THE EVALUATION OF MASS-PRODUCED INTERIM HOUSING IN POST-NATURAL DISASTER AREAS

By

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To those in Mississippi and Louisiana who were affected by Hurricane Katrina

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Natural disasters are consequences of inevitable environmental cycles throughout the biosphere. Human beings do not have the capacity to wield a mechanism to stop natural disasters. The best preventative measures to alleviate the damages and future loss from disasters are to enforce stringent building codes for the construction of commercial and residential buildings. The effectiveness and employment of these building codes determines a community's susceptibility to vulnerability. Vulnerability is increased with lenient building codes, poor quality materials, and inadequate labor.

Following a disaster, housing must be deployed and reconstruction must begin to address the loss of housing and infrastructure. Mass-produced housing can address these dire needs. Mass-produced housing can be divided into three subcategories: modular housing, manufactured housing, and container housing. Within these subcategories are models that must adhere to the unique local, state, and federal government disaster remediation plans. The inherent characteristics of mass-produced housing provide a sufficient transition from initial disaster relief to long term housing communities.

The purpose of this research is to identify the most appropriate mass-produced architecture to be implemented in the aftermath of a natural disaster. The remediation efforts to address temporary and permanent housing often do not meet needs. The objective of this research is to evaluate the housing models currently being deployed in disaster regions. In addition, this research identified characteristics that are essential to the construction of mass-produced architecture. This was achieved by analyzing previous deployed models during Hurricane Katrina with a select group of case-study housing techniques. The identified characteristics developed into an analysis matrix for the design and construction of rapidly deployable post-disaster housing.

CHAPTER 1
INTRODUCTION

Natural Disasters

As a global society, human beings experience many disasters throughout a lifetime; some are natural disasters and some are unnatural events such as terrorist attacks. The frequency and severity of such events have been escalated by the rapid growth of the world's population and an increased concentration of that population in hazardous environments. Natural disasters are catalysts for destruction that occur when hazards meet vulnerability. The vulnerability of communities in disaster prone areas have been amplified by global warming, deforestation, lenient building codes, too much governmental assistance in terms of coastal flood insurance, weak communications, inadequate governmental assistance, lack of budgetary allocation for disaster prevention, and insufficient infrastructure. The aptitude at which the effecting population can resist loss depends on the inherent resilience and potential susceptibility to vulnerability.

The General Assembly of the United Nations proposed the following, "It is impossible to prevent the occurrence of natural disasters and their damages", on December 22, 1989, during an international conference. However, it is possible to reduce the impact of disasters by adopting suitable disaster mitigation strategies. Disaster mitigation mainly addresses the following:

- Minimize the potential risks by developing disaster early warning strategies
- Prepare and implement development plans to provide resilience to such disasters
- Mobilize resources including communication and tele-medicinal services

Disaster management, on the other hand involves:

- Pre-disaster planning, preparedness, and monitoring including relief management

- Prediction and early warning strategies
- Damage assessment and relief management
- Systemic plan of disaster reduction

Effects of Hurricane Katrina

Hurricane Katrina developed initially from tropical depression #12, in the Southeastern Bahamas on August 23, 2005. Before Katrina made landfall in North Miami Beach, Florida, it became a category (1) hurricane with wind speeds approaching 80 mph. As the storm moved across the southern point of the Florida peninsula, wind speeds decreased and it became a tropical storm after spending seven hours over land. Once the tropical depression moved into the warmer waters of the Gulf of Mexico, it quickly regained hurricane wind speeds and continued to move westward up the Gulf coast line. Continuing to strengthen and move northwards during the next 48 hours, Katrina reached maximum wind speeds on the morning of Sunday, August 28th, of over 170 mph (category (5)), and minimum central pressure dropped that afternoon to 902 mb - the fourth lowest on record for an Atlantic storm (NOAA, 2005).

Hurricane Katrina was the sixth strongest hurricane ever recorded and the third strongest hurricane ever recorded that made landfall in the U.S.. Typical hurricanes of category (5) strength are rarely sustained for long durations due to the entrainment of dry air and the opening of the eye-wall. Although Katrina was subjected to the contributing factors, the storm maintained strong category (4) wind speeds during initial landfall. With sustained winds during landfall of 125 mph (a strong category three hurricane on the Saffir-Simpson scales) and minimum central pressure the third lowest on record at landfall, Katrina caused widespread devastation along the central Gulf Coast states of the US. Cities such as New Orleans, LA, Mobile, AL, and Gulfport, MS bore the brunt of Katrina's force and will need an undetermined amount of time for recovery efforts to restore normality" (NOAA, 2005). There have only been four storms within the last 100-years that have exceeded Hurricane Katrina's sustained winds that made have made land fall.

The Labor Day Hurricane, Florida Keys, September, 1935, Category (5), 200 mph
Hurricane Camille, Mississippi, August 17, 1969, Category (5), 190 mph
Hurricane Andrew, Southeast Florida, August 24, 1992, Category (5), 165 mph
Hurricane Charley, Punta Gorda, Florida, August 13, 2004, Category (4), 150 mph
(NOAA, 2005)

In New Orleans, Louisiana, the evacuation plan was particularly crucial because the surrounding region was in the Storm Surge Zone, below sea level (up to six feet in some areas). The storm surges that ensued from Hurricane Katrina were estimated at 20 feet high above sea level. The subsequent rising flood waters placed an overwhelming strain on the levees of New Orleans, which were only designed for a category (3) hurricane (Katrina made land fall as a category (3)). The failure of the levees was inevitable, and due to system design flaws for the most part, combined with the lack of adequate maintenance, the levees gave way and spilled their retained waters into the surrounding regions and parishes. An estimated 80% of New Orleans was underwater (up to 20 feet) due to tidal surges and flooding caused by the broken levees, an area of 90,000 square miles was affected by Hurricane Katrina. The final death toll was 1,836, primarily from Louisiana (1,577) and Mississippi (238); it is difficult to determine the exact cause of the deaths but they were all caused either directly or indirectly by the Hurricane. Hurricane Katrina caused $75 billion in estimated physical damages, the most costly hurricane in history, but it is estimated that the total economic impact in Louisiana and Mississippi may exceed $150 billion (NOAA, 2005). Before the hurricane, the coastal region supported approximately one million non-farm jobs, with over half of them in New Orleans. Due to an unstable infrastructure and lack of coordination hundreds of thousands of local residents were left unemployed by the hurricane. The remaining survivors of Hurricane Katrina were left with the overwhelming task of rebuilding their communities from the foundations up.

FEMA

The primary purpose of Federal Emergency Management Agency (FEMA) is to coordinate the response to a disaster that has occurred in the U.S., were local and state authorities' resources have become overwhelmed. FEMA is an agency of the United States Department of Homeland Security, initially created by Presidential Order, on April 1, 1979 (FEMA, 2010). A chain of custody exists to initiate FEMA into the disaster area, the governor of the state in which the disaster has occurred must declare a *state of emergency* and formally request from the President, that FEMA and the federal government respond to the disaster. While on-the-ground support of disaster recovery efforts is a major part of FEMA's charter, the agency provides state and local governments with experts in specialized fields and funding for rebuilding efforts and relief funds for infrastructure, in conjunction with the Small Business Administration (FEMA, 2010). In addition to this, FEMA provides funds for the training of response personnel throughout the U.S. and its territories as part of the agency's preparedness effort; FEMA also assists individuals and businesses with low interest loans.

FEMA is authorized by the President under the Robert T. Stafford Disaster Relief and Emergency Assistance Act, to provide temporary housing and other disaster response and recovery activities. The Stafford Act sanctions the Individual and Households Program (IHP), along with a variety of programs intended to address the unmet needs resulting from a major disaster for families, individuals, and state and local governments. Two separate Stafford Act authorities implement the mission of FEMA – Section 403 has provisions for emergency sheltering and Section 408 has provisions for temporary housing.

Stafford Act Section 403

Section 403 addresses immediate threats to life and property through federal assistance, in the form of medicine, food and other consumables, and work/services on both public and private owned land. Emergency shelter, mass-care, medical services, search and rescue services, and debris removal fall under the guidelines of the work/services category. The immediate response for housing following a disaster by the state and/or FEMA is referred to as "emergency shelter". Hurricane Katrina necessitated a need for a multi-objective housing strategy that would adapt to the aftermath left behind that included: mass-shelters, cruise ships, hotels and motels, and apartment rentals.

Mass-shelters

At its peak, the post-Katrina mass shelter network provided shelter for over 273,000 evacuees (McCarthy, 2008). The traditional emergency shelter system was overwhelmed and inadequate to address the concerns of health and safety for both the special need population and the available trained volunteers that staff the facilities. The temporary emergency shelters funded under Section 403 authority were intended to close and move disaster victims to more suitable housing situations by October 15, 2005, about six weeks after the hurricane, meant that many families and individuals had to quickly find housing alternatives. Although charting such an ambitious goal did speed up the emptying of the shelters, it also meant that alternative forms of housing were needed prior to the registration of evacuees with FEMA, and before any individuals and/or families could be presented with other options for their long term housing goals (McCarthy, 2008).

Cruise ships

Cruise ships were chartered by the Navy to provide housing for both victims and relief workers in private rooms in close proximity to the disaster area, and to have on-site feeding facilities. The proximity to the areas of disrepair allowed access for mobile work forces alleviated unnecessary traveling. A serious concern following a catastrophic disaster is the demand for a large work force that requires arrival into the disaster area while simultaneous mass evacuation coupled with the destruction of rental units is underway. During their use, the ships housed over 8,000 people and served over two million meals to Katrina victims and workers helping in the recovery (McCarthy, 2008). While meeting emergency needs, critics questioned the cost of housing victims on the ships, the efficacy of the plan, the location of some ships, the cost and length of the contract, and the process used to arrive at the agreement.

Hotels and motels

Corporate Lodging Consultants (CLC), a private contractor, worked in coordination with the Red Cross and then FEMA to manage the housing of victims into hotels and motels throughout the country. The hotels and motels vacancies were quickly filed by self-evacuated families and individuals as well as disaster evacuees who were moved out of shelters and into these establishments by FEMA. Housing the work forces responsible for clearing the debris and rebuilding repairable buildings became a feasible solution for the rental units. The majority of the hotel and motel residence were families and individuals who moved from mass shelters to the hotels and motels to meet the

October 15, 2005 deadline mandated by FEMA. The peak was reached in late October of 2005, when 85,000 households were housed across the country in hotels and motels in 48 states (McCarthy, 2008). The CLC's secondary responsibility was to track occupancy and managed the payments to the participating facilities.

Hotels and motels were previously employed as short-term solutions to meet emergency housing, but the unique circumstances created by Hurricane Katrina, created a national program of unprecedented size. The privately occupied rooms provided privacy for families that were recently transplanted from the very public mass-shelters. However, the deadline for the movement out of shelters left little or no time for establishing protocols for lodging costs or exploring alternative housing. (McCarthy, 2008)

Apartment rentals

The hotel and motel housing solution quickly became overrun and provided very few vacancies beyond the initial surge of evacuees. FEMA began placing both self-evacuated and those transported by FEMA, to many states that supplied: rented apartments for the evacuees; provided other necessary support such as furnishings, food, transportation, and limited medical assistance; and made the rent payments that were subsequently reimbursed by FEMA under Section 403 (McCarthy, 2008). There were, at the peak of this operation, approximately 67,000 apartment leases in 32 states that were reimbursable leases of up to 12 months by FEMA. The potential hosting states were promised full reimbursement of their disaster related costs, with the general instruction to treat the Hurricane Katrina evacuees as they would disaster victims within their own state borders (McCarthy, 2008).

Stafford Act Section 408

Section 408 is responsible for determining eligibility of Section 403 applicants for longer-term housing aid. The transitional-shift from shorter-term Section 403 sheltering/housing to longer-term Section 408 temporary housing assistance was a challenging task due to the damage of permanent housing stock (both private homes and rental properties). FEMA's staff was deployed within the field of disaster to assess the applicants' situation; registrations were also possible through telephone and on-line connect. The process involved contacting the applicant and explaining the process of eligibility and the time-table associated with the various methods of housing. Units of housing had to be available before applicants could qualify for them, which increased the intermission time between application and approval. Eligibility for Section 408 assistance was based on predetermined criteria:

- The applicant's primary residence was unlivable
- The applicant was experiencing financial hardship
- There are other related difficulties in the aftermath of a declared disaster event (McCarthy, 2008)

When home repair or available rental units cannot meet the demands of disaster victims, FEMA will traditionally uses mobile homes and travel trailers as housing solutions. The FEMA mobile home is a larger dwelling unit intended for longer-term disaster housing needs and is suitable alternative when rental units are unavailable. Travel trailers have been used previously for shorter-term housing, and are smaller units that are usually parked adjacent to the home so that the individual or family can continue repairs while the home itself cannot be occupied and not have to pay for the space to park the trailer (McCarthy, 2008). The mobile units are also placed on existing commercial lots and in parks created by FEMA for the purpose of creating manageable complexes.

The travel trailer is not classified as a home or dwelling due to the presence of an axle for transportation allowing for mobility from site to site for recreational purposes. The U.S. Department of Housing and Urban Development (HUD) has established standards for mobile homes, but not for travel trailers; the mobile homes are “designed to be used as a dwelling”. The distinction between housing and transportation also becomes important when considering FEMA’s own regulations which do not permit the placement of mobile homes within flood plains as temporary housing unless they are elevated above the base flood elevation (McCarthy, 2008). This allows trailers to be placed in flood plain areas on a temporary basis, particularly in group sites, while mobile homes may not. As the duration of temporary housing expires the occupants gain permanence. The Stafford Act allows the provisions to be sold directly to the individual occupant, if the individual lacks the means to provide a household for permanent housing.

While manufactured homes are occasionally used, FEMA considers them the last viable housing option to be employed, and then only if home repairs are impractical or if there are no available units for rental assistance (McCarthy, 2008). Although the evacuees are afforded sufficient housing, manufactured homes not only spread disaster victims across the nation but also make home repair work difficult and slow at best. Manufactured housing became the primary means of providing temporary housing in Gulf Coast communities for an extended period of time (McCarthy, 2008).

Building Codes

Building codes are the laws and regulations that specify the way a building or infrastructure should be constructed. The methods of portable architecture must comply with the various building codes that regulate different categories of building throughout the U.S.. The federal government requires that the HUD building code be used for all manufactured homes. Modular building construction is regulated at the state and local levels the same way traditional site-built homes are. The regulations that govern modular buildings apply to the particular project based on the address of the physical building site and the agencies that have jurisdiction over that area where the building's components are constructed.

International Building Code

The traditional method of home construction and modular construction, both comply with the International Building Code (IBC), the most prevalent building code applied throughout the U.S.. Modular Homes are constructed under the same state and local building codes and are subjected to the same zoning regulations as site-built homes. State and local agencies in some regions of the U.S. enforce codes that will meet or exceed the IBC. In 2000, The International Code Council (ICC) had completed the International Codes series and ceased development of the legacy codes: BOCA National Building Code, Uniform Building Code, and the Standard Building Code; in favor of their national successor.

International Residential Code

The International Residential Code (IRC) is a subsection of the IBC, and only applies to residential construction. The IRC is a comprehensive document that addresses the use of conventional wood-frame construction in low-wind areas and almost all seismic areas, and references prescriptive engineering-based documents for high-wind designs. The IRC applies to detached one- and two-family dwellings not more than three-stories in height with separate means of egress.

Housing and Urban Development

The "HUD code" is a set of national manufactured home industry standards. Published and maintained by the U.S. Department of Housing and Urban Development (HUD), the code establishes the required standards for design and construction, strength and durability, fire resistance, energy efficiency, transportability, and quality control. It also sets performance standards for the heating and air conditioning, plumbing, thermal, and electrical systems (Title 24, n.d.).

