	
	Sheating type	OSB	
	Stud spacing	16	in
	Stud thickness	2x4	
	Number of windows	2	
	Total window area	24	ft^2
	Window fixed/operable	fixed	
	Window frame type	aluminum clad wood window frame double pane	
	Window glazing type	double glazed hard coated air	
	Number of doors	2	
	Door type	aluminum exterior door, 80% glazing	
	Envelope	(1) gypsum regular 1/2 in. thick	
	Length	72.125	ft
	Height	8.9375	ft

Exterior Walls - Floor 1, no GB	Stud type	wood stud	
	Wall type	load bearing	
	Sheating type	OSB	
	Stud spacing	16	in
	Stud thickness	2x4	
	Number of windows	2	
	Total window area	24	ft^2
	Window fixed/operable	fixed	
	Window frame type	aluminum clad wood window frame double pane	
	Window glazing type	double glazed hard coated air	
	Number of doors	11	
	Door type	aluminum exterior door, 80% glazing	
	Envelope	none	
Interior Walls - Upper Floors	Length	422.75	ft
	Height	8.9375	ft
	Stud type	wood stud	
	Wall type	non-load bearing	
	Sheating type	none	
	Stud spacing	16	in
	Stud thickness	2x4	
	Number of windows	0	
	Window fixed/operable	fixed	
	Window frame type	none	
	Window glazing type	none	
	Number of doors	26	
	Door type	hollow core wood interior door	
	Envelope	(2) gypsum regular 1/2 in. thick	
Exterior Walls - Upper Floors	Length	401.23	ft
	Height	8.9375	ft
	Stud type	wood stud	
	Wall type	load bearing	
	Sheating type	OSB	
	Stud spacing	16	in
	Stud thickness	2x4	
	Number of windows	2	
	Total window area	24	ft^2
	Window fixed/operable	fixed	
	Window frame type	aluminum clad wood window frame double pane	
	Window glazing type	double glazed hard coated air	
	Number of doors	0	
	Door type	aluminum exterior door, 80% glazing	
	Envelope	(1) gypsum regular 1/2 in. thick	

Roof	Type	Wood joist	
	Width	24.29	ft
	Span	10.15	ft
	Live Load	50	psf
	Decking Type	OSB	
	Decking Thickness	1/2	in
	Envelope	(1) gypsum regular 1/2 in. thick	
	Extra Materials	(0.0116) mfbm small dimension softwood lumber (642.14) lbs roofing asphalt	
Floor 2	Type	Wood joist	
	Width	24.29	ft
	Span	10.15	ft
	Decking Type	OSB	
	Live Load	50	psf
	Decking Thickness	1/2	in
	Envelope	none	
Floor 3	Type	Wood joist	
	Width	24.29	ft
	Span	10.15	ft
	Decking Type	OSB	
	Live Load	50	psf
	Decking Thickness	1/2	in
	Envelope	(1) gypsum regular 1/2 in. thick	
Floor 4	Type	Wood joist	
	Width	24.29	ft
	Span	10.15	ft
	Decking Type	OSB	
	Live Load	50	psf
	Decking Thickness	1/2	in
	Envelope	(1) gypsum regular 1/2 in. thick	
Floor	Extra Materials	(0.2782) mfbm small dimension softwood lumber	
Columns and Beams, Floor 1	Number of columns	11	
	Numer of beams	0	
	Bay size	10	ft
	Supported span	7.10622	ft
	Supported area	464.25	ft^2
	Column height	8.9375	ft
	Supported element	floor	
	Live Load	50	psi
	Column type	softwood lumber	
	Beam type	glulam	
	Number of columns	5	
	Numer of beams	0	

Columns and Beams, Floor 2	Bay size	10	ft
	Supported span	5.4	ft
	Supported area	108	ft^2
	Column height	8.9375	ft
	Supported element	floor	
	Live Load	50	psi
	Column type	softwood lumber	
	Beam type	glulam	
Columns and Beams, Floor 3	Number of columns	4	
	Numer of beams	0	
	Bay size	10	ft
	Supported span	5.4	ft
	Supported area	54	ft^2
	Column height	8.9375	ft
	Supported element	floor	
	Live Load	50	psi
	Column type	softwood lumber	
	Beam type	glulam	
Columns and Beams, Floor 4	Number of columns	4	
	Numer of beams	0	
	Bay size	10	ft
	Supported span	5.4	ft
	Supported area	54	ft^2
	Column height	8.9375	ft
	Supported element	roof	
	Live Load	50	psi
	Column type	softwood lumber	
	Beam type	glulam	

		3-Story Hotel Building	
Project	Project name	Hotel	
	Project location	Atlanta	
	Building type	Multi Unit Residential - Rental	
	Building life expectancy	50	yrs
	Building height	34.458	ft
	Gross floor area	45979	ft^2
Foundation	Type	Concrete Slab on Grade	
	Length	294	ft
	Width	64.83	ft
	Thickness	4	in
	Concrete	4000	psi
	Envelope	none	
Interior Walls - Floor 1, corridor walls	Length	492.58	ft
	Height	10.25	ft
	Stud type	wood stud	
	Wall type	non-load bearing	
	Sheating type	none	
	Stud spacing	16	in
	Stud thickness	2x4	double
	Number of windows	0	
	Window fixed/operable	fixed	
	Window frame type	none	
	Window glazing type	none	
	Number of doors	29	
	Door type	hollow core wood interior door	
	Envelope	(2) gypsum regular 5/8 in. thick	
Interior Walls - Floor 1, other walls	Length	583.42	ft
	Height	10.25	ft
	Stud type	wood stud	
	Wall type	non-load bearing	
	Sheating type	none	
	Stud spacing	16	in
	Stud thickness	2x4	
	Number of windows	0	
	Window fixed/operable	fixed	ft^2
	Window frame type	none	
	Window glazing type	none	
	Number of doors	1	
	Door type	hollow core wood interior door	
	Envelope	(2) gypsum regular 5/8 in. thick	
	Length	760.83	ft
	Height	10.25	ft
	Stud type	wood stud	

Exterior Walls - Floor 1	Wall type	load bearing	
	Sheating type	OSB	
	Stud spacing	16	in
	Stud thickness	2x6	
	Number of windows	40	
	Total window area	800	ft^2
	Window fixed/operable	fixed	
	Window frame type	aluminum clad wood window frame double pane	
	Window glazing type	double glazed hard coated air	
	Number of doors	6	
	Door type	fiberglass exterior door, 50% glazing	
	Envelope	(1) gypsum regular 5/8 in. thick	
Interior Walls - floor 2	Length	1192.67	ft
	Height	9.33	ft
	Stud type	wood stud	
	Wall type	non-load bearing	
	Sheating type	none	
	Stud spacing	16	in
	Stud thickness	2x4	
	Number of windows	0	
	Window fixed/operable	fixed	
	Window frame type	none	
	Window glazing type	none	
	Number of doors	34	
	Door type	hollow core wood interior door	
	Envelope	(2) gypsum regular 5/8 in. thick	
Interior Walls - floor 3	Length	1329.92	ft
	Height	8.083	ft
	Stud type	wood stud	
	Wall type	non-load bearing	
	Sheating type	none	
	Stud spacing	16	in
	Stud thickness	2x4	
	Number of windows	0	
	Window fixed/operable	fixed	
	Window frame type	none	
	Window glazing type	none	
	Number of doors	40	
	Door type	hollow core wood interior door	
	Envelope	(2) gypsum regular 5/8 in. thick	
	Length	760.83	ft
	Height	9.33	ft
	Stud type	wood stud	
	Wall type	load bearing	