According to the Department of Housing and Urban Development (HUD), manufactured homes are factory-built dwellings that are at least 320 square feet. The manufactured homes are constructed following precise guidelines to ensure safety and the ability of the home to be transported to its initial and future sites. HUD requires each manufactured home to include:

- Exterior windows or doors that cover at least 8% of the gross floor area
- Kitchens, bathrooms and laundry facilities may use artificial light
- A ventilation system that operate independent of heating and cooling systems
- Each habitable room must have a ceiling height of no less than 7 feet
- Other areas have a 5-foot ceiling requirement
- Must include a living area with no less than 150 square feet
- Minimum area requirement for bedrooms is 50 square feet
(Traffer, n.d.)

According to the U.S. Department of Energy's Energy Savers program, HUD was required to amend its manufactured homes code as a result of the Energy Policy Act of 1992. This resulted in stronger energy efficiency standards along with higher insulation levels were put into place and double pane windows became a requirement in all climate zones; the new rules made kitchen and bathroom ventilation fans mandatory as well. Energy Savers points out that while there is still room for improvement, some builders produce manufactured homes that exceed minimum energy efficiency standards, as of March 2010; these homes use 30 to 50% less energy than those built to HUD's minimum regulations (Pendola, 2010).

Mass-Produced Architecture

The mechanization of the industrial revolution has given us a plethora of inventions as a result of human tasks becoming automated by machines. The onset of machine based manufacturing marked a major turning point in human history; almost every aspect of daily living was influenced in some way (Lucas, 2002). The introduction of steam powered machinery inevitably lead to the integration of engines performing various tasks in industrial settings. New technologies granted factories the capacity to automate jobs that would previously be undertaken by human labor (Deane, n.d.). Mass-production was now possible and every industry had an increasing demand for precision components, thus an assembly line was formed that rapidly increased production. Industries such as construction lacked the implementation of automation due to the one-off nature of construction tasks, therefore traditional methods in the construction industry neglected the attributes that an assembly line could render in terms of productivity.

Prefabricated construction is an emerging method that employs the automation of both humans and machines to preassemble building components. Prefabricated construction has been transforming the construction industry much in the same way the industrial revolution reformed the manufacturing industry back in the 18th and 19th centuries (Bhatt, 1996). Prefabrication uses the techniques of an assembly line of sorts to preassemble the materials in a factory and then transports the complete assemblies or sub-assemblies to the construction site where they are fastened together. The primary distinction between prefabrication and conventional construction methods is the physical location of where the basic materials are transformed into building elements (Deemer, 1996). Three types of mass-produced exist: modular, manufactured, and container-style homes. The three types use conventional methods to transport the basic materials to the site where they are inevitably assembled to construct a desired building.

Modular

Modular homes are prefabricated in segments that consist of multiple modules or sections which are pre-assembled in remote facilities and then later delivered to their intended site of use. The homes usually require the addition of plumbing, heating, ventilating and air-conditioning; windows, roofing, or siding may also be needed (McIlwain, 2006). Modular homes are considerably different than manufactured homes chiefly due to the absence of an axle or a frame used for transportation. Modular homes use a typical transportation method by means of a flat-bed truck. Financially, manufactured homes and modular homes are appraised differently by banks for lending purposes. The codes that govern the construction of these types of homes play a vital role in their appraisal values. Modular homes are constructed according to the International Building Code (IBC), or in some case the more stringent local jurisdiction; these are the same codes that govern the construction of any conventional site constructed home (Aladdin, 1917). The materials used for construction are the same as conventional site constructed home as well. Therefore, the deprecation values of modular homes are consistent with the trends associated with typical homes because the final products are congruent in quality and craftsmanship. Modular buildings are similar to any traditional building except they are modules (pieces) that are pre-built in factories and then assembled together using giant cranes in a similar fashion to Lego blocks (McKinley, n.d.).

Manufactured

The term manufactured home specifically refers to a home built entirely in a protected environment under federal codes set by the US Department of Housing and Urban Development, informally known as HUD (Bruce & Sandbank, 1972). Much like the prefabricated homes of WWII, the factory built homes developed a negative stereotype because of their low cost. The derogatory concept of a trailer park has been consistently linked to lower-income families which have led to prejudice and zoning restrictions, which include limitations on the number and density of homes permitted on any given site, minimum size requirements, limitations on exterior colors and finishes, and foundation mandates. Great strides have been made by HUD to monitor the quality of manufactured homes but they still struggle with the unvarying construction problems associated set-up issues. These homes arrive at the site in turnkey condition and require only utility hookup, because mobile homes are typically not affixed to the land, they are usually defined as personal property (McIlwain, 2006). Multi-part manufactured units are joined at their destination and the building segments are not always placed on a permanent foundation, compounding the issue of re-financing (McKinley, n.d.).

Shipping Container

Container homes are box-shaped modular homes manufactured from International Standards Organization (ISO) standardized containers and are typically outfitted with prefabricated components (McIlwain, 2006). The surplus of ISOs has initiated a movement dedicated to the re-use and re-programming of the abundant building component. The popularity of container homes has exponentially increased from year-to-year. ISOs are the strongest mobile or stationary structure in the world built to withstand typhoons, tornados, hurricanes and even earthquakes, and are now being incorporated into inhabitable designs such as offices, hotels, student housing, safe rooms, and emergency shelters. The benefits of using container homes can be witnessed in short/medium land use projects, when the project duration has expired, the containers can be unbolted and relocated or stored when the land is required for alternative uses.

CHAPTER 2
LITERATURE REVIEW

Chronology of Portable Architecture

Pre-Industrial Revolution

The Hut. Man's earliest ancestors sought protection from the elements and predators in natural shelters such as caves and overhangs embedded within rock formations (Chiei & Decker, 2005). Mobility for man as a hunter/gatherer was essential; survival was dependent upon his capabilities to follow his food as it migrated with the changing of seasons. The inception of portable buildings was thus introduced in the form of a hut – a simple construct, consisting of a few vertical partitions and horizontal members acting as a roof. Evidence of a wooden hut was found at Terra Amata near Nice, France, dating back to the Mindel Glaciation period between 450,000-380,000 BCE; which included a hearth and fireplace (Chiei & Decker, 2005).

The Tipi. The basic hut remained virtually unaltered for a million years, until around the seventeenth century, when Native Americans built transportable structures from readily available materials. The nomadic people of the Great Planes lived in portable cone-shaped structures called tipis, from *ti*, which means "dwelling", and *pi*, meaning "used for", translated from the Sioux language. When the Native Americans' food source migrated, the tribes, following the buffalo, disassembled the tipis and hauled them to the next location. The North American tipi can be compared to a single cell of a space frame truss system (Kronenburg, 2003), adapted to use animal hides, membranes without inherent strength. By incorporating a twin skin system, natural air movement patterns were created, aiding the adaption into the natural environment.

Wooden Plank Home. The most notable native dwelling of North America, the wooden plank houses of the north-west coast most closely resembled Western architecture (Chiei & Decker, 2005), combining aesthetic considerations in addition to functional ones. The plank house used long boards of hand-milled cedar to furnish the sloping roofing and rectilinear walls, forming a rectangular shape. The façade or entry of the house was programmatically placed facing the body of water in which the house sat within proximity of. The waterways were considered the source of life, but in the winter when the waters began to freeze the temporal nature of the plank house experienced as the dwellers would dismantle the construct and carry them inland to make new temporary shelters within the forests where fishing and berry gathering propagated.

Red-River Frame. In the 1860s, the Hudson Bay Company severed the mining communities during the Gold Rush by building a chain of retail stores in British Columbia and Alaska. The Hudson Bay Company, invented a building form called the Red-river Frame which adopted the log cabin design, a long building using logs with dove-tail corners that ran the full length of the wall, in lieu of the post-on-sill construction. The walls were generally twelve to fifteen rounds high, combined with a steep-pitch roof, allowed for a spacious attic, often used for the storage of furs and as sleeping quarters for the prospects (Chiei & Decker, 2005). The remote nature of prospecting required housing that was easily assembled with readily available resource.

Industrial Revolution

Crystal Palace. In 1851, a building pioneered the use of cast-iron structure, prefabricated units, and an antecedent glass curtain wall, called the Crystal Palace. The building accommodated the 1851 Great Exhibition, in central London, were it showcased the modern marvels of the industrial revolution. Joseph Paxton built the

990,000 square feet of exhibition space using prefabrication techniques and demountable modules which allowed the building to be erected in an unconventional nine months; the footprint of the building encompassed nineteen acres. The exhibit in Hyde Park, London, was limited to a life of six months and needed to be relocated to Sydenham Park, an affluent area outside of London, England. The “glass monster”, demonstrated its flexibility and transportability when it was reconstructed in six months upon a new foundation. The Crystal Palace has been called “proto-modern architecture” and was widely imitated in Europe and throughout the U.S (Chiei & Decker, 2005).

Manning Portable Colonial Cottage. With the advent of industrial assembly techniques, Britain produced a small-scale portable building in the nineteenth century called the Manning Portable Colonial Cottage. The Manning cottage was mass-marketed as a demountable, prefabricated, and modular, easily transported and erected building. The Manning Portable Cottage was the first advertised prefabricated home. The open-platform allowed owners to assign their unique program without being constrained by predetermined assumptions of use; this marketing strategy perpetuated the distribution of the Manning Cottage all over Britain and the U.S.. The Manning Cottage’s rein came to an end with the induction of the Sears mail-order catalog which developed and sold house plans to the general public.

Post-Industrial Revolution

Sears Catalog Home. Prefabricated buildings are not to be confused with the ready-to-assemble homes such as the Sears Catalog Homes that were sold from 1908 to 1940. The catalog homes were shipped via railroad boxcars and consisted of a kit of parts that would later be assembled by the new homeowner and/or friends and relatives. The crucial distinction between prefabricated buildings and the kit home is the physical location where the individual parts are assembled to form a building component e.g. wall or roof. The catalog did however offer over 200 different models to choose from, which varied in price based upon specifications; the average kit was comprised of 25 tons of materials, with over 30,000 parts (Stevenson & Jandl, 1995). Sears also had the ability to mass-produce the materials in their factories which inevitably reduced manufacturing costs and lowered traditional construction time by up to 40%, thus lowering purchase costs for customers and increasing productivity rates. Sears, Roebuck and Company, sales of the homes peaked in 1929; an estimated 70,000 homes were sold in total, just before the onset of the Great Depression (Thornton, 2002). The stalled sales after the depression later came to a halt due to changes in housing codes and the complexity of modern construction making the kit homes less desirable.

World War I

Nissen Hut. On April 18, 1916, Major Peter Norman Nissen of the 29th Company Royal Engineers began to experiment with hut designs (McCosh, 1997). Nissen produced three semi-cylindrical hut prototypes of his design using the aesthetics of a drill-shed at Queen's University, Kingston, Ontario as inspiration. The third prototype was selected and critiqued by fellow officers. The prototype later went into production in August of 1916; at least 100,000 units were produced for World War I (McCosh, 1997). Nissen designs were subjected to two influencing factors. First, the building had to be economical in its use of materials, especially considering wartime shortages of building material. Second, the building had to be portable and easily erectable within desolate locations. The wartime shortages of shipping space increased the demand for the design to be prefabricated for ease of erection and removal. The Nissen hut was easily packed in a standard Army wagon and erected by six men in four hours; the current world record for erection was 1 hour 27 minutes (McCosh, 1997).

Production of the Nissen hut diminished between World War I and World War II, but was revived in 1939 when Nissen Buildings Ltd. lifted their patent rights for wartime production. The multi-functional design of the Nissen hut became a component that made it effortlessly mass-producible to the general public as a means of accommodation. Nissen-Petren Ltd. later converted the Nissen hut into a prefabricated two-story house, but the adaptation of the semi-cylindrical hut to non-institutional uses was not popular (McCosh, 1997). The hut meet criticism for its shape, rectangular furniture does not fit into curved wall shapes very well, nor does it conform to the status of a house.

World War II

Dymaxion House. Buckminster Fuller (1895-1983), was arguably one of the most significant advocates of prefabricated construction. Ephemeralization is a coined term meaning "doing more with less"; it was promoted by Fuller, a philosopher, inventor and designer (Robertson, 1974). He attempted to inspire humanity to take a comprehensive view of the world we live in and the infinite possibilities for an ever-increasing standard of living within it. In 1927, Fuller advanced the argument that conventional housing designs and construction were entirely inadequate (Pawley, 1991). To make his point, he designed a prefabricated low-cost house for mass-production. The Dymaxion House was suspended on a central core or mast, which contained the building's utility services, including an elevator, laundry, air conditioning system, plumbing, and electrical wiring. The roof and floor were both suspended by cables from the top of the mast. Using pre-assembled panels, the builder with help from friends or family, could often put up the

Dymaxion House up in one day. Only two prototypes of the Dymaxion House were ever fully constructed.

Fuller saw his second Dymaxion Deployment Unit as an answer to the U.S. Government's increased need for fast, inexpensive and collapsible housing for the mobilizing defense industry as the country prepared to enter Word War II. An experimental model was erected in Washington, D.C., were those who lived in it "vouched for its qualities of comfort and living efficacies" (Pawley, 1991). However, with canvas curtain partitions, a lack of privacy became an issue among some of the occupants. Metal shortages ultimately restricted the government's purchase of the Dymaxion II to only a few models used by the military for special uses in the field.

Quonset Hut. The successor of the Nissen hut was the Quonset huts used by the U.S. during World War II. The name comes from their site of first manufacture, Quonset Point, at the Davisville Naval Construction Battalion Center in Davisville (Chiei & Decker, 2005), a village located within the town of North Kingstown, Rhode Island, U.S.. The hut was adapted to specialized functions; each hut plan indicated the building modifications necessary to make the conversion and the location of equipment necessary for that particular design (Kronenburg, 2003). The hut's formal design specifications were adjusted for varying climatic regions. In tropical climates, increased ventilation, water collecting techniques, and overhangs were implemented to mitigate the accumulation of humid within the unit. In total, 41 design variations, including a dispensary/surgical hut, a laboratory, laundry facility, pharmacy, dental facility, hospital ward, barbershop, morgue, guard house, and tailor shop, served multitudes of needs for the military's forward bases (Chiei & Decker, 2005).

Between 150,000 and 170,000 Quonset huts were manufactured during World War II. The huts minimalistic approach to prefabricated design cost between $800 and $1,100 to produce. After the war, the U.S. military sold the remaining surplus to the general public for approximately $1,000 each, depending on the features of the unit. As troops began to re-establish their lives after the war, the Quonset hut became an acceptable means of temporary postwar housing. It was throughout this time period that prefabrication made a name for itself by saving time on-site and reducing overall costs (Kronenburg, 2003). However, the kinks of prefabrication were not ironed out at this time and low-quality was a result. As the effects of temporary housing lingered longer than anticipated, the prefabricated houses' designed life was exceeded and adversely developed a certain stigma.

Modern

Geodesic Dome. Although Buckminster Fuller has left a remarkable legacy of inventive housing designs, he is most notably associated with his work concerning geodesic domes. Fuller began experimenting with geodesic domes in the late 1940s, at Black Mountain College, an experimental institution in North Carolina (Pawley, 1991). The form appealed to the innovative engineer because geodesic domes are extremely strong for their weight, their Omni-triangular surface provides a stable structure, and because a sphere encloses the most volume for the least amount of surface area (Robertson, 1974). He had hopes that the domes, like both versions of his Dymaxion House, would address the post-World War II housing crisis. During the 1960s and 1970s, many people looking for alternative, creative and affordable housing turned to geodesic domes (Pawley, 1991).

Modular Home. Modern prefabricated homes are also popularly known as modular homes as you can put together any number of rooms to create the kind of home you desire. Modular homes are increasingly witnessing high demand due to a variety of reasons when compared to conventionally constructed homes. The construction of a prefab home is much faster than a conventionally built home; within two months of order time your home is typically constructed (Vanegas, 1995). Since each sectional room is built within a manufacturing facility, all the client has to do is to place an order with the prefab house builders and the house will be built to specification, transported to their site and then assembled together. On the other hand, a traditional home can take several months or even years, life has become expedited and people are perennially short of time; modern modular homes are an ideal option as they are faster to build and relatively hassle-free in comparison.