Exterior Walls - floor 2	Sheating type	OSB	
	Stud spacing	16	in
	Stud thickness	2x6	
	Number of windows	40	
	Total window area	800	ft^2
	Window fixed/operable	fixed	
	Window frame type	aluminum clad wood window frame double pane	
	Window glazing type	double glazed hard coated air	
	Number of doors	0	
	Door type	none	
	Envelope	(1) gypsum regular 5/8 in. thick	
Exterior Walls - floor 3	Length	760.83	ft
	Height	8.083	ft
	Stud type	wood stud	
	Wall type	load bearing	
	Sheating type	OSB	
	Stud spacing	16	in
	Stud thickness	2x6	
	Number of windows	41	
	Total window area	820	ft^2
	Window fixed/operable	fixed	
	Window frame type	aluminum clad wood window frame double pane	
	Window glazing type	double glazed hard coated air	
	Number of doors	0	
	Door type	none	
	Envelope	(1) gypsum regular 5/8 in. thick	
Roof	Type	Steel joist	
	Roof width	446.70	ft
	Span	18.04	ft
	Decking type	OSB	
	Decking Thickness	5/8	in
	Steel gauage	16	ga
	Joist type	1 5/8 x 10	in
	Joist spacing	24	in
	Envelope	(2) gypsum regular 5/8 in. thick	
	Extra Materials	(11352.49) lbs roofing asphalt	
Floor 2	Type	Wood joist	
	Width	538.80	ft
	Span	14.96	ft
	Decking Type	OSB	
	Live Load	50	psf
	Decking Thickness	5/8	in
	Envelope	(1) gypsum regular 5/8 in. thick	

Floor 3	Type	Wood joist	
	Width	538.80	ft
	Span	14.96	ft
	Decking Type	OSB	
	Live Load	50	psf
	Decking Thickness	5/8	in
	Envelope	(1) gypsum regular 5/8 in. thick	
Floor	Extra Materials	(2.2649) mfbm small dimension softwood lumber	
Columns and Beams	Extra Materials	(1.5344) tons of hollow structural steel	

Bill of Materials

Bill of Materials Report

Project: Apartment Building (4-Story)

Material	Unit	Total Quantity	Columns & Beams	Floors	Foundations	Roofs	Walls	Project Extra Materials	Mass Value	Mass Unit
1/2" Regular Gypsum Board	sf	13,485.6808	0.0000	813.5935	0.0000	271.1978	12,400.8894	0.0000	11.1312	Tons (short)
Aluminum Clad Wood Window Frame	lbs	202.2441	0.0000	0.0000	0.0000	0.0000	202.2441	0.0000	0.1011	Tons (short)
Aluminum Extrusion	Tons (short)	0.6199	0.0000	0.0000	0.0000	0.0000	0.6199	0.0000	0.6199	Tons (short)
Concrete Benchmark 4000 psi	yd3	11.8531	0.0000	0.0000	11.8531	0.0000	0.0000	0.0000	23.0401	Tons (short)
Double Glazed Hard Coated Air	sf	107.8223	0.0000	0.0000	0.0000	0.0000	107.8223	0.0000	0.1788	Tons (short)
Galvanized Sheet	Tons (short)	0.0232	0.0000	0.0174	0.0000	0.0058	0.0000	0.0000	0.0232	Tons (short)
Glazing Panel	Tons (short)	1.2109	0.0000	0.0000	0.0000	0.0000	1.2109	0.0000	1.2109	Tons (short)
Joint Compound	Tons (short)	1.3783	0.0000	0.0832	0.0000	0.0277	1.2674	0.0000	1.3783	Tons (short)
Large Dimension Softwood Lumber, kiln-dried	Mbfm large dimension	1.0119	0.0000	0.7589	0.0000	0.2530	0.0000	0.0000	0.7902	Tons (short)
Nails	Tons (short)	0.2647	0.0000	0.0117	0.0000	0.0039	0.2491	0.0000	0.2647	Tons (short)
Oriented Strand Board	msf (3/8")	7.4850	0.0000	0.9810	0.0000	0.3270	6.1770	0.0000	4.6285	Tons (short)
Paper Tape	Tons (short)	0.0158	0.0000	0.0010	0.0000	0.0003	0.0145	0.0000	0.0158	Tons (short)
Roofing Asphalt	lbs	1,459.4091	0.0000	0.0000	0.0000	1,459.4091	0.0000	0.0000	0.7297	Tons (short)
Small Dimension Softwood Lumber, kiln-dried	Mbfm small dimension	8.4776	0.8941	0.3005	0.0000	0.0125	7.2705	0.0000	6.4423	Tons (short)
Water Based Latex Paint	Gallons (us)	8.9447	0.0000	0.0000	0.0000	0.0000	8.9447	0.0000	0.0280	Tons (short)
Welded Wire Mesh / Ladder Wire	Tons (short)	0.0861	0.0000	0.0000	0.0861	0.0000	0.0000	0.0000	0.0861	Tons (short)