Implementation of Today's Shipping Container

The demand for lower priced, high-technology products from China have been answered by the modern day shipping container. The rapid growth of manufacturing in China have created a global demand for Chinese products; the shipping container allows the facilitation of the products from one side of the globe to the other. Unfortunately, one of the side effects of importation from other countries is the immediate accumulation of excess containers. The U.S. exports very little resource beyond the country's borders using shipping containers as a means of cargo holding. In 2005, the U.S. was estimated to contain nearly one million containers. Eventually Americans caught on to the mass-accumulation through publicity and interest, and by the end of 2007, the quantity of containers dropped to 500,000. Table 2-1 highlights the most recent deficit of exported containers from the Port of Los Angeles in 2010, in relation to the containers being imported.

Through great exposure of the problem globally, in conjunction with the inherent strengths and ease of shipping container construction, the problem has transformed into one of the fastest building trends globally. For many reasons, shipping containers are the strongest mobile or stationary structure in the world built to withstand typhoons, tornados, hurricanes and even earthquakes; thus, one or more of these incredible steel modules are the safest superstructure for a home, school, office, apartment, dormitory, storage unit, emergency shelter (Sanders, n.d.).

The International Organization for Standardization (ISO), have standardized the dimensions of a common shipping container as 20' or 40' feet long, 8' feet wide, and 8'6" feet tall. A taller version of the common shipping container is also deployed named High Cube (HQ), which shares the same length options and width as the common shipping container, but has an additional one foot on the common's height measuring in at 9'6" feet versus 8'6" feet. Both units are constructed using an non-corrosive Corten steel that resists mold. The Corten steel is used on the interior and exterior of the container and have been engineered to withstand greater bearing loads than traditional carbon steel.

The common types of ISO shipping containers are:

- 20' GP
- 40' GP
- 20' HQ (High Cube. The difference is 1' foot taller than a standard 20' GP)
- 40' HQ (High Cube. The difference is 1' foot taller than a standard 40' GP)
- Open top
- Open side
- Freezer
- Refrigerated are also available, but are not recommended for ISBU construction.

Container Homes

The physical properties that are intrinsic to the shipping container have contributed to the progression of the container from industrial transportation services to military adaptations. The implementation of shipping containers as small workshops, and refrigerators by the military have presented opportunities for the containers to be issued as offices and employee cabins. When the container made the transitional shift from transportation to building component, the term ISO Shipping Container is replaced by the term Intermodal Steel Building Unit (ISBU). The popularity of the ISBUs has created a great demand that is often meet by purchasing the units from the manufacturers directly, simply for the purpose of construction, without ever being used for shipping services.

There are three main implementations of shipping containers in construction:

- Leaving the container intact and inhabiting the singular dwelling unit
- Developing a module for modular building construction
- Converting the containers into intermodal steel building units (ISBU)

ISBUs provide many advantages in the field of green construction: the units themselves are recycled, the amount of wood needed to build is reduced by as much as 99%, and waste is mitigated from landfills due to construction and assembly in a factory setting. Insulation is replaced with NASA-inspired Super Therm® insulation, it has no VOCs, utilizes different types and sizes of ceramics that block 95% of the sun's radiant heat in the visible, ultra violet rays and infra spectra. The insulation is spray painted inside and out: it is said to give an R-value of R-19 if just sprayed externally, and an R-value of R-28.5 if sprayed on the exterior and interior (Sanders, n.d.). The integration of an inclined roof could be used with a gutter system to capture and evacuate water for grey-water applications. With thoughtful innovative design, the initial construction costs could be lowered, as well as ongoing operating costs, both of which are critical issues regarding housing in disaster relief areas for temporary and permanent needs.

Depending on the configuration and intricacy of the container home, the per-square-foot cost of construction using repurposed shipping containers have been reported to run from 50 to 65%of traditional construction costs (Sanders, n.d.). However, costs should come down for larger projects or for individual projects done with large amounts of owner labor and repurposing of locally found materials. Container-built homes are popping up in design competitions, urban planning sessions, and university housing discussions worldwide because they are ready-made, consistent, strong, and available. This pre-fab architecture is likely to continue, helping to house homeless and displaced populations, build-up without eating-up valuable land, and create easy, modernist expressions for urbanites and nature lovers alike (Sanders, n.d.).

Singular Dwelling Unit

A single shipping container provides either 160 or 320 square feet of interior space, depending on the selected unit. The design options are limitless of how the unit will be manipulated, but holding true to its original external dimensions will provide an inherent efficient means of transportation. Mass-production of a manufactured home using an ISO shipping container allows for self-containment. Two projects have been specifically highlighted here: LOT-EK’s MDU, a high-end factory constructed house easily adapted into mass-production for disaster relief; and Earth Science Australia’s research facility, that promotes DIY techniques within remote areas. The two projects were selected based upon the integral discrepancies they have in relation to each other, but in the end, both share a common thread of ingenuity, the manipulation of a shipping container into a singular dwelling unit that can be readily deployed into a post-disaster area.

Mobile dwelling unit

A Mobile Dwelling Unit is generated from a single shipping container by cutting the envelope of the container and transforming the residual interior space into "sub-volumes" as encapsulated living quarters, work or storage function. The three interior divisions within the MDU provide accommodations for social, entertainment and private functions. Each sub-division is delineated by large horizontal windows breaking the potentially rigid spaces into user friendly illuminated comingled areas (Figure 2-1). The three distinguished divisions are extruded from the boundaries of the shipping container, increasing the interior volume of the spaces and allow for the capturing of light and views.

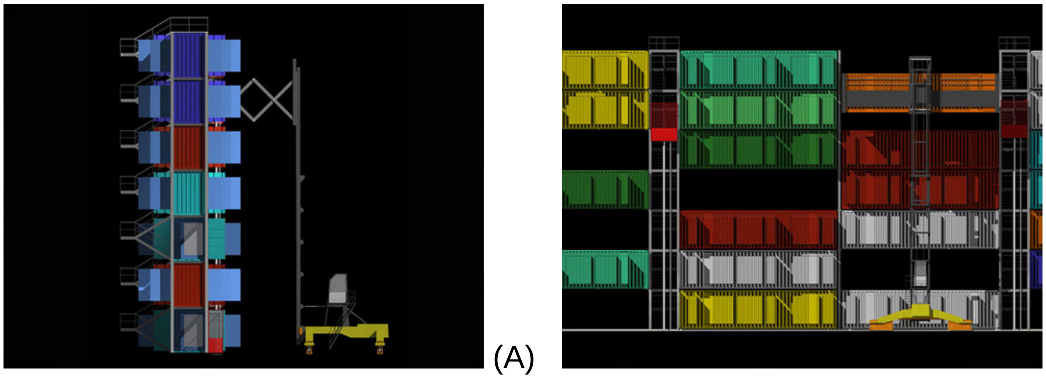
(A)


(B)

Figure 2-1. LOT-EK MDU ISBU (Lot-EK, n.d.). A) Exterior view of MDU, (B) Interior view of MDU.

In the event of transporting the unit from assembly to destination, the extruded "sub-volumes" are pushed into the container's original dimensional boundaries leaving the outer skin of the container flush to allow worldwide standardized shipping (Lot-EK, n.d.). When delivered to the site the sub-volumes are pushed out, leaving the interior of the container completely unobstructed with all functions accessible along the sides. The interior and “sub-volumes” are entirely fabricated using plastic coated and non-coated plywood, including the furnishings and fixtures. The interior floor plan is approximately 550 square feet when the “sub-volumes” are deployed and has an estimated total construction cost of $75,000 dollars, resulting in a cost of $136.36 dollars per square foot.,

MDUs are conceived for individuals that may require traveling from one temporary destination to another. The MDU travels with its dweller to the next long term destination, fitted with all live/work equipment and filled with the dweller’s belongings concealed safely within the ISO boundaries. Once it reaches its destination, the MDU is loaded into a MDU Vertical Harbor (Figure 2-2), a multiple level steel rack, measuring eight feet in width (the width of one container) and varying in length to accommodate the site. The Vertical Harbor is a stretched linear development that is generated by the repetition of MDUs and vertical distribution corridors, which contains elevators, stairs and all systems (power, data, water, sewage). A crane slides parallel to the building, along the entire length, on its own tracks; it picks up MDUs as they are driven to the site and loads them onto slots along the rack. Steel brackets support and secure MDUs in their assigned position, where they are plugged-in to connect all systems. The Vertical Harbor is in constant transformation as MDUs are loaded and unloaded from the permanent rack. Like pixels in a digital image, temporary patterns are generated by the presence or absence of MDUs in different locations along the rack, reflecting the ever-changing composition of these colonies scattered around the region (Lot-EK, n.d.).



(A) (B)

Figure 2-2. LOT-EK ISBU Docking Station (Lot-EK, n.d.). A) MDU Housing Plan Section View, (B) MDU Housing Plan Elevation View

Earth science Australia

Remote construction is an obstacle that many traditional forms of building construction have an exorbitant amount of difficultly with. Post-disaster housing sometimes present challenges in the methods of logistics and the equipment required for physical construction. Using shipping containers as a means of construction in remote access areas alleviates some of the logistical constraints; some option include: hauling a standard 20' foot shipping container on a flat-bed truck, dragging the container using a tractor or 4wd vehicle, or using third-party developed wheel systems that are placed on the underside of the container allowing for hand or vehicle maneuverability.

A research team in Far North Queensland required a facility in the dense World Heritage Rainforest in order to conduct 1:1 studies with the environment. The area surrounding the site has red lateritic clay that is extremely slippery when doused by the annual 18 feet of rain. The design consisted of two conventional shipping containers creating 320 square feet of living space, to be elevated off of the rainforest's ground by four feet to maintain a flood resistant stature. Vehicular infrastructure to this remote location was non-existent and was only accessible via a narrow track previously cleared by woodcutters in 1928. The techniques used to construct the facility are simple and employ a limited palette of building construction skills. The decision to use shipping containers as the primary building component was based upon Hansen's understanding, "They produce a dry, durable, vermin proof, confortable, removable facility with low ecological impact".

Site preparation first involved clearing of trees and low-lying shrubbery, eight holes where then excavated to receive PVC piping filled with rebar and concrete mix for structural support, the entire procedure lasted two days. A small low profile rubber tracked crane was initiated to lift the containers into place in 30 minutes atop the cured concrete piles (Figure 2-3), in lieu of using a mechanical jacking system to place the containers. The containers were spaced six feet apart from one another and adjoined using galvanized C-section steel sections. The galvanized expanded metal mesh walkway served four purposes:

- It kept the research team from tracking mud into the dry living areas
- It helped keep snakes and other vermin such as rats out of the containers
- It connected the two containers, which were separated by six feet
- In the high rainfall, it permitted the rain to fall straight through to mitigate run off or splash would enter into the dry interior of the container (Hansen, 2008).


(A)

(B)

Figure 2-3. Earth Science Australia Early Stages of Development (Hansen, 2008). (A) PVC piles used for foundation, (B) Shipping containers elevated into place.

The modifications to the container's envelope included windows that were fitted with screens and door openings that allowed access to the roof for observational purposes. By elevating the observation area from the ground or plinth, the team was able to capture more breezes and were above the normal flight level of the small number of evening mosquitoes (Hansen, 2008). The adaptation of three cheap conventional car ports were installed atop the roof for the purpose of sitting out, drying clothes, and small research projects. The plastic roofing had serendipitous advantages, it reduced the noise of the intense tropical downpours as well as making the lower floor used for cooking nearly waterproof. A PVC storm water pipe was used to collect the rainwater from the carport's roof and redirect it into a cistern for drinking water.

The rainforest research facility cost approximately $17,250 dollars, resulting in a cost of $53.91 dollars per square foot., including the two containers, transporting the containers, screening in the cargo doors, - the lot. (Hansen, 2008). The facility has a floor area of 90 square feet of totally dry sleeping area, 45 square feet of mostly dry cooking area and 135 square feet of covered sitting out area - a total area of 270 square feet undercover and protected from harsh rainfall. After completion of the facility in 2006, the research team experienced an astounding 24 feet of rainfall during the rainy season, which did not penetrate the envelope of the containers. On March 20, 2006, the research facility was subjected to a Cyclone Larry, Category five cyclone with local wind gusts exceeding 176 mph. The only subsequent damage resulting from the natural disaster was tearing within the carports canvas that would later need replacing (Figure 2-4).

 (A)  (B)

Figure 2-4. Earth Science Australia Intact Structure (Hansen, 2008). (A) Facility before Cyclone Larry, (B) Damage after Cyclone Larry.

Modular Container Construction

Containers present the ability to be stacked during transportation anywhere from a single level for train transportation, to twelve units high for cargo ship transportation. The stacking effect has been noticed and implemented in many architectural designs due to one the most basic characteristic of a container, its ability to be stacked. With a little ingenuity the container can be transformed into various configurations to suite the intended program’s needs. A consistent characteristic always arises from the designs, the need for service cores to facilitate utilities and circulation. Two projects have been highlighted, the Container City which made use of repurposed land and Keetwonen, a temporary facility used as dormitories for college students.

Container City

Container City is an innovative and highly versatile system of construction that uses shipping containers linked together to provide high strength, prefabricated steel modules that can be combined to create a wide variety of building shapes. This modular technology enables construction times and costs to be reduced by up to half that of traditional building techniques, while remaining significantly more environmentally friendly (USM, 2001). To date Urban Space Management Ltd has used the Container

City system successfully to create a multitude of spaces such as office spaces, retail spaces, artist studios, youth centers and live/work spaces. USM Ltd most prominent development is a four million dollar project called Container City, which was built using two phases of construction, Container City I and Container City II.

The original Container City is located at Trinity Buoy Wharf, in the heart of London's Docklands and was completed in 2001. Architects Nicholas Lacey and Partners, along with engineer Buro Happold, developed 15 unit live/work studio spaces by manipulating 20 ISO shipping containers. The installation time to elevate and place the 20 containers took four days with the entire complex being completed in five months. The original configuration of Container City I was three-stories high providing 12 studios across 4,800 square feet in combined floor area; an additional fourth floor was later installed and provided three additional live/work apartments. As well as being very cost effective, Container City I is environmentally friendly with over 80% of the building created from recycled materials (USM, 2001). The total cost including installation onsite cost $1,613,056, resulting in a cost of $268.84 dollars per square foot.


(A)

(B)

Figure 2-5. Container City (USM, 2001). (A) Placement of the last container completing the fourth floor, (B) Container City I completed.

The second phase of Container City II, was both an extension and evolution of the Container City I. Built by the original architect and engineer in 2002, five floors were erected using 30 ISO containers, providing 22 studio spaces in total. The total cost including installation onsite cost $2,386,944, resulting in a cost of $305.04 dollars per square foot. The placement of the 30 ISO containers took eight days to lift into the intricate design. Interconnecting bridges between phases I and II provide the two buildings with horizontal circulation, while a vertical circulation core provides an elevator for disabled occupants (Figure 2-5). In contrast to the first phase, Container City II is a funky ziggurat shape and painted in bright colors to reflect the creative flair of those who work within the unique structure (USM, 2001). Insulation was applied to the interior walls and finished with drywall, providing the occupants with a finished surface to paint and hang picture frames upon.

Small studio and office space requirements are fulfilled by single 8’ x 40’ containers, but other spaces require interiors to be larger than the provided standard of eight feet wide. To suffice larger spaces, the container’s side walls were eliminated and supports were welded to the container’s edges to maintain structural integrity. By combining multiple containers with no interior barriers studios could range from 240-540 square feet (Sherwood, 2002). Infrastructure has been created for service corridors located at the bridge entrances reducing the need for plumbing walls to run continuously from the ground floor up, thus allowing for the maximum free interior space within the studios.

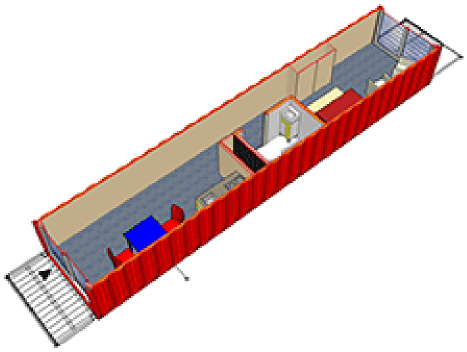
 (A)  (B)

Figure 2-6. Container City (USM, 2001). (A) Circulation connection between Container City I and II, (B) Container City II completed.

Keetwonen

H.J.E. Wenckebachweg 3010, Amsterdam, Netherlands, is home to the world's largest container city, built for temporary student housing, there are 1000 units arranged in blocks creating a new community, which includes a cafe, supermarket, office space, and even a sports area. The architectural firm Tempohousing is responsible for the design of the facility which broke ground on the 340,000 square foot compound on August 29, 2002. The estimated cost of construction was $32,054,122 dollars, resulting in a cost of $94.28 dollars per square foot, which came in under budget from its original preliminary estimates. The project was initially developed to only stay on the site for five years and then relocated to another destination within Amsterdam that required affordable mass-housing, but the relocation plan has been postponed until 2016. The project began at the end of 2005 when the first 60 homes were commissioned and was completed in mid-2006.

Many of the initial fears were put to rest once the students adapted to their new homes, such as the small size, the loud noise levels, and maintaining climate control. Since the dormitories' completion, it has become the second most popular student dormitory offered by the student housing corporation De Key (Kimberley, 2010). Each of the units is complemented with its own bathroom, kitchen, balcony, separate sleeping and study areas, large windows that provide daylight and views of the adjacent area. Heating throughout the units is supplied by a centrally located natural gas boiler system and is fully insulated on the interior walls. Keetwonen integrates a rooftop that helps with water shedding during heavy rains while providing heat dispersal and insulation for the top floor units.


(A)

(B)

(C)

(D)

Figure 2-7. Keetwonen (Kimberley, 2010). (A) Modular ISBU, (B) Elevating the first 60 dormitory units into place, (C) Completed building unit with balcony attachments installed, (D) Aerial view of 1,000 unit complex.

Intermodal Steel Building Units

Intermodal Steel Building Units (ISBU) construction is similar to modular container construction in many ways but with a more adaptive approach to traditional building techniques. ISBUs are integrated fully into traditional building methods and incorporated into the building's envelope and structure. The fusing of ISBUs and wood framing or concrete masonry units (CMU) has increased the potential for shipping containers to be assimilated and thought as a serious building component. More than 50 years ago, the U.S. converted steel shipping containers for use as portable command centers and medical facilities in Korea. Now, architects, designers, planners, and homeowners are finding renewed interest in these inter-modal steel building units as they look for affordable, sustainable housing options for the 21st century.

A container-based home offers a fast, green, and sustainable approach to building an average sized home with almost no wood. These ISBUs are manufactured in a factory-controlled environment so they are standardized and reliable. When building with ISBUs, the building blocks are ready-made and ready to transport. Shipping containers are purchased and shipped to factories for modifications. Once there, the house blueprints are reviewed and each unit is custom fit for construction. In a home where four containers are to sit side by side, all but the outermost side panels are removed so that, once connected, the ISBUs create an open 40’ x 32’ foot interior space (SG Blocks, 2011). The vertical steel support beams are left in place for load-bearing purposes, with five along each remaining side of a container. When the design permits, openings are cut into the outer walls for doors and windows.

A container-based house sits on a traditional concrete block foundation with a 40’ x 32’ foot stem-wall foundation set and reinforced with steel rebar. Concrete filled cells are fitted with half-inch thick steel plates that are embedded into the concrete at the corners to secure the incoming ISBUs. Each steel-plate uses a J-hook, which connects the container to the exposed rebar and ties it all the way down to the footing. Additional footings are poured and individual concrete blocks are placed inside the foundation to support the sides of adjoining ISBUs. The exterior of the ISBU is treated with a sprayed on ceramic coating that insulates the structure, thus reducing heating and cooling loads year round. When the ISBUs arrive on site, they are crane-lifted one by one onto the foundation, hooked into place, and welded down to marry them completely to the foundation (SG Blocks, 2011). Attaching them to embedded steel reinforcements and welding them in place ensures they will sustain extremely heavy winds.

A conventional hip roof can be placed and secured atop the “big steel box” structure in a matter of two or three hours if architectural vernacular is desired(SG Blocks, 2011). At four foot intervals metal straps connect the rafters to the ISBU, while Simpson hurricane clips attach the steel roof to the rafters to prevent uplifting during high winds. The ISBUs are dried in via impact-resistant windows, the window openings are measured and cut prior to delivery of the ISBUs on site. Inside, workers install a ½-inch plywood floor over the existing ¾- inch plywood sub-floor (SG Blocks, 2011). The crew runs metal hat channels for wiring along the walls and vertical support beams that dot the interior. Metal studs and drywall are used for interior partition walls. Once insulated, the existing container walls are faced in drywall for finishing, transforming the corrugated-steel interior and prepping them for paint or wallpaper. The exterior is clad with James Hardie fiber-cement siding. Windows and doors are installed into pre-cut openings with a minimal use of wood framing. Doors are hung and the roof is shingled, leaving the house ready for furnishing.

SG Blocks

SG Blocks have developed a building system that have meet the safe and sustainable housing needs in the U.S. by designing a system that satisfies the requirements of builders, developers, government officials, urban planners, architects and engineers looking for fast and affordable housing alternatives. SG Blocks have achieved conformance with the International Code Council (ICC) requirements by designing and manufacturing the system to specifically cater to the regulations as the standard is used by 90% of governmental jurisdictions (SG Blocks, 2011). The building system has been deployed and tested within areas prone to earthquakes, tornados and hurricanes. Adapting to the regions architectural vernacular, SG Blocks can be used to build to any style of construction, from traditional to modern. SG Blocks containers can be delivered with a highly durable surface finish, or delivered ready to be clad with any type of standard or green technology friendly building skin (SG Blocks, 2011). The application of cladding to exterior of the SG Block includes limestone, stucco, shingles, brownstone, brick and aluminum siding. In addition to cladding adhered to the container's surfaces SG Blocks works with a variety of insulation including traditional and emerging insulation technologies that meet or exceed insulation requirements and provide adequate thermal protection.

It takes an estimated 8,000 kWh of energy to melt a four-ton shipping container, about 6,500 kWh to make a ton of steel of virgin material and almost 1,800 kWh to recycle a ton of steel from 100% scrap, but 400 to 800 kWh to convert a shipping container into an SG Blocks building unit, according to the company and its representatives. In terms of supply, proponents of container construction estimate that there are 16 to 22 million containers in active circulation with 1 million new units becoming available each year and some 700,000 being retired. SG Blocks has its own term for recycling the containers it acquires.

- Once on site, the process can reduce construction time by up to 40% over other common construction methods.

- 10% to 20% less expensive than traditional construction methods, particularly in urban locations and multi-story projects.
- SG Blocks has one of, if not the lowest, embodied energy utilization of any structural building product on the market today, making it the environmentally friendly choice in building.
- As a client's needs expand or contract, the system may be expanded or reduced to meet those changing needs much later in the design process than other forms of construction.
- SG Blocks can be dismantled and relocated if needed. This makes the SG Blocks Building System a leading option in temporary or transitional building construction and creates much greater options for urban planners and planning authorities. (SG Blocks, 2011)

Shipping containers typically have a useful life of 10-15 years in the shipping industry. The cost of reclaiming the raw steel from a used container is economically unfeasible. Through a process SG Block calls "Value-Cycling" conversion of a container into an SG Block takes 1/20th the amount of energy required to reprocess a comparable weight of steel (SG Blocks, 2011). Increasing the lifespan of a container to about 100 years, the SG Blocks system saves significant board feet of lumber and tons of new steel in addition to dramatic savings in energy expenditures, all contributing to LEED certification.

Fort Bragg. SG Block built a 4,322 square foot, two-story office building using 12 recycled Hi-cube shipping containers for the 249th Engineers Company Operations Building at Fort Bragg, North Carolina. The Operations Building was the first multi-story commercial structure in the U.S.. Construction of the structure took 101 days to complete and was estimated at $150 dollars per square foot. The Operations Building was delegated a $750,000 budget for the job according the U.S. Army, which SG Blocks only used $648,300 dollars of that estimate and came in at two-thirds under budget if traditional construction methods were used. SG Block claims to be the first to have applied brick and an insulation finishing system to the exterior of a building envelope and to completely finish the inside of the containers as an integral building component.

- Client: U.S. Army Corps of Engineers
- Location: Fort Bragg, NC
- Architect: Lawrence Group
- Builder: Alberici Constructors
- Engineer: SG Blocks
- Total Construction Time: 75 days – 40% faster than traditional method (180 days)
- Project Size: 4,322 square feet
- Completion Date: November 2007
  (SG Blocks, 2011)


(A)


(B)


(C)

Figure 2-8. Operations Building at Fort Bragg (SG Blocks, 2011). (A) Assembly of SG Blocks into place, (B) Truss system installed atop SG Blocks, (C) Completed building with exterior finishes applied.

St. Petersburg Home. A single family residence in St. Petersburg, Florida was constructed to bring affordable, storm resistant housing to a neighborhood that is subjected to severe weather. The ISBU Housing Pilot Project was the result of a collaborative effort among St. Petersburg Neighborhood Housing Services, Inc. (SPNHS); Tampa Armature Works (TAW); and the Federal Alliance for Safe Homes

(FLASH); and was funded by $185,000 grant from The Home Depot Foundation to build two homes. (Rivera, 2008). Only half of the budget was allocated to the physical construction of a single home, the total cost including installation of a single home resulted in an onsite cost of $92,500, creating a cost of $57.81 dollars per square foot. The mission of the program was to provide affordable housing options for low- and moderate-income families to withstand high wind speeds of up to 120 mph, and resist water and termites. The project was constructed under the regulations set by Miami-Dade County (FL) construction standards, the toughest standards in the country.

- Client**:** St. Petersburg Neighborhood Housing Services
- Location: St. Petersburg, FL
- Builder: Barrow Construction
- Engineer**:** SG Blocks
- Total Construction Time: 4 months
- Project Size: 1,600 square feet
- Completion Date: September 2006
  (SG Blocks, 2011)

Figure 2-9. St. Petersburg Home (SG Blocks, 2011).

FEMA Housing

The Federal Emergency Management Agency (FEMA) has provided $5.5 billion dollars directly to Hurricane Katrina victims for housing and other needs assistance through the Individuals and Households Assistance Program. The six billion dollars disbursement of aid is the single largest contribution ever provided by FEMA for any single natural disaster. After processing all requests for housing relief, 950,000 applicants were determined eligible for assistance under the Individuals and Households Program. FEMA provided $4.2 billion dollars for housing assistance, covering temporary housing, repair, replacement and permanent housing construction following Hurricane Katrina. FEMA has also paid out $1.3 billion dollars to nearly 550,000 applicants in Louisiana and Mississippi under the DHS Transitional Housing program for homes that were inaccessible to inspectors due to persistent flooding (FEMA, 2006). The following is a breakdown of how FEMA dispersed the assistance under the Individuals and Households Program:

- Hotel/Motel Program – 85,000 households & $650 million
- Housing Inspections and Repair – 1.3 million inspections
- Travel Trailers and Mobile Homes– 121,922 households (Occupied as of 8/25/06)
- The Louisiana Total = 71,134: mobile home – 3,169, travel trailers – 60,981
- The Mississippi Total = 36,127: mobile home – 4,709, travel trailers – 31,418
- The Alabama Total = 897: mobile homes – 0, travel trailers – 897
- Cruise Ships – Housing over 7,000 for the initial six months after Katrina
- Public Assistance Projects - $4.8 billion
- Debris Clean-up – 99 million cubic yards paying out $3.7 billion dollars
- Crisis Counseling $126 Million
- Evacuation Reimbursements -$735 million to 45 states for Evacuee Host States (FEMA, 2006)

FEMA - Travel Trailer and Mobile Home

The FEMA travel trailer is intended to provide temporary housing to victims of natural disasters until homes are able to be rebuilt or repaired. The trailers are typically installed on the private property of the victim, usually on lawns and sometimes in driveways next to the house depending on the amount of debris in the area. In places where the debris is too abundant to manage or flood water and lingering mold spores are present, FEMA constructs trailer parks where storm victims are relocated. The size of the trailer park ranges from several trailers reoccupying abandonment parking lots to a compound of thousands of trailers constructed on green fields with a perimeter of chain linked fence monitored by police security.

The typical FEMA trailer consists of a master bedroom with a standard size bed, a living area with kitchen and stove, bunk beds, and a bathroom with shower. Each trailer is equipped with electricity, air conditioning, indoor heating, running cold and hot water, a propane-operated stove and oven, a small microwave oven, a large refrigerator, and a few pieces of fixed furniture attached to the floor, usually a sofa bed, a small table, and two chairs (FEMA, 2006). The trailers are elevated two feet above the ground and supported by shallow concrete piles. The raised body of the trailer requires a wooden or aluminum stairwell or ADA specified handicap ramps for the disabled occupant (Figure 2-10). Each trailer is equipped with two propane tanks providing hot water, indoor heating, and gas for the stove and oven. Infrastructure is required of all trailer units to provide sanitary running water for consumption and hygiene, sewage lines directed to underground sewage mains, and power utility hook-ups. Although the trailers are equipped with telephone, cable and internet access, it is the responsibility of the resident to arrange services.

The occupancy rating of the one bedroom trailers are rated at a single family, i.e., two adults with two children; larger units are available to accommodate larger families. The upkeep of the trailer is delegated to the family occupying the unit and is inspected once a month by officials for the occupant’s safety and convenience: if upkeep is deemed useless, new accommodations will be required. The mobile homes are constructed and regulated under the Department of Housing and Urban Development (HUD) which sets the standards that all mobile homes must adhere to in the U.S.; the travel trailer is considered a vehicle and is exempt from HUD or any code used for the construction of a building; the park model is regulated by transportation authorities and by manufacturer acceptance of a voluntary American National Standards Institute standard applying to their construction (McCarthy, 2008).

A municipal airport in Purvis, Mississippi was the largest FEMA trailer storage and staging areas in the country after Hurricane Katrina. Following the hurricanes of 2005, FEMA ordered 145,000 mobile homes and trailers from manufactures across the nation, at a cost of more than $2.7 billion (Coolidge, n.d.). The total cost not including installation onsite of a mobile home was $26,000, resulting in a price of $30.95 dollars per square foot. The total cost not including installation onsite of a FEMA travel trailer was less at $19,000, resulting in a price of $74.22 dollars per square foot. The total cost not including installation onsite of a FEMA park trailer was $22,000, resulting in a price of $58.82 dollars per square foot, this price reflects the additional square footage of the travel trailer. FEMA's estimates for the lifespan costs of housing units the agency employs are $26,379 for a travel trailer, $37,379 for a park model, and $52,634 for a mobile home.

Most were delivered and deployed, but many tens of thousands of nearly identical and brand-new trailers remained at storage yards, the largest of which were in Purvis, Mississippi (Figure 2-10), and Hope, Arkansas, unable to be delivered due to concerns about formaldehyde. Of the ones that were deployed, after the allowed period of use in the field, they were taken back by FEMA, and they too were stored, and auctioned off, sometimes in lots of 10,000 at a time. On the sale day of January 29, 2010, more than

100,000 Travel Trailer units were sold for $133 million, 7% of the original price paid for each unit. (Coolidge, n.d.)

(A) (B)

Figure 2-10. FEMA Trailers (Sorlien, 2006). (A) FEMA trailer with handicap ramp installed, (B) Purvis, Mississippi storage facility for FEMA trailers.

Katrina Cottage

The Katrina Cottage is a small, structurally sound house that can be delivered via semi-trailer truck at the cost of a FEMA trailer. The original cottage arose as a solution for post-disaster housing during the Mississippi Renewal Forum, which took place in Biloxi, Mississippi in October 2006, six weeks after Hurricane Katrina (Sorlien, 2006). Several months following the installation of thousands of FEMA trailers, it became apparent that the initially estimated $70,000 lifecycle cost of the semi-permanent FEMA trailer would be exceeded and a succeeding replacement was dire. The State of Mississippi, through the Governor's Office for Recovery & Renewal, took the initiative to apply for a substantial grant for this purpose (Sorlien, 2006). President George Bush approved a pilot program for all five Gulf States, which allocated $400 million dollars for the pursuit of designs and construction for future hurricanes. In addition to this program, President Bush signed the Baker Bill, which will allow FEMA to provide permanent structures after future disasters (Sorlien, 2006).