Bill of Materials Report

Project: FEMA MHU

Material	Unit	Total Quantity	Columns & Beams	Floors	Foundations	Roofs	Walls	Project Extra Materials	Mass Value	Mass Unit
1/2" Regular Gypsum Board	sf	2,702.0912	0.0000	0.0000	0.0000	0.0000	2,702.0912	0.0000	2.2303	Tons (short)
Aluminum Clad Wood Window Frame	lbs	244.5313	0.0000	0.0000	0.0000	0.0000	244.5313	0.0000	0.1223	Tons (short)
Aluminum Extrusion	Tons (short)	0.0954	0.0000	0.0000	0.0000	0.0000	0.0954	0.0000	0.0954	Tons (short)
Double Glazed Hard Coated Air	sf	135.5249	0.0000	0.0000	0.0000	0.0000	135.5249	0.0000	0.2247	Tons (short)
Galvanized Sheet	Tons (short)	0.0616	0.0000	0.0153	0.0000	0.0463	0.0000	0.0000	0.0616	Tons (short)
Glazing Panel	Tons (short)	0.1863	0.0000	0.0000	0.0000	0.0000	0.1863	0.0000	0.1863	Tons (short)
Joint Compound	Tons (short)	0.2762	0.0000	0.0000	0.0000	0.0000	0.2762	0.0000	0.2762	Tons (short)
Large Dimension Softwood Lumber, kiln-dried	Mbfm large dimension	1.2681	0.0000	1.2681	0.0000	0.0000	0.0000	0.0000	0.9903	Tons (short)
Metal Roof Cladding - Residential (30 Ga.)	sf	1,841.7350	0.0000	0.0000	0.0000	1,841.7350	0.0000	0.0000	0.6675	Tons (short)
Nails	Tons (short)	0.0736	0.0000	0.0132	0.0000	0.0095	0.0510	0.0000	0.0736	Tons (short)
Oriented Strand Board	msf (3/8")	3.9415	0.0000	1.1884	0.0000	1.1884	1.5647	0.0000	2.4373	Tons (short)
Paper Tape	Tons (short)	0.0032	0.0000	0.0000	0.0000	0.0000	0.0032	0.0000	0.0032	Tons (short)
Small Dimension Softwood Lumber, kiln-dried	Mbfm small dimension	2.8936	0.0000	0.0000	0.0000	1.1681	1.7255	0.0000	2.1989	Tons (short)
Water Based Latex Paint	Gallons (us)	1.8506	0.0000	0.0000	0.0000	0.0000	1.8506	0.0000	0.0058	Tons (short)

Bill of Materials Report

Project: Single Family Dwelling

Material	Unit	Total Quantity	Columns & Beams	Floors	Foundations	Roofs	Walls	Project Extra Materials	Mass Value	Mass Unit
1/2" Regular Gypsum Board	sf	4,894.2041	0.0000	0.0000	0.0000	1,425.5999	3,468.6042	0.0000	4.0397	Tons (short)
Aluminum Clad Wood Window Frame	lbs	267.7843	0.0000	0.0000	0.0000	0.0000	267.7843	0.0000	0.1339	Tons (short)
Concrete Benchmark 4000 psi	yd3	16.5168	0.0000	0.0000	16.5168	0.0000	0.0000	0.0000	32.1053	Tons (short)
Double Glazed Hard Coated Air	sf	141.5260	0.0000	0.0000	0.0000	0.0000	141.5260	0.0000	0.2347	Tons (short)
Galvanized Sheet	Tons (short)	0.0670	0.0000	0.0000	0.0000	0.0670	0.0000	0.0000	0.0670	Tons (short)
Joint Compound	Tons (short)	0.5002	0.0000	0.0000	0.0000	0.1457	0.3545	0.0000	0.5002	Tons (short)
Nails	Tons (short)	0.1039	0.0000	0.0000	0.0000	0.0150	0.0888	0.0000	0.1039	Tons (short)
Oriented Strand Board	msf (3/8")	1.4915	0.0000	0.0000	0.0000	0.0000	1.4915	0.0000	0.9223	Tons (short)
Paper Tape	Tons (short)	0.0057	0.0000	0.0000	0.0000	0.0017	0.0041	0.0000	0.0057	Tons (short)
Roofing Asphalt	lbs	4,276.6429	0.0000	0.0000	0.0000	4,276.6429	0.0000	0.0000	2.1383	Tons (short)
Small Dimension Softwood Lumber, kiln-dried	Mbfm small dimension	4.0748	0.0000	0.0000	0.0000	1.6895	2.3853	0.0000	3.0965	Tons (short)
Softwood Plywood	msf (3/8")	1.7189	0.0000	0.0000	0.0000	1.7189	0.0000	0.0000	0.8316	Tons (short)
Water Based Latex Paint	Gallons (us)	5.2434	0.0000	0.0000	0.0000	0.0000	5.2434	0.0000	0.0164	Tons (short)
Welded Wire Mesh / Ladder Wire	Tons (short)	0.1199	0.0000	0.0000	0.1199	0.0000	0.0000	0.0000	0.1199	Tons (short)