The Katrina Cottages are designed with the intention to either be temporary or permanent; a sense of permanence has been designed allowing the expansion of the unit to become incorporated into a full-sized dwelling plan (Figure 2-11). The foundation principles of Katrina Cottages include:

- Design quality must be excellent.
- Buildings must be appropriate to the regional conditions, culture, and climate.
- Buildings must be deliverable by all major delivery methods, including manufactured houses, modular houses, kit houses, panelized houses, and site-built houses.

The cottages were designed under the International Residential Code (IRC) and are built using hurricane-resistant materials. The secure structure will be anchored to a conventional foundation using footings rather than being placed on slab, with cement siding and a metal roof that will withstand 130-mile winds and a Category 3 hurricane (Intbau, 2006). It may be built of any technology or delivery system, including mobile home standards, pre-manufactured elements, panelized construction, or site-built of any material (Sorlien, 2006). The 308' square foot model of the Katrina cottage was most popular unit to deploy because it fell in between the 200’ to 400’ square foot FEMA trailer range. The total cost not including installation onsite of cottage was estimated at $35,000, resulting in a price of $113.64 dollars per square foot. The cost of construction including delivery of materials of the 308 square foot model anywhere along the Gulf Coast is estimated to be $70,000 dollars. The life cycle cost is less as the FEMA trailer, estimated to be an additional $70,000 for the duration of the unit’s intended use.

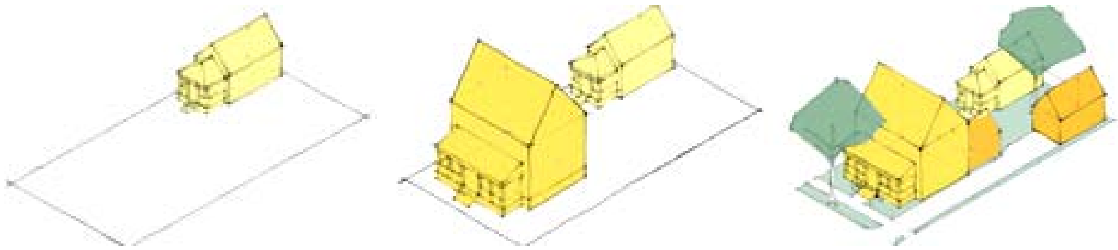


Figure 2-11. Katrina Cottage Plan From Immediate-to-Long Term Use (Sorlien, 2006).

The Katrina cottage is one room wide, providing the proper width for cross-ventilation and reducing the dependence upon air conditioning during warm summer months. A metal roof (Figure 2-12) aids in the reflection of radiant energy, while the tall interior spaces allow the warm summer air to accumulate towards the ceiling away from the occupants. The windows installed on the cottages are proportionally larger than typically sized residential homes and are double-hung so residents can lower the top sash and raise the bottom sash on summer evenings, allowing warm air near the ceiling to escape and cooler air to enter at the bottom. The small stature of the cottages is more adaptive to the South and the mid-Atlantic region by using design features that are appropriate for the climate.

Figure 2-12. Katrina Cottage (Sorlien, 2006). Metal roof cladding. Photo courtesy of

The Katrina cottages are intended for small lots that are typically 1/30 of an acre of net land per cottage. Traditionally built homes are constructed on a ½ of an acre of net land which is almost double the size and therefore double the cost of the lot required for the Katrina cottage. The cottages employ a five foot side yard setback creating the illusion the houses are actually more loosely spaced because the proportion of the house is smaller. The small lot size also contributes to walkability of the neighborhood because of the compact nature of the cottages; more households are placed within walking distance of the corner store, the neighborhood school, the playground, and the meeting hall. The need for automotive transportation is also decreased due to the compact, close proximity, diverse neighborhoods, with many residents in similar situations only requiring one vehicle for long distance commutes beyond the neighborhood limits.

There are seven different types of residential Katrina Cottages: the Katrina Tiny Cottage, the Katrina Thin Cottage, the Katrina Double Cottage, the Katrina Kernel Cottage, the Katrina Courtyard Cottage, the Katrina Loft Cottage, and the Katrina Tall Cottage.

The Katrina Tiny Cottage. The Katrina Tiny Cottage measures 500 square feet or less and is one story tall. It is also less than 16' wide (measured to the eaves) so that it may be loaded onto a truck and hauled to another site if desired. (Figure 2-13)

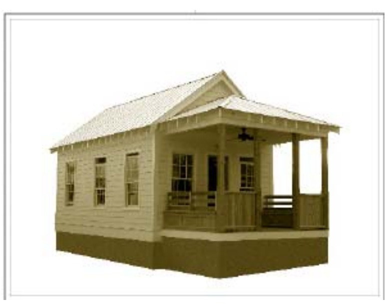


Figure 2-13. Katrina Tiny Cottage (Sorlien, 2006).

The Katrina Thin Cottage. The Katrina Thin Cottage is the same width of the Tiny Cottage, but includes more interior square footage due to the cottage’s increased length. The Thin Cottages compartmentalize the bedrooms to create private sections within the home providing hallways to access the cottage from the front to rear without walking through private bedrooms. (Figure 2-14)

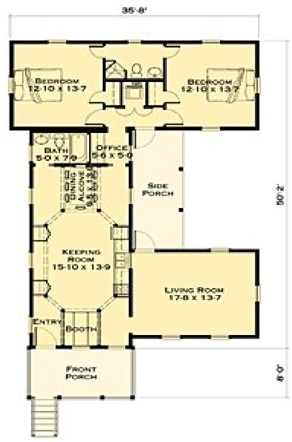
Figure 2-14. Katrina Thin Cottage (Sorlien, 2006).

The Katrina Double Cottage. The Katrina Double Cottage is similar to the Katrina Thin Cottage, except it is up to twice as wide. All Katrina Double Cottages are designed to be divided into two parts if they ever need to be moved, although they are less likely to be moved than Katrina Tiny Cottages and Katrina Thin Cottages. Katrina Double Cottages generally have the most bedrooms and the greatest living space. They may be the beginning of a Kernel House, or may often stand alone. (Figure 2-15)

Figure 2-15. Katrina Double Cottage. Photo courtesy of Katrinacottages.com.

The Katrina Kernel Cottage. The Katrina Kernel Cottage looks similar to both the Katrina Thin Cottage and the Katrina Tiny Cottage from the exterior; the difference is in the layout of the floor plan. The Kernel Cottage is designed to grow into a Kernel House, it has at least three *Grow Zones* from which the house can be extended in one or two directions. Growth should be easy, and is usually accomplished by simply changing a window into a door. (Figure 2-16)

(A)



(B)

Figure 2-16. Katrina Kernel Cottage (Sorlien, 2006). (A) First Deployed Unit, (B) Attached construction to the exterior of the first deployed unit.

The Katrina Courtyard Cottage. The Katrina Courtyard Cottage is made up of two or more wings that surround a courtyard on two, three, or four sides. Each of the wings is less than 16' wide. A Courtyard Cottage can be one or two stories. See Positive Outdoor Space for ideas of how to design the outdoor living space in the courtyard. (Figure 2-17)


(A)

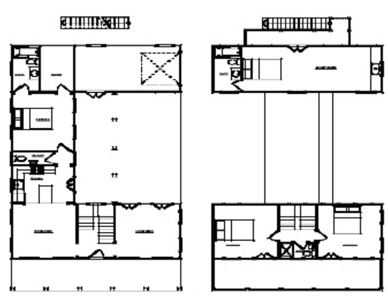

(B)

Figure 2-17. Katrina Courtyard Cottage (Sorlien, 2006). (A) Street view of exterior, (B) Floor plans highlighting the wings bracketing the courtyard.

The Katrina Loft Cottage. The Katrina Loft Cottage has low eaves like any other one-story cottage, but it tucks a loft up under those eaves. Because the Loft Cottage is designed to be shippable like all of the other Katrina Cottages, it is also 16' wide or less, measured at the eaves. If shipped, it would ship in two parts and be assembled on-site with a crane. (Figure 2-18)

Figure 2-18. Katrina Loft Cottage (Sorlien, 2006). Lateral and Longitudinal Elevations.

The Katrina Tall Cottage. The Katrina Tall Cottage is a full two stories tall. Like the Loft Cottage, it is 16' wide or less, and if manufactured, ships in two parts that are assembled on-site with a crane. (Figure 2-19)

Figure 2-19. Katrina Tall Cottage (Sorlien, 2006). Street view of exterior

Mississippi Cottage

The Mississippi Cottages were constructed to serve as alternative homes for those in travel trailers. The cottages adopted the vernacular of the coastal Mississippi homes and were constructed using two primary models. The two models are similar aesthetically but vary internally due to dissimilar interior square footage. The Park model offers 340 square feet and costs an estimated $22,295 to build in modular home factories, resulting in $65.57 per square foot; an additional $5,000 will cover transportation and installation. The Mississippi Cottage will come in two sizes: a 704-

square-foot model at $53,940, resulting in $76.62 per square foot, plus $8,000 for transportation and installation; and an 850-square-foot model at $64,140, resulting in $75.46 per square foot, plus $10,000 for transportation and installation. The company responsible for building the cottage said the construction time is expected to be completed within four weeks of the order date (Swinney, 2007).

The cottages are expected to withstand sustained 150 mph winds, or a Category four hurricane and are built to serve as interim to permanent dwellings. The cottages have been regulated by the International Residential Code (IRC) and meet or exceed all local and state codes in the Mississippi / Louisiana region. The undercarriage used for transportation the cottages to their destination is constructed under the HUD building code and can either be removed upon arrival to establish community and permanency (Figure 2-20) or remain in-place for future relocation.

The Mississippi Cottage is 14' wide, with either a 704 or 850 square foot interior living area, plus an exterior six-foot front porch (Swinney, 2007). The cottage has a traditionally designed five/twelve hip roof with 30-year architectural asphaltic shingles. The units were constructed to withstand the harsh coastal environment by use Hardiboard siding with a 30-year warranty to clad the exterior walls, thermo pane windows in all openings, a vinyl soffit, all steel construction exterior doors, and vinyl aluminum rails on the front porch; all of which prohibits early stages of pre-mature weather. All the designs for construction help create a low maintenance cottage designed for long lasting beauty.

Residents can live rent-free in the cottages for at least two years before they would have to purchase the units at fair market prices. In 2006, state officials have reported approximately 80,000 people are living in about 23,000 FEMA trailers in Mississippi; every month, about 1,000 trailers are abandoned as families move into alternative housing (Swinney, 2007). Persons once residing in FEMA trailers are the only applicants eligible to be entered into a limited group to receive one of the cottages to replace the cramped trailers in which they lived; some residents waited as long as two years before relocating to permanent housing.

Figure 2-20. Mississippi Cottage community (Swinney, 2007).

Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty in the 1970s, based on mathematics and psychology. AHP provides a proven, structured technique to process complex decision making by identifying and weighting select criterion, analyzing the data collected for the criterion and expediting the decision making process (Saaty, 102). The technique is used to arrive at the optimum solution that best suits the goals and understandings of the problem. AHP calculates both subjective and objective evaluation measures, providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested. The primary aim of the AHP is to alleviate decision bias when making complex decisions involving multiple criterions. To accomplish this, the AHP provides a framework for structuring the decision making process, for representing and quantifying the elements, and correlating those elements to the overall goal, by evaluating all alternative solutions (Saaty, 102).

The first stage of the AHP involves decomposing the complex problem into sub-problems, placing them in a hierarchical order, to be analyzed independently. The placing of sub-problems into a hierarchical order can use any aspect related to the complex problem. After the hierarchy model is constructed, the systematic evaluation of the various elements are compared two at a time, with respect to their impact on the element that precedes them in the hierarchy (Saaty, 102). It is best to use objective data about the elements when comparing them, but subjective judgments relative to the element’s meaning and importance may be considered. The AHP renders the most optimized results when subjective judgments are used, in conjunction with objective underlying information to perform the evaluations.

The evaluations are then converted to numerical values that can be processed and compared over the entire region of the complex problem. In order to establish consistency in a rational way, a numerical weight is derived for each element of the hierarchy. The weighting of the hierarchical elements distinguishes the AHP from other decision making techniques (Forman & Gass, 49). To complete the process, numerical weights are calculated for each of the decision alternatives; these weights represent the capacity the alternative has to achieve the complex problem.

Application

The AHP is most useful where a complex problem exists with a group of individuals responsible for the outcome, involving human perceptions and opinionated biases. The advantages of using this technique is the capability to quantify and compare the various subjective elements into a cohesive terminology that is consistent among all parties involved in the decision making process. The application of the AHP to resolve complex problems is wide spread, involving: planning, resource allocation, priority setting, selection among alternatives, forecasting, total quality management, business process re-engineering, quality function deployment, and the Balanced Scorecard (Forman & Gass, 49). AHP is used in designing highly specific procedures for particular situations throughout all fields of research.

Forman and Gass, of Operations Research, apply the method of AHP to:

- Ranking - Putting a set of alternatives in order from most to least desirable
- Prioritization - Determining the relative merit of members of a set of alternatives, as opposed to selecting a single one or merely ranking them
- Resource allocation - Apportioning resources among a set of alternatives
- Benchmarking - Comparing the processes in one's own organization with those of other best-of-breed organizations
- Quality management - Dealing with the multidimensional aspects of quality and quality improvement
- Conflict resolution - Settling disputes between parties with apparently incompatible goals or positions

Table 2-1. Container Statistics for 2010

Month	In Loaded (TEUs)	In Empty (TEUs)	In Total (TEUs)	In Empty (%)	Out Loaded (TEUs)	Out Empty (TEUs)	Out Total (TEUs)	Out Empty (%)	Total (TEUs)	Change (%)
January	296,304	6,387	302,692	2.11%	141,243	129,032	270,276	47.74%	572,969	-2.39%
February	267,361	7,578.65	274,939	2.76%	147,925	102,593	250,518	40.95%	525,458	26.95%
March	269,634	12,114	281,748	4.30%	161,816	106,684	268,501	39.73%	550,249	4.51%
April	302,224	9,118	311,343	2.93%	158,338	125,602	283,940	44.24%	595,283	11.87%
May	342,171	9,566	351,737	2.72%	160,621	177,062	337,683	52.43%	689,420	19.94%
June	371,888	7,078	378,967	1.87%	154,558	196,792	351,350	56.01%	730,317	32.38%
July	369,388	6,412	375,800	1.71%	146,368	208,575	354,944	58.76%	730,745	26.82%
August	399,150	7,540	406,691	1.85%	147,608	209,537	357,145	58.67%	763,837	24.69%
September	373,249	6,535	379,784	1.72%	139,800	192,028	331,828	57.87%	711,613	21.94%
November	333,710	10,614	344,324	3.08%	170,319	152,326	322,646	47.21%	666,970	14.95%
December	299,304	13,556	312,860	4.33%	161,625	138,166	299,791	46.09%	612,651	8.82%
Total 2010	3,973,933	105,198	4,079,131	2.58%	1,841,273	1,911,496	3,752,770	50.94%	7,831,902	16.05%

Table source: Port of Los Angeles, (2011). *TEU Statistics (Container Counts).* Retrieved May 26, 2011, from The Port of Los Angeles: http://www.portoflosangeles.org/maritime/stats_2010.asp

CHAPTER 3
METHODOLOGY

Data Collection

The research of this thesis was performed to evaluate the most appropriate mass-produced model to be implemented following a post-natural disaster. The process through which the mass-produced architectural models were identified was completed by gathering information collected from prevalent sources that have explicitly covered possible models in both developmental stages and currently deployed stages. The mass-produced models identified through this research were carefully considered and selected, based on a stringent performance criteria list. The study is a comparative analysis of models that have been previously deployed following Hurricane Katrina by FEMA and shipping container models that were overlooked due to the lack of understanding and awareness of their potential.