Bill of Materials Report

Project: Hotel (3-Story)

Material	Unit	Total Quantity	Columns & Beams	Floors	Foundations	Roofs	Walls	Project Extra Materials	Mass Value	Mass Unit
5/8" Regular Gypsum Board	sf	123,830.8286	0.0000	17,732.9849	0.0000	17,728.6289	88,369.2148	0.0000	130.4903	Tons (short)
Aluminum Clad Wood Window Frame	lbs	5,265.4356	0.0000	0.0000	0.0000	0.0000	5,265.4356	0.0000	2.6327	Tons (short)
Concrete Benchmark 4000 psi	yd3	242.9090	0.0000	0.0000	242.9090	0.0000	0.0000	0.0000	472.1664	Tons (short)
Double Glazed Hard Coated Air	sf	3,712.9175	0.0000	0.0000	0.0000	0.0000	3,712.9175	0.0000	6.1572	Tons (short)
Expanded Polystyrene	sf (1")	178.5733	0.0000	0.0000	0.0000	0.0000	178.5733	0.0000	0.0132	Tons (short)
Galvanized Sheet	Tons (short)	0.2572	0.0000	0.2572	0.0000	0.0000	0.0000	0.0000	0.2572	Tons (short)
Galvanized Studs	Tons (short)	12.3442	0.0000	0.0000	0.0000	12.3442	0.0000	0.0000	12.3442	Tons (short)
Glass Fibre	lbs	462.9702	0.0000	0.0000	0.0000	0.0000	462.9702	0.0000	0.2315	Tons (short)
Glazing Panel	Tons (short)	0.2646	0.0000	0.0000	0.0000	0.0000	0.2646	0.0000	0.2646	Tons (short)
Hollow Structural Steel	Tons (short)	1.5497	1.5497	0.0000	0.0000	0.0000	0.0000	0.0000	1.5497	Tons (short)
Joint Compound	Tons (short)	12.6561	0.0000	1.8124	0.0000	1.8120	9.0318	0.0000	12.6561	Tons (short)
Laminated Veneer Lumber	ft3	7.8469	0.0000	0.0000	0.0000	0.0000	7.8469	0.0000	0.1335	Tons (short)
Large Dimension Softwood Lumber, kiln-dried	Mbfm large dimension	24.3800	0.0000	24.3800	0.0000	0.0000	0.0000	0.0000	19.0392	Tons (short)
Nails	Tons (short)	1.2734	0.0000	0.2551	0.0000	0.0170	1.0014	0.0000	1.2734	Tons (short)
Oriented Strand Board	msf (3/8")	65.9434	0.0000	26.7270	0.0000	13.3602	25.8562	0.0000	40.7778	Tons (short)
Paper Tape	Tons (short)	0.1453	0.0000	0.0208	0.0000	0.0208	0.1037	0.0000	0.1453	Tons (short)
Roofing Asphalt	lbs	25,801.1136	0.0000	0.0000	0.0000	25,801.1136	0.0000	0.0000	12.9006	Tons (short)
Screws Nuts & Bolts	Tons (short)	0.1190	0.0000	0.0000	0.0000	0.1190	0.0000	0.0000	0.1190	Tons (short)
Small Dimension Softwood Lumber, kiln-dried	Mbfm small dimension	54.0539	0.0000	2.4461	0.0000	0.0000	51.6078	0.0000	41.0762	Tons (short)
Solvent Based Alkyd Paint	Gallons (us)	0.4784	0.0000	0.0000	0.0000	0.0000	0.4784	0.0000	0.0015	Tons (short)
Water Based Latex Paint	Gallons (us)	32.0774	0.0000	0.0000	0.0000	0.0000	32.0774	0.0000	0.1004	Tons (short)
Welded Wire Mesh / Ladder Wire	Tons (short)	1.7640	0.0000	0.0000	1.7640	0.0000	0.0000	0.0000	1.7640	Tons (short)

Bill of Materials Report

Project: Katrina Cottege

Material	Unit	Total Quantity	Columns & Beams	Floors	Foundations	Roofs	Walls	Project Extra Materials	Mass Value	Mass Unit
1/2" Regular Gypsum Board	sf	3,253.1619	0.0000	0.0000	0.0000	924.0000	2,329.1619	0.0000	2.6852	Tons (short)
Aluminum Clad Wood Window Frame	lbs	361.1828	0.0000	0.0000	0.0000	0.0000	361.1828	0.0000	0.1806	Tons (short)
Aluminum Extrusion	Tons (short)	0.0954	0.0000	0.0000	0.0000	0.0000	0.0954	0.0000	0.0954	Tons (short)
Double Glazed Hard Coated Air	sf	207.6900	0.0000	0.0000	0.0000	0.0000	207.6900	0.0000	0.3444	Tons (short)
Galvanized Sheet	Tons (short)	0.0568	0.0000	0.0134	0.0000	0.0434	0.0000	0.0000	0.0568	Tons (short)
Glazing Panel	Tons (short)	0.1863	0.0000	0.0000	0.0000	0.0000	0.1863	0.0000	0.1863	Tons (short)
Joint Compound	Tons (short)	0.3325	0.0000	0.0000	0.0000	0.0944	0.2381	0.0000	0.3325	Tons (short)
Large Dimension Softwood Lumber, kiln-dried	Mbfm large dimension	1.2704	0.0000	1.2704	0.0000	0.0000	0.0000	0.0000	0.9921	Tons (short)
Metal Roof Cladding - Residential (30 Ga.)	sf	1,762.6520	0.0000	0.0000	0.0000	1,762.6520	0.0000	0.0000	0.6388	Tons (short)
Nails	Tons (short)	0.0782	0.0000	0.0124	0.0000	0.0097	0.0560	0.0000	0.0782	Tons (short)
Oriented Strand Board	msf (3/8")	3.5109	0.0000	1.1141	0.0000	1.1141	1.2827	0.0000	2.1711	Tons (short)
Paper Tape	Tons (short)	0.0038	0.0000	0.0000	0.0000	0.0011	0.0027	0.0000	0.0038	Tons (short)
Small Dimension Softwood Lumber, kiln-dried	Mbfm small dimension	2.7044	0.0000	0.0000	0.0000	1.0951	1.6093	0.0000	2.0551	Tons (short)
Water Based Latex Paint	Gallons (us)	2.4675	0.0000	0.0000	0.0000	0.0000	2.4675	0.0000	0.0077	Tons (short)