Data Analysis

The Analytic Hierarchy Process (AHP) was used as an evaluation method for comparing design concepts based on an overall value per design concepts. The AHP is a valuable decision-making tool that is used to evaluate program alternatives based on specific evaluation criteria weighted by importance. The Analytic Hierarchy Process allowed the scores of all criteria to be summed up into an overall value per performance alternative. The AHP assigns scores to the degree to which a design alternative satisfies a criterion; however, the criteria that are used to evaluate the design alternatives might differ in their importance. The process of assigning weights to the different criteria allows the study to take into account the difference in importance between the criteria. The AHP's application into the study was used because an optimized solution needed to be derived from a select number of design alternatives.

The matrix is constructed with the alternatives listed along one left side of the chart and the review criteria along the top of the chart. A box to insert the specific assigned weight is located with each criterion. A hierarchical evaluation scale is established for the whole matrix ranging from five to one using the Likert scale. The ranking of the alternative based on its ability to address the specific criteria is entered into the appropriate cell. The total scores are then available to use in ranking alternatives.

The procedural starting point of the AHP began with a limited number of design alternatives that were promising candidates to address the demand for mass-produced architecture in post-natural disaster areas. Criteria used within the matrix analysis were selected from a compositional list of requirements, which were integral to success of the implemented architectural unit. After the criteria were limited, appointed weights were assigned to the criteria based on their importance for the evaluation. To determine the weight factor of the criteria, the weights were ranked on a scale from one to five on the Likert scale. The criterions have been ranked according to performance standards using a weighted scale range that includes: Major = 5, High = 4, Medium = 3, Minor = 2, No Significance = 1 (Appendix E). By evaluating alternatives based on their performance with respect to individual criteria, a value for the alternative can be identified. The values for each alternative can then be compared to create a rank order of their performance related to the criteria as a whole.

The performance criterion weighting results were transcribed into the model analysis matrix (Appendix F). A matrix was constructed, with the performance criteria in columns and the design concepts in the rows. The model analysis matrix rating scale range includes: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, Poor = 1. The subjective grades were then multiplied by the weighted average for the individual criterion to arrive at a final criterion score. All the scores were totaled and ranked in accordance with the highest score considered as the most appropriate model to implement for interim-to-permanent housing following a natural disaster.

CHAPTER 4
RESULTS ANALYSIS

Mass-Produced Housing

We do not have the capacity to stop natural disasters, we do however, have within our abilities to mitigate the billions of dollars of damage and loss of life. ISBU home or business construction is a composition of multiple steel modules that create a solid uni-body construction that are resilient to disasters. The small number of buildings throughout the globe that have implemented intermodal steel building units (ISBUs) within the structure of buildings have survived every catastrophic disaster to date. Whether the hurricanes and tornadoes in America or tsunami and earthquakes in Japan, the shipping containers and ISBU shipping container construction have always survived (Figure 4-1) and is well documented by local residents and government official (ISBU Association, 2008). The reason for the high survival rate of ISBU constructed buildings is the inherent properties the shipping container possesses - the shipping container was designed to survive.


(A)


(B)

Figure 4-1. Shipping Containers After a Disaster (NOAA, 2005). (A) Shipping containers resting on the debris left by thousands of homes devastated by an F-5 hurricane, (B) Shipping containers after earthquake in Japan.

The designed life of a shipping container starts within an ISO certified factory and then is successively subjected to the loading of tons of cargo inside; from the jarring ride to the docks; the bangs and drops when being loaded onto the ships at the port; the weeks of wind, rain, bouncing, banging and salt water at sea; they finally arrive at the next port for unloading and transfer. Upon arrival, the shipping container is once again banged, dropped, swung, twisted, hit, stacked on, then moved and repeated many times before sorting and trucked or sent by rail to their final destination.

Advantages of Mass-Production

By shifting the substantial portions of work offsite, several crucial productivity losses are mitigated entirely; they are: waiting for information, receiving inadequate documents, unnecessary material handling, redo work, waiting for resources, jobsite accidents, site constraints, etc.

The overall cost for a project that uses off-site work can be less than a traditional constructed project, which can be caused by a variety of factors. The local labor for on-site work may be expensive or inefficient for the project. Severe on-site conditions and weather problems can lead to costly delays that can be avoided by preassembling sections of the work in factories that are isolated from the environment. Also, on-site interference and worker congestion or trade stacking can be avoided, increasing productivity and lowering costs.

The on-site construction duration can be substantially shortened through the use of prefabrication. Greater quantities of work for a project can be completed before going to the site so that the construction schedule is decreased by eliminating the typical contingency days allotted for delays (Kelly, 1951). This can be an important factor for owners with a compressed schedule or limited on-site resources.

Overall project safety can be improved through the use of off-site work. The risk to owners and contractors of worker accidents and lost time is reduced with construction work that is transferred away from the jobsite. On-site work can be relatively unsafe due to ever changing conditions, elevated work, and congestion. Manufacturing and offsite work reduce all of these factors to provide a safe and productive environment with greater efficiencies.

Quality can also be improved through the use of off-site work. Controlled factory and production conditions and repetitive procedures and activities, along with automated machinery can lead to a higher level of quality than can be attained on-site. This is partly due to reduced jobsite construction duration and a decrease in field labor requirements. Labor availability can be an advantage as well for offsite work. There is generally a constant, employed workforce for offsite prefab plants.

Weather is less of a factor for prefabrication, providing an additional advantage over the conventional methods of building on-site. The prefabrication and modularization shops take advantage of controlled environments that are not affected by harsh weather. Work is not interrupted and productivity can remain at a consistent easily measurable level. Simultaneous production, or parallel work, can be exploited with the use of preassembly. Instead of performing tasks in a strictly linear sequence on-site, construction activities can be broken up and completed simultaneously at multiple locations. This process shortens the construction duration and reduces on-site congestion by dispersing the workers.

Disadvantages of Mass-Production

The principle of learning curves can be applied in construction for the prediction of the time/cycle of future work, work performance levels, and other performance measures. More affordable mass produced factory housing may be seen as a long term win-win situation but early experience is showing demonstration projects are generally struggling to meet their anticipated targets for reductions in capital costs. While much of this may be due to the early learning curve, the fragmented nature of the housing market is not allowing leading manufacturers to generate economies of scale nor providing the assurance of business continuity. Unfortunately, the repetitive nature of the prefabrication assembly line is infrequent resulting in an inefficient learning curve model. For a learning curve to establish itself and flourish a constant flow of work must be completed by the same crewmembers; if variables within the model are altered the factors will inevitably alter the progress of the curve. A learning curve model will never see progress in a stop and go sequencing of repetitive activities.

The multitude of advantages clearly overshadows the disadvantages but they still should be mentioned in this report to balance the argument. The intricate nature the building components inherently possess may become a factor when transporting from the facility to the site. Special handling precautions must be instilled to prevent the components from developing stress cracks along the component's seams. As these joints become assembled in the field special attention should paid to the strength and corrosion-resistance of the physical jointing sections. It is essential the bonding surface of the joints form an impermeable seal to prevent leaks along the seam.

When the sections arrive on the job-site large heavy-duty cranes are required to lift and install the various components into the respective places. The specified tolerances require a skilled labor force for installation. When large monotonous prefabricated sections are erected the aesthetical design factor is subdued. One of the most adverse site specific effects of prefabrication are the lost jobs to outsourcing. Since prefabrication is a relatively modern concept that has just begun to make its way into the national market there are only a selective group of companies that are invested in the prefabricated construction industry.

The actual logistics of transporting the contents to the job-site from the manufacturing facility can be a considerable planning effort. The costs of transporting voluminous prefabricated sections can be significantly higher when compared to the efficient packaging of the individual unassembled building materials. Transportation costs can within certain geographical locations can be a disadvantage to off-site work (CII, 1992). This is especially true for large modularized sections that must be transported over a long distance. Size constraints and limitations exist, based on the method of travel, which directly leads into cost and schedule considerations. The dimensions of the transported section are constrained by the regulations of the Department of Transportation (DOT, n.d.), which limit the weight, height, width and length of the vehicles carrying the load.

There is a need for substantial increases in engineering effort upfront concurrent with the conceptual design stage of the architect (CII, 1992). This means that design work and extensive planning must be completed before construction documents can be finalized and the commencing of work can begin. Building information modeling software should be used to detect any interference among the construction divisions to alleviate future conflicts. In practice, these activities can lead to a better performing project altogether. While there may be a sense of inflexibility associated with prefabrication, because it is much more difficult to make modifications after a project has begun, it may in fact lead to better scope control.

Housing Model Analysis

Each case study has introduced a number of essential assets that should be incorporated into an optimized housing solution for disaster relief and reconstruction. The model analysis has been broken down into five categories (Appendix A and B), which enables the assortment of housing options to be investigated at a finer level of detail that include:

- Project Demographics
- Time Constraints
- Project Requirements
- Architectural Qualities
- Project Specifications

Project Demographics

Project demographics has been categorized into two sub-categorizes: date of construction and construction site. The more significant sub-category within project demographics is the construction site, for it influences the remaining criterion within the model analysis the most significantly. The demographics provide a layer of information that is crucial to the planning portion of disaster relief and reconstruction efforts. The companies responsible for assembling the units either on/off site rely on the date of construction by means of code revisions and up to date building technologies.

Construction Site. The location of the construction site used for construction of the building components is intrinsic to the project and presides an explicit method of constructability. The technologies used to design and preassemble mass-produced housing are inherently different, which limits the applicant pool of companies able to perform the intricate work. Design and construction resources such as materials, facilities, and infrastructure required to complete certain types of implementation can varying in availability as well. The physical construction onsite following a natural disaster can be limited in accessibility and create coordination issues concerning material handling and installation of the housing units. The method of construction in some cases may not be facilitated by the limited accessibility issues present on the site. The installation of the unit onsite will require additional services to prep the site before construction can begin, the addition of services will increase the final cost of the housing unit.

The Likert scale was used to determine the performance of the criterion, includes: (5) = 100% Offsite, (4) = 75%Offsite, (3) = 50% Offsite, (2) = 25% Offsite, (1) = 0% Offsite (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, construction site, was ranked as a (4) = High, on the Likert scale. The importance of the criterion establishes the value of the criterion in relation to the other criterion being considered.

Date of Construction. The date of construction is a direct reflection upon the technology and the paradigms of the time that facilitate such a structure to be designed and constructed. Older units, although perhaps groundbreaking at the time of inception may have become obsolete or replaced by newer technological approaches. With newer technologies presents the notion of more stringent design controls and the ability to cut costs through more efficient methods of construction. The most recent housing models are constructed under the latest building code revisions, therefore they are less susceptible to vulnerabilities that plagued previous inadequate code requirements, and therefore, are superior over their predecessors.

The Likert scale was used to determine the importance of the criterion, includes: (5) = Present-2007, (4) = 2006-2005, (3) = 2004-2003, (2) = 2002-2001, (1) = 2000-Older (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, date of construction, was ranked as a (2) = Minor, on the Likert scale.

Time Constraints

Time is an essential component in relation to how local, state, and federal governments can provide reconstruction and relief effects following a natural disaster. The ability to properly coordinate time management is contingent upon the efficiency of the mass-produced housing that will soon be deployed into the field. In an effort to combat time associated with the logistics of mass-produced housing - local, state and federal entities have always stockpiled thousands of supplies for housing throughout the U.S. to alleviate some of the initial demand for housing. Therefore, the only critical time associated with deploying housing relief is construction and assembly times. After the arrival of the housing unit, the duration of intended use of the proposed building is a key component when ranking the dispersed housing options. The ability for the housing model to make the transitional shift from temporary-to-interim-to-permanent is one of the most valuable attributes the housing model can possess.

Construction Time. The time to construct a single housing unit is broad in range and is significant when considering the selection of the most appropriate model to use. Models that can be deployed, constructed and assembled quickly are generally best matched for relief in a temporary role. Models that require a greater amount of time from the initial order placed to the date of occupancy may be best equipped to meet the demand for interim-to-permanent housing. The availability of the shipping containers directly translates into the time required for production, however, when using this type of method the time of construction is longer than the time of assembly onsite. A stockpiled fleet of preassembled housing is the optimum solution and would easily meet the massive demand for housing following a disaster. In this study, even though the FEMA trailers were stockpiled, the time construction time was included to reach equilibrium for comparison amongst the housing models.

The Likert scale was used to determine the importance of the criterion, includes: (5) = 1-30 days, (4) = 31-60 days, (3) = 61-90 days, (2) = 91-120 days, (1) = >121 days (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, construction time, was ranked as a (5) = Excellent, on the Likert scale.

Project Duration. The life of the installed unit is contingent upon the duration of its intended use. Trying to quantify the duration of projects to a uniform comparable standard, each project is branded as: interim/temporary, permanent, interim, interim/temporary, or temporary. The factors that have contributed to the classification of the project include: case study durations, intended use, and the ability to adapt to a long-term housing plan. Some methods of construction are better enabled to address the concerns of permanency. Some types of construction are more appropriate for temporary relief, while others are converted to long-term reconstruction more effectively.

The Likert scale was used to determine the importance of the criterion, includes: (5) = Interim/Permanent, (4) = Permanent, (3) = Interim, (2) = Interim/Temporary, (1) = Temporary (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, project duration type, was ranked as a (4) = High, on the Likert scale.

Project Requirements

Project requirements are necessities that will ensure the assembly and construction of the building. The requirements include: skilled labor, equipment requirements and foundation requirements; all of which are factors used to keep the study's limits within an obtainable range. Some of the requirements are weighted slightly larger than the others due to the importance within the field during disaster relief and reconstruction.

Skilled Labor Requirements. The task forces that are used to construct mass-produced housing are divided into two classifications: general labor and skilled labor. The distinction between the two can be contributed to a worker's expertize, specialization, wages, and supervisory capacity. The skilled worker is typically trained more effectively, higher wage earning, and have more responsibilities delegated to them than general laborers. An influential factor is the role of the educational background of the worker. Education has been linked to an increase in a person's skill level (Wood, 1981). The general laborer and skilled worker each have a crucial role in the assembly and construction of mass-produced housing i.e. you cannot have one without the other. Both skill levels should be evaluated within the model analysis to determine the capacity of the taskforce required to implement the relief housing.

The associated cost of having a ratio of more skilled workers versus general laborers directly affects the overall cost of the project. Although the number of people seeking high school education or higher in the U.S. has been increasing year to year, the number of available skilled tradesman within certain geographical locations throughout the U.S. is still low. The low number of skilled workers within certain locations can be attributed to lower wages, poor education, and lack of jobs requiring skilled workers. The overall project cost is increased because of the increased demand and lack of adequate skilled members to perform the job and therefore specialized crews are required to complete the work.

The Likert scale was used to determine the importance of the criterion, includes: (5) = 0% Skilled, (4) = 25% Skilled, (3) = 50% Skilled, (2) = 75% Skilled, (1) = 100% Skilled (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, skilled labor requirements, was ranked as a (4) = High, on the Likert scale.

Equipment Requirements. The equipment used to assemble a mass-produced house is dramatically decreased from the standard number of tools required to construct a traditional house. Mass-produced housing uses equipment that are more sophisticated in order to achieve limited tolerances and precision repetitively. The model analysis will be primarily concerned with the equipment associated with the mobility of the models. Following a natural disaster the infrastructure of a region can be compromised and will limit the size and type of equipment because of accessibility issues. The study has been refined to only include the equipment selection of using a truck type with or without a crane, to provide equilibrium for the weighting portion of the study. Models that require the use just a truck without a crane are agile and have increased mobility versus models that require the use of a truck for transportation to the site followed by a crane to conduct the lifting and assembly of the unit(s) into their respective place.

The Likert scale was used to determine the importance of the criterion, includes: (5) = Standard Truck, (4) = Flat-bed Truck, (3) = Semi-Truck, (2) = Flat-bed Truck/Crane, (1) = Semi-Truck/Crane (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, equipment requirements, was ranked as a (3) = Medium, on the Likert scale.