Bill of Materials Report

Project: RAPIDO Core

Material	Unit	Total Quantity	Columns & Beams	Floors	Foundations	Roofs	Walls	Project Extra Materials	Mass Value	Mass Unit
1/2" Regular Gypsum Board	sf	2,993.4665	0.0000	0.0000	0.0000	422.4000	2,571.0666	0.0000	2.4708	Tons (short)
Aluminum Clad Wood Window Frame	lbs	159.8880	0.0000	0.0000	0.0000	0.0000	159.8880	0.0000	0.0799	Tons (short)
Aluminum Extrusion	Tons (short)	0.0954	0.0000	0.0000	0.0000	0.0000	0.0954	0.0000	0.0954	Tons (short)
Double Glazed Hard Coated Air	sf	80.3112	0.0000	0.0000	0.0000	0.0000	80.3112	0.0000	0.1332	Tons (short)
Galvanized Sheet	Tons (short)	0.0695	0.0000	0.0496	0.0000	0.0199	0.0000	0.0000	0.0695	Tons (short)
Glazing Panel	Tons (short)	0.1863	0.0000	0.0000	0.0000	0.0000	0.1863	0.0000	0.1863	Tons (short)
Joint Compound	Tons (short)	0.3059	0.0000	0.0000	0.0000	0.0432	0.2628	0.0000	0.3059	Tons (short)
Metal Roof Cladding - Residential (30 Ga.)	sf	927.7860	0.0000	0.0000	0.0000	927.7860	0.0000	0.0000	0.3362	Tons (short)
Nails	Tons (short)	0.0375	0.0000	0.0041	0.0000	0.0045	0.0290	0.0000	0.0375	Tons (short)
Oriented Strand Board	msf (3/8")	1.9971	0.0000	0.5093	0.0000	0.5093	0.9785	0.0000	1.2350	Tons (short)
Paper Tape	Tons (short)	0.0035	0.0000	0.0000	0.0000	0.0005	0.0030	0.0000	0.0035	Tons (short)
Small Dimension Softwood Lumber, kiln-dried	Mbfm small dimension	2.3646	0.0000	0.5927	0.0000	0.5006	1.2712	0.0000	1.7969	Tons (short)
Water Based Latex Paint	Gallons (us)	0.3084	0.0000	0.0000	0.0000	0.0000	0.3084	0.0000	0.0010	Tons (short)

APPENDIX B. BUILDING PERFORMANCE CURVES

HAZUS (DHS, 2015) building performance curves were originally adopted to measure the hazard vulnerability of the temporary housing units for a wind hazard event. Figure 11 reproduces the building performance curves from HAZUS for building samples that closely match the units in consideration. The marginally engineered building represents the apartment building and hotel with four stories and three stories respectively. The residential building represents the single-family dwelling home. Two performance curves were pulled for the manufactured homes, one meeting pre-HUD standards, and one meeting 1994 HUD standards[2]. To evaluate the hazard vulnerability of the temporary housing units according to the measurement described in chapter 4 with equations 8 and 9, the 50th percentile wind speed of each unit at each damage state should be recorded. However, with the building performance curves shown, 1994 HUD manufactured housing units significantly outperform the marginally engineered buildings and residential home in each damage state which seems counterintuitive. To reduce this gap, the pre-HUD building performance curves for manufactured homes were examined more closely under the assumption that possibly not all manufactured units distributed as temporary housing would be up to the 1994 standards. While the wind speeds are reduced for pre-HUD manufactured homes, they still are shown to outperform the other buildings in consideration.

[2] Manufactured homes built after 1976 are referred to as "HUD-code homes." Units built prior to 1976 are considered "pre-HUD homes." HUD changed its wind load requirements in 1994; therefore, those referred to as "1994 HUD" have the most up to date wind load design as specified by HUD.