Foundation Requirements. The foundation of a building is the point of contact between the ground and the structure of the building; at this moment, the weight of the building is transferred upon the foundation. The selection of which type of foundation to utilize is based upon such factors as: the soil bearing capacity, differential settlement, frost lines and engineering designs. The foundation required for mobile housing included in this study are pile foundation, slab on-grade, stem-wall foundation and in some cases no foundation is required at all. It is vital that the appropriate means are provided to support the structure of a building in an effort to mitigate failure and a compromised structure. In some areas, flood waters are persistent and require an elevated foundation even though the traditional foundation for the housing model may not require the raised stature and must be adapted to incorporate the elevated foundation. The time required erecting the foundation and time allotted for the curing of concrete is a task sometimes overlooked when considering time sensitive disaster relief.

The Likert scale was used to determine the importance of the criterion, includes: (5) = None, (4) = Pile-Driven/None, (3) = Pile-Driven, (2) = Stem-wall, (1) = Slab on-grade (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, foundation requirements, was ranked as a (3) = Medium, on the Likert scale.

Architectural Qualities

Architectural qualities are a composition of objective and subjective reactions to the physically built characteristics of the building. The architectural qualities that have been considered in this study include: square foot per occupant, number of bedrooms, architectural vernacular and expandability. The qualities are calculated upon the model's exterior and interior characteristics.

Square Foot per Occupant. The occupancy rating of the building has been delineated by building codes and fire code enforcement which determine the acceptable square footage for a single occupant. To determine the proper occupancy of the building, the square footage of interior living space was divided by the number of persons to occupy the building. The occupancy rating gives a more accurate representation of the capacity the project has to offer to the thousands of displaced Katrina victims, rather than looking at the building's cost per square foot solely.

The Likert scale was used to determine the importance of the criterion, includes: (5) = >150 Sq. Ft., (4) = 149-125 Sq. Ft., (3) = 124-100 Sq. Ft., (2) = 99-75 Sq. Ft., (1) = <76 Sq. Ft. (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, Square Foot per Occupant, was ranked as a (3) = Medium, on the Likert scale.

Architectural Vernacular. The architectural vernacular of the coastal regions of Louisiana and Mississippi are used to reflect the environmental, cultural and historical context of place. It has been argued by some that architecture designed is not vernacular, but a model based off of vernacular. In either case, in order to regain normalcy within the disaster areas, a sense of place most be re-established using the architectural tokens that once centered the communities. The projects that have been suggested include: no style, modern, contemporary, and traditional vernacular. The effect of one vernacular style versus another is subjective and experienced differently by the designer and occupant. For the purposes of this study, the weighted model analysis will be from the perspective of the subjective occupant not the designer nor local, state, or federal officials, whom will never occupy the building.

The Likert scale was used to determine the importance of the criterion includes: (5) = Adaptable, (4) = Traditional, (3) = Contemporary, (2) = Modern, (1) = No Style (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, architectural vernacular, was ranked as a (5) = Excellent, on the Likert scale.

Expandability. The expandability of a structure is a forwarded thinking idea that will facilitate the transition from interim housing-to-permanent housing. If the structure is not expandable, the sequence of events that will follow include: removing the structure after temporary life, relocating the structure to a holding facility, storing the unit for an undetermined amount of time, watching the unit degrade thus requiring maintenance, and finally selling off the abundant accumulated units to private entities. A unit that is not expandable in some fashion will only be sufficient for temporary housing relief not long term reconstruction efforts. If using shipping containers for temporary housing, the opportunity of converting the container into an Intermodal Steel Building Unit (ISBU) presents the opportunity to fulfill the transition into permanent housing.

The Likert scale was used to determine the importance of the criterion includes: (5) = No effort, (4) = Little effort, (3) = Effort, (2) = Great effort, (1) = Not possible (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, expandability, was ranked as a (4) = High, on the Likert scale.

Project Specifications

The specifications of the model analysis are the objective figures that are essential in comparing the suggested models for mass-produced housing following a natural disaster. The specifications are emphasized by using: building codes, shipping size, project costs, and cost per square foot to determine the most appropriate model for implementation. The individual models have been translated into dollars and dimensions to provide a uniform plane to assess the models against one another.

Building Code Stringency. Building codes are the guidelines that address how a building is to be constructed within acceptable tolerances to protect the property, building, and most importantly the occupant inside. Mass-produced housing must adhere to the most stringent building codes available to ensure they meet the codes that govern the region which they will be implemented within. Building codes that have been adopted by the selected models include: International Building Code (IBC), International Residential Code (IRC), United States Department of Housing and Urban Development (HUD), International Council of Building Officials (ICBO), and other region building codes.

The Likert scale was used to determine the importance of the criterion, includes: (5) = Local Jurisdiction, (4) = IBC/IRC, (3) = HUD, (2) = ANSI, (1) = None (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, building code stringency, was ranked as a (4) = High, on the Likert scale.

Shipping Size. The shipping size of the materials to be transported to the relief site is crucial concerning logistical coordination following a natural disaster. Dimensional limitations are in place to maximize safety and to protect the load from physical damage. The consumption of fuel is a factor when mentioning logistical transportation from a distant storage site to the relief area. Directly correlated to fuel consumption is the weight of the load being placed onto trucks or boats from transportation i.e. the larger the unit being transported, the more fuel will be consumed from its weight. The shipping container is the current paradigm for transporting all goods from one region to another due its dimensional standardization. A network of infrastructure currently exists to facilitate the shipping container from ship to truck and vise-versa.

The dimensional width of the FEMA manufactured homes require oversized trailers to transport the unit from factory to site, increasing the cost of transportation and need for proper logistical accessibility. According to the Department of Transportation, a normal width of 8.5’ feet (102 inches) is allowed without additional fees, however the maximum allowable vehicle load width for highway travel is 10’ feet wide (120 inches). Housing models that exceeded to DOT regulations are subjected to permit fees and special handling procedures, including front and rear vehicle escorts to maintain safety boundaries. Given the nature of disaster relief efforts, the permitting fees are typically waved, but fees for escorts are not absorbed by the local, state, or federal transportation services and will become additional costs paid by the company/home owner.

The Likert scale was used to determine the importance of the criterion includes: (5) = Standard Truck, (4) = Flat-bed Truck (3) = Semi-Truck, (2) Extended Semi-Truck, (1) = Oversized Semi-Truck (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, shipping size, was ranked as a (3) = Medium, on the Likert scale.

Cost. The cost of each unit varies greatly based upon many factors within the model analysis such as: shipping costs, size of the building, architectural detailing, skill level of task force, etc. It is safe to say that every category mentioned with the model analysis has some contributing factor associated with the overall cost of the project. Some factors are slightly more influential than others, but the largest contributor to overall cost of the suggested models is the type of construction that has been implemented to facilitate construction e.g. modular, ISBU, manufactured home, etc. In order to arrive at the square footage cost of each model, the overall cost of the completed building was divided by the given interior living area.

The Likert scale was used to determine the importance of the criterion includes: (5) = <$50 per Sq. Ft., (4) = $51-100 per Sq. Ft., (3) = $101-150 per Sq. Ft., (2) = $151-200 per Sq. Ft., (1) = >$201 per Sq. Ft. (Appendix E). The higher the number on the Likert scale the more appropriate the criterion is for interim-to-permanent housing. The importance of the criterion, architectural vernacular, was ranked as a (5) = Excellent, on the Likert scale.

Conclusion

Through a preference weighting process called Analytic Hierarchy Process (AHP), each design attribute was given a score by means of the five-level Likert scale. The graded criterions' values were then placed into a pairwise comparison chart resulting in a weighted score. The weighted scores were then applied to the performance criterion quantitating a final score total. The totals were ranked according to hierarchy with the highest score equating to the most appropriate model to be implemented.

Using performance criterion weighting and an analysis matrix to perform an evaluation on a select group of housing models, the precluding results were:

1. Katrina Cottage
2. Mississippi Park
3. Keetwonen Dormitories
4. Mississippi Cottage (Two Bedrooms)
5. Mississippi Cottage (Three Bedrooms)
6. Operations Building at Fort Bragg
7. FEMA Mobile Home
8. St. Petersburg Home
9. Mobile Dwelling Unit
10. Container City I
11. FEMA Park
12. Container City II
13. FEMA Travel Trailer
14. Research Facility

(Appendix F)

The results from the analysis matrix ranked the most appropriate model to be deployed following a natural disaster to meet the demand for interim-to-long term housing to be the Katrina Cottage. The cottage presents the most advantageous characteristics that are warranted in comparison to the other suggested models in the study. The cottage is the clearly ranked the superior housing model in the analysis matrix (Appendix F).

This study provides the framework for future disaster reconstruction efforts and enables local, state, and federal governments to quantify the unique design criteria of future housing solutions into a comparable analysis matrix. The criterions have been selected to illustrate the most comprehensive design attributes when selecting housing for reconstruction. Since time is of the essence for disaster relief and management, the matrix will prove to be a vital tool in reducing the initial set up times associated with the collection of preliminary data to weigh against possible housing solutions.

CHAPTER 5
RECOMMENDATIONS

In the event of a future researcher continuing the study, it should be noted that the research could include the application of energy modeling software to mass-produced housing throughout the building's life-cycle. With the induction of computer simulation becoming an apparent staple in popular construction techniques, building owners are becoming more affluent with how their buildings will operate soon after occupancy.

The study would also benefit from visiting or monitoring the selection process of initial, interim, and permanent housing by local, state, or federal entities to be implemented into disaster regions. This perspective would introduce unforeseen issues that must be remediated before and after a housing plan has been selected. The incite would demonstrate the importance of disaster preparation and how the potential damages and loss from a natural disaster can be mitigated

APPENDIX A
MODEL ANALYSIS OF SHIPPING CONTAINER HOUSING

Project Demographics				
Name	Manufacturer	Country of Origin	Date of Construction	Construction Site
Mobile Dwelling Unit	LOT-EK	USA	1999	100% Offsite
Research Facility	Earth Science Australia	Australia	2006	0% Offsite
Container City I	Urban Space Management	England	2001	75% Offsite
Container City II	Urban Space Management	England	2002	75% Offsite
Keetwonen	Tempohousing	Amsterdam	2002	75% Offsite
Fort Bragg Operations Bldg	SG Block	USA	2007	50% Offsite
St. Petersburg Home	SG Block	USA	2006	25% Offsite

Time Constraints (Days)				
Name	Construction	Assembly	Per Family	Duration Type
Mobile Dwelling Unit	24	1	25	Interim
Research Facility	2	21	22	Temporary
Container City I	4	50	4	Permanent
Container City II	8	103	5	Permanent
Keetwonen	N/A	1,440	2	Interim/Permenant
Fort Bragg Operations Bldg	75	101	44	Permanent
St. Petersburg Home	N/A	122	122	Permanent

Project Requirements			
Name	Skilled Labor	Equipment Requirements	Foundation Type
Mobile Dwelling Unit	100% Skilled	Flat-Bed Truck	None
Research Facility	0% Skilled	Flat-Bed Truck	Pile Foundation
Container City I	75% Skilled	Semi-Truck and Crane	Slab on-grade
Container City II	75% Skilled	Semi-Truck and Crane	Slab on-grade
Keetwonen	75% Skilled	Semi-Truck and Crane	Slab on-grade
Fort Bragg Operations Bldg	50% Skilled	Semi-Truck and Crane	Slab on-grade
St. Petersburg Home	50% Skilled	Flat-Bed Truck	Stem-wall Foundation

Architectural Qualities					
Name	Sq. Ft. per Person	Area (Sq. Ft)	# of Bedrooms	Vernacular	Expandability
Mobile Dwelling Unit	1 Single Family (4) = 138 Ft.	550	1	Modern	Effort
Research Facility	1 Single Family (4) = 80 Ft.	320	2	No Style	Effort
Container City I	Single Family (60) = 100 Ft.	6,000	15	Modern	Little Effort
Container City II	2 Single Family (88) = 88 Ft.	7,825	22	Modern	Little Effort
Keetwonen	k Single Family (4k) = 85 Ft.	340,000	1,000	Modern	Effort
Fort Bragg Operations Bldg	Single Family (15) = 288 Ft.	4,322	(4) Possible	Contemporary	Not Possible
St. Petersburg Home	1 Single Family (4) = 400 Ft.	1,600	3	Adaptable	Great Effort

Specifications				
Name	Building Code	Shipping Size	Cost	Cost/sq. Ft.
Mobile Dwelling Unit	None	(1) 20'x8.5'x8.5' = Flat-bed Truck	$75,000	$136.36
Research Facility	None	(1) 20'x8.5'x8.5' = Flat-bed Truck	$17,250	$53.91
Container City I	UBC	(23) 40'x8.5'x8.5' = Semi-Truck	$1,613,056	$268.84
Container City II	UBC	(30) 40'x8.5'x8.5' = Semi-Truck	$2,386,944	$305.04
Keetwonen	Dutch Building Code	(1k) 40'x8.5'x8.5' = Semi-Truck	$32,054,122	$94.28
Fort Bragg Operations Bldg	California Building Code	(12) 40'x8.5'x9.5' = Semi-Truck	$648,300	$150.00
St. Petersburg Home	Miami-Dade County Code	(2) 40'x8.5'x9.5' = Semi-Truck	$92,500	$57.81

APPENDIX B
MODEL ANALYSIS OF FEMA HOUSING

Project Demographics				
Name	Manufacturer	Country of Origin	Date of Construction	Construction Site
FEMA Travel Trailer	Various	USA	2005	100% Offsite
FEMA Park	Various	USA	2005	100% Offsite
FEMA Mobile Home	Various	USA	2005	75% Offsite
Mississippi Park	Forest River Housing Inc.	USA	2006	75% Offsite
Mississippi Cottage	Lexington Homes	USA	2006	75% Offsite
Mississippi Cottage	Lexington Homes	USA	2006	75% Offsite
Katrina Cottage	Cusato Designs	USA	2006	75% Offsite

Time Constraints (Days)				
Name	Construction	Assembly	Per Family	Duration Type
FEMA Travel Trailer	10	1	11	Temporary
FEMA Park	14	1	15	Temporary
FEMA Mobile Home	18	42	60	Interim/Permanent
Mississippi Park	28	1	29	Interim/Permanent
Mississippi Cottage	205	1	206	Interim/Permanent
Mississippi Cottage	214	1	215	Interim/Permanent
Katrina Cottage	20	1	21	Interim/Permanent

Project Requirements			
Name	Skilled Labor	Equipment Requirements	Foundation Type
FEMA Travel Trailer	25% Skilled	Standard Truck	Pile Foundation / None
FEMA Park	25% Skilled	Standard Truck	None
FEMA Mobile Home	50% Skilled	Semi-Truck	Pile Foundation / None
Mississippi Park	50% Skilled	Semi-Truck	Pile Foundation / None
Mississippi Cottage	50% Skilled	Semi-Truck	Pile Foundation
Mississippi Cottage	50% Skilled	Semi-Truck	Pile Foundation
Katrina Cottage	50% Skilled	Semi-Truck	Pile Foundation / None

Architectural Qualities					
Name	Sq. Ft. per Person	Area (Sq. ft.)	# of Bedrooms	Vernacular	Expandability
FEMA Travel Trailer	1 Single Family (4) = 64 Ft.	256	1	None	Not Possible
FEMA Park	1 Single Family (4) = 93 Ft.	374	2	None	Not Possible
FEMA Mobile Home	1 Single Family (4) = 210 Ft.	840	3	None	Effort
Mississippi Park	1 Single Family (4) = 85 Ft.	340	2	Adaptable	No Effort
Mississippi Cottage	1 Single Family (4) = 176 Ft.	704	2	Adaptable	No Effort
Mississippi Cottage	1 Single Family (4) = 212 Ft.	850	1	Adaptable	No Effort
Katrina Cottage	1 Single Family (4) = 77 Ft.	308	1	Adaptable	No Effort

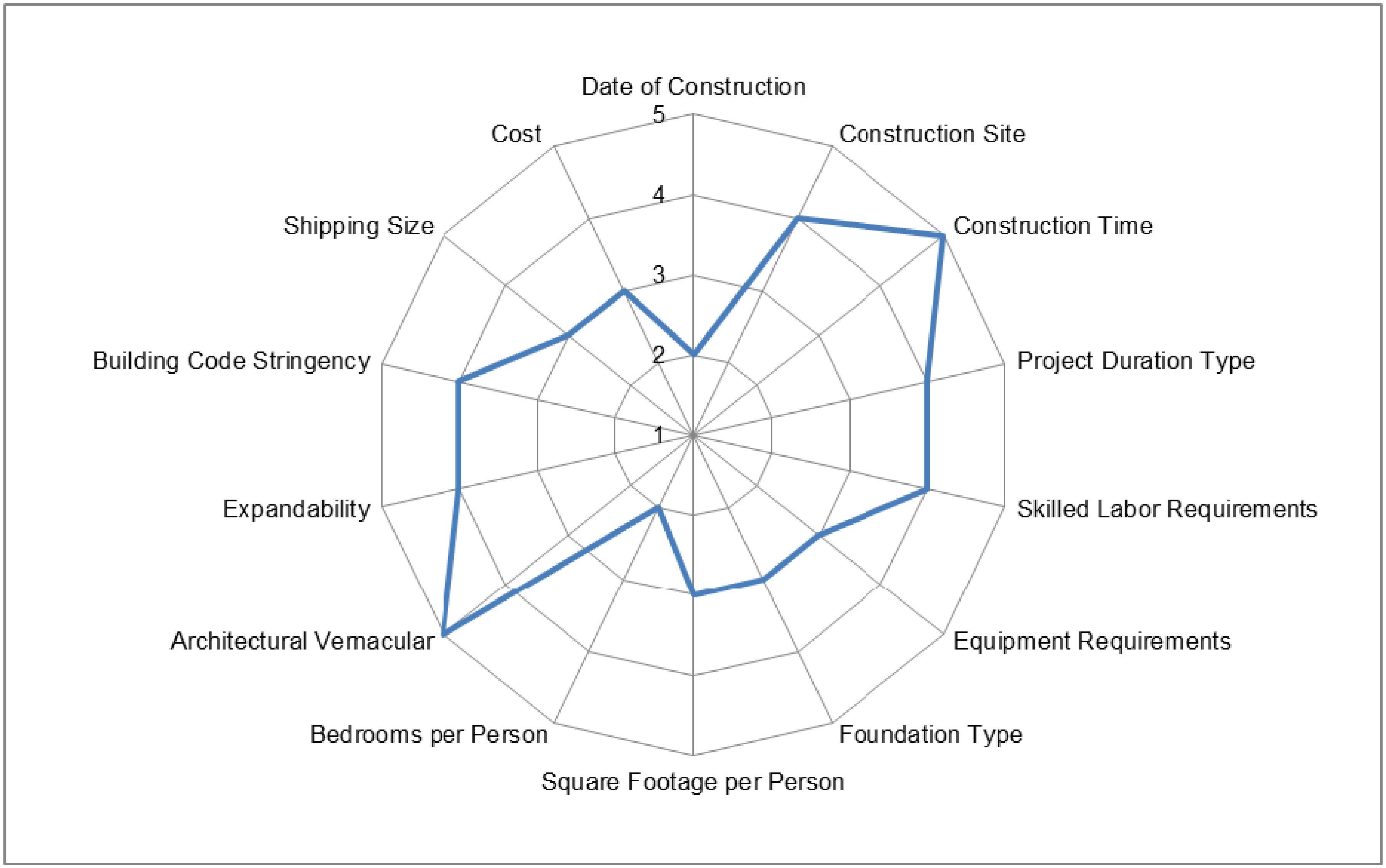
Specifications				
Name	Building Code	Shipping Size	Cost	Cost/sq. Ft.
FEMA Travel Trailer	None	32'x8'x14' = Truck	$19,000	$74.22
FEMA Park	ANSI	46'x8'x14' = Truck	$22,000	$58.82
FEMA Mobile Home	HUD	60'x14'x14' = Oversized Semi-Truck	$26,000	$30.95
Mississippi Park	IRC	38'x11'x14' = Oversized Semi-Truck	$22,295	$65.57
Mississippi Cottage	IRC	52'x13.5'x14.6' = Oversized Semi-Truck	$53,940	$76.62
Mississippi Cottage	IRC	60'x13.5'x14.6' = Oversized Semi-Truck	$64,140	$75.46
Katrina Cottage	IRC	24'x11'x14.6' = Oversized Semi-Truck	$35,000	$113.64

APPENDIX C
CRITERION WEIGHTING

	CRITERION		Date of Construction	Construction Site	Construction Time	Project Duration Type	Skilled Labor Requirements	Equipment Requirements	Foundation Type	Square Footage per Person	Bedrooms per Person	Architectural Vernacular	Expandability	Building Code Stringency	Shipping Size	Cost	Weighted Score
		Importance of criterion	**2**	**4**	**5**	**4**	**4**	**3**	**3**	**3**	**2**	**5**	**4**	**4**	**3**	**5**	
			(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	
(A)	Date of Construction	**2**	X	0.5	0.4	0.5	0.5	0.7	0.7	0.7	1	0.4	0.5	0.5	0.7	0.4	7.37
(B)	Construction Site	**4**	4	X	0.8	1	1	4	4	4	4	0.8	1	1	4	0.8	30.40
(C)	Construction Time	**5**	5	5	X	5	5	5	5	5	5	1	5	5	5	1	57.00
(D)	Project Duration Type	**4**	4	1	0.8	X	1	4	4	4	4	0.8	1	1	4	0.8	30.40
(E)	Skilled Labor Requirements	**4**	4	1	0.8	1	X	4	4	4	4	0.8	1	1	4	0.8	30.40
(F)	Equipment Requirements	**3**	3	0.8	0.6	0.8	0.8	X	1	1	3	0.6	0.8	0.8	1	0.6	14.55
(G)	Foundation Type	**3**	3	0.8	0.6	0.8	0.8	1	X	1	3	0.6	0.8	0.8	1	0.6	14.55
(H)	Square Footage per Person	**3**	3	0.8	0.6	0.8	0.8	1	1	X	3	0.6	0.8	0.8	1	0.6	14.55
(I)	Bedrooms per Person	**2**	1	0.5	0.4	0.5	0.5	0.7	0.7	0.7	X	0.4	0.5	0.5	0.7	0.4	7.37
(J)	Architectural Vernacular	**5**	5	5	1	5	5	5	5	5	5	X	5	5	5	1	57.00
(K)	Expandability	**4**	4	1	0.8	1	1	4	4	4	4	0.8	X	1	4	0.8	30.40
(L)	Building Code Stringency	**4**	4	1	0.8	1	1	4	4	4	4	0.8	1	X	4	0.8	30.40
(M)	Shipping Size	**3**	3	0.8	0.6	0.8	0.8	1	1	1	3	0.6	0.8	0.8	X	0.6	14.55
(N)	Cost	**3**	3	0.8	0.6	0.8	0.8	1	1	1	3	0.6	0.8	0.8	1	X	14.95

IMPORTANCE SCALE	Major = 5	High = 4	Medium = 3	Minor = 2	No Significance = 1

APPENDIX D
ANALYSIS MATRIX RADAR DIAGRAM



APPENDIX E
PERFORMANCE RATING SCALE

Likert Scale Rating	5	4	3	2	1
Construction Site	100% Offsite	75% Offsite	50% Offsite	25% Offsite	0% Offsite
Construction Time	1-30 days	31-60 days	61-90 days	91-120 days	>121 days
Project Duration Type	Interim/Permanent	Permanent	Interim	Interim/Temporary	Temporary
Skilled Labor Requirements	0% Skilled	25% Skilled	50% Skilled	75% Skilled	100% Skilled
Equipment Requirements	Standard Truck	Flat-bed Truck	Semi-Truck	Flat-Bed Truck /Crane	Semi-Truck/Crane
Foundation Type	No Foundation	Pile-driven/None	Pile-driven	Stem-Wall	Slab on-grade
Square Footage per Person	>150 Sq. Ft.	149-125 Sq. Ft.	124-100 Sq. Ft.	99-75 Sq. Ft.	74-1 Sq. Ft.
Bedrooms per Person	1 Bedroom/ 1 Person	3 Bedroom/ 4 People	2 Bedroom/ 4 People	1 Bedroom/ 4 People	None
Architectural Vernacular	Adaptable	Traditional	Contemporary	Modern	No Style
Expandability	No Effort	Little Effort	Effort	Great Effort	Not Possible
Building Code Stringency	Local Jurisdiction	IBC	HUD	ANSI	None
Shipping Size	Standard Truck	Flat-bed Truck	Semi-Truck	Extended Semi-Truck	Oversized Semi-Truck
Cost	<$50 per Sq. Ft.	$51-100 per Sq. Ft.	$101-149 per Sq. Ft.	$150-199 per Sq. Ft.	>$200 per Sq. Ft.

APPENDIX F
ANALYSIS MATRIX

		Date Built	Construction Site	Construction Time	Project Duration Type	Skilled Labor Requirements	Equipment Requirements	Foundation Type	Square Footage per Person	Bedrooms per Person	Architectural Vernacular	Expandability	Building Code Stringency	Shipping Size	Cost		
CRITERION		(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)		
WEIGHTED SCORES		7.37	30.40	57.00	30.40	30.40	14.55	14.55	14.55	7.37	57.00	30.40	30.40	14.55	14.95	**SCORE TOTAL**	
Shipping Container Homes																	
1	Mobile Dwelling Unit	1	5	5	3	1	4	5	5	2	2	3	1	4	3	1,123.05	9
	Score	7.36667	152	285	91.2	30.4	58.2	72.75	72.75	14.7333	114	91.2	30.4	58.2	44.85		
2	Research Facility	4	1	5	1	5	4	3	2	3	1	3	1	4	4	947.52	14
	Score	29.4667	30.4	285	30.4	152	58.2	43.65	29.1	22.1	57	91.2	1	58.2	59.8		
3	Container City I	2	4	5	4	2	1	1	3	2	2	4	4	3	1	1,107.02	10
	Score	14.7333	121.6	285	121.6	60.8	14.55	14.55	43.65	14.7333	114	121.6	121.6	43.65	14.95		
4	Container City II	2	4	5	4	2	1	1	2	2	2	4	4	3	1	1,092.47	12
	Score	14.7333	121.6	285	121.6	60.8	14.55	14.55	29.1	14.7333	114	121.6	121.6	43.65	14.95		
5	Keetwonen	2	4	5	5	2	1	1	2	2	3	3	5	3	4	1,224.72	3
	Score	14.7333	121.6	285	152	60.8	14.55	14.55	29.1	14.7333	171	91.2	152	43.65	59.8		
6	Fort Bragg	5	3	5	4	3	1	1	5	2	3	1	5	3	2	1,169.37	6
	Score	36.8333	91.2	285	121.6	91.2	14.55	14.55	72.75	14.7333	171	30.4	152	43.65	29.9		
7	St. Petersburg Home	4	2	1	4	3	4	2	5	4	5	2	5	3	4	1,150.83	8
	Score	29.4667	60.8	57	121.6	91.2	58.2	29.1	72.75	29.4667	285	60.8	152	43.65	59.8		
FEMA Implemented Homes																	
1	FEMA Travel Trailer	4	5	5	1	4	5	4	1	2	1	1	1	5	4	1,029.05	13
	Score	29.4667	152	285	30.4	121.6	72.75	58.2	14.55	14.7333	57	30.4	30.4	72.75	59.8		
2	FEMA Park	4	5	5	1	4	5	5	2	3	1	1	2	5	4	1,095.92	11
	Score	29.4667	152	285	30.4	121.6	72.75	72.75	29.1	22.1	57	30.4	60.8	72.75	59.8		
3	FEMA Mobile Home	4	4	4	5	3	3	4	5	4	2	1	3	1	5	1,151.23	7
	Score	29.4667	121.6	228	152	91.2	43.65	58.2	72.75	29.4667	114	30.4	91.2	14.55	74.75		
4	Mississippi Park	4	4	5	5	3	3	4	2	3	3	5	4	1	4	1,351.27	2
	Score	29.4667	121.6	285	152	91.2	43.65	58.2	29.1	22.1	171	152	121.6	14.55	59.8		
5	Mississippi Cottage	4	4	1	5	3	3	3	5	3	4	5	4	1	4	1,209.37	4
	Score	29.4667	121.6	57	152	91.2	43.65	43.65	72.75	22.1	228	152	121.6	14.55	59.8		
6	Mississippi Cottage	4	4	1	5	3	3	3	5	2	4	5	4	1	4	1,202.00	5
	Score	29.4667	121.6	57	152	91.2	43.65	43.65	72.75	14.7333	228	152	121.6	14.55	59.8		
7	Katrina Cottage	4	4	5	5	3	3	4	2	2	4	5	4	1	3	1,385.95	1
	Score	29.4667	121.6	285	152	91.2	43.65	58.2	29.1	14.7333	228	152	121.6	14.55	44.85		

PERFORMANCE SCALE	Excellent = 5		Very Good = 4		Good = 3		Fair = 2		Poor =1

LIST OF REFERENCES

Aladdin. (1995). *Aladdin "Built in a Day" House Catalog, 1917.* New York: Dover Publications Inc.

Alemany, C. (2000). *The Effects of Computers on Construction Foremen.* CCIS Report.

Bhatt, V. (n.d.). *Summerly's Exhibition and Paxton's Crystal Palace*. Retrieved 5 15, 2011, from http://www.mcgill.ca/mchg/cp/crystal.html

Birch, E., & Wachter, S. (2006). *Rebuilding Urban Places After Disaster: Lessons from Hurricane Katrina.* Philiadelphia: University of Pennsylvania Press.

Bruce, A., & Sandbank, H. (1972). *A History of Prefabrication.* New York: The John B. Pierce.

Charkesworth, E. (2006). *Architects Without Frontiers.* Burlington: Elsevier Ltd.

Chiei, C., & Decker, J. (2005). *Quonset Hut.* New York: Princeton Architectural Press.

Colean, M. (1944). *American Housing: Problems and Prospects.* New York: Twentieth Century.

Coolidge, M. (n.d.). *Hope Field FEMA Trailer Yard*. Retrieved June 5, 2011, from The Center for Land Use Interpretation: http://ludb.clui.org/ex/i/AR8235/

Deane, P. (n.d.). *The First Industrial Revolution.* Cambridge: Cambridge University Press.

Deemer, G. R. (1996). Modularization Reduces Cost and Unexpected Delays. *Hydrocarbon Processing*, 75(10), 143-151.

FEMA. (2006, August 25). *Frequently Requested National Statistics Hurricane Katrina – One Year Later*. Retrieved June 5, 2011, from FEMA Mobile Site: http://www.fema.gov/hazard/hurricane/2005katrina/anniversary_factsheet.shtm

FEMA. (2010, August 11). *FEMA History*. Retrieved May 24, 2011, from U.S. Department of Homeland Security: http://www.fema.gov/about/history.shtm

Forman, E. H., & Gass, S. I. (49). The analytical hierarchy process—an exposition. *Operations Research* , 469-487.

Hansen, P. (2008). *Shipping Container Home*. Retrieved June 2, 2011, from Earth Science: http://earthsci.org/education/fieldsk/container/container.html

Intbau, C. (2006). *Katrina Cottage Types*. Retrieved June 21, 2011, from Katrina Cottages: http://www.katrinacottages.com/plans/types.html

ISBU Association. (2008, June). *Part I- The Unnecessary Loss, But ISBU's Survived*. Retrieved June 4, 2011, from Intermodal Steel Building Units & Container Homes: http://www.isbuinfo.org/permalink/article_2008_june_disaster_part1.htm

Kelly, B. (1951). *The Prefabrication of Houses.* New York: John Wiley and Sons, Inc.

Kimberley, M. (2010, March 1). *Keetwonen (Amsterdam Student Housing)*. Retrieved June 2, 2011, from Open Architecture Network: http://openarchitecturenetwork.org

Kronenburg, R. (2003). *Portable Architecture.* Burlington: Elsevier Ltd.

Kronenburg, R. (2003). *Transportable Environments .* New York: Spoon Press.

Kunkel, C. R. (2007). *Implementation of Mass-Produced Housing in Disaster Relief and Reconstruction.* Gainesville: University of Florida.

Lot-EK. (n.d.). *Mobile Dwelling Unit*. Retrieved May 31, 2010, from Lot-Ek: http://www.lot