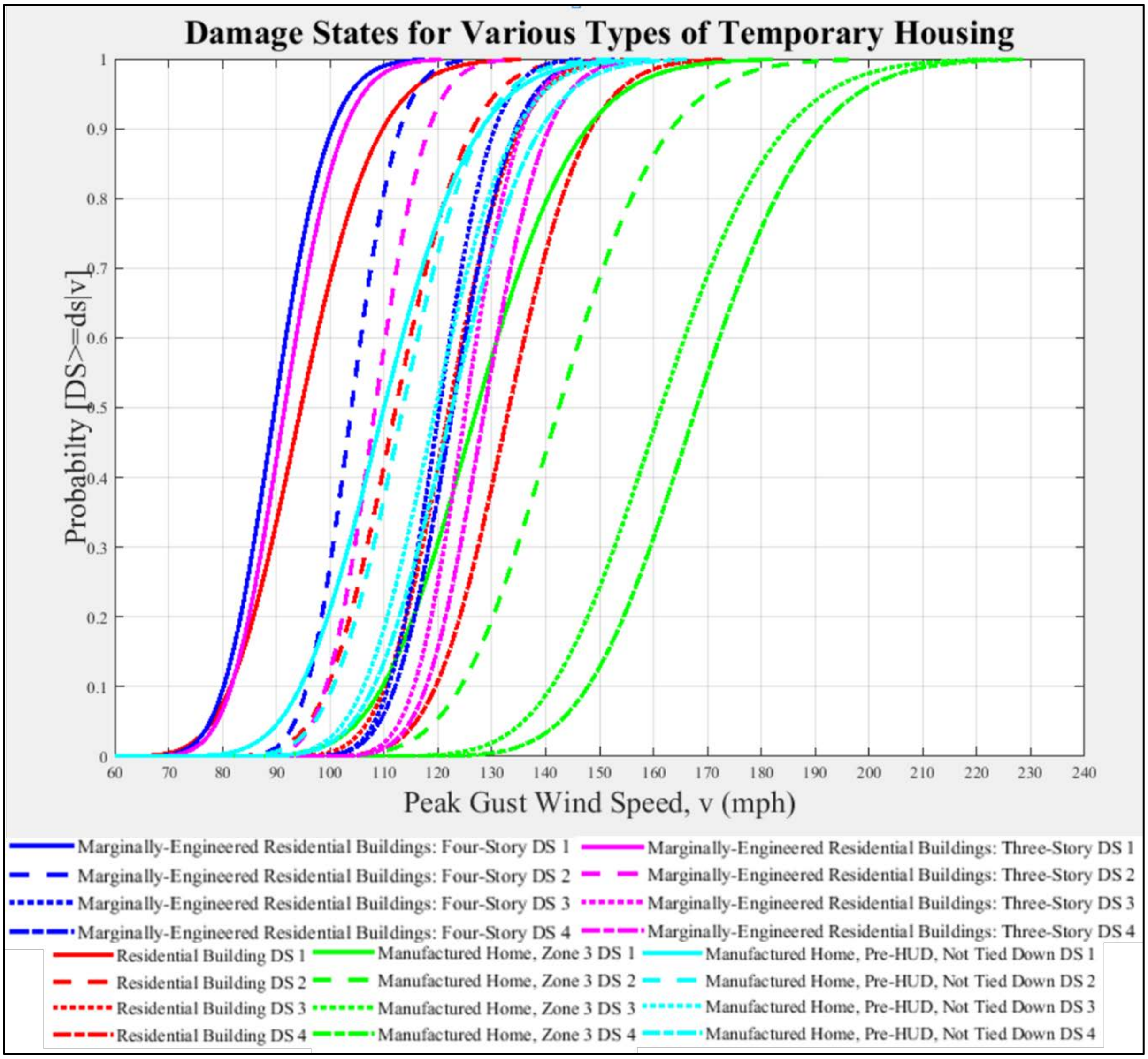


Figure 11. Damage State Fragility Functions (DHS, 2015)

Other building performance curves were investigated for residential building to explore if curves existed for residential buildings performing better than the manufactured home curves from HAZUS (DHS, 2015). Ellington et al (2004), Dong and Li (2016), and Lee and Rowosky (2005) were all consulted, but these did not have the depth needed to evaluate the hazard vulnerability of all types of temporary housing units with consistency. Ellington et al (2004) designed fragility curves for different structural elements of a building, such as a roof panel, and a roof to wall connection, not for the building as an entire unit. Dong and Li (2016) had the same limitation with respect to evaluating hazard vulnerability with fragility curves for elements such as sheathing and roof covering, and Lee and Rowosky (2005) discuss roof sheathing complementary fragilities.

A combination of curves from various sources could have been used to achieve the depth needed; however, different studies and simulations have different assumptions, methods, and test building dimensions, so assuming accuracy across these varying sources prove to make the information obsolete. With these hurdles in building performance data, the hazard vulnerability for all the temporary housing options was set to unity for the household-level example until more in-depth data can be collected in this regard. The development of measuring hazard vulnerability in this research can only be as accurate as the building performance used for evaluation; therefore, more research and development in this area is crucial to the proper outputs of the model developed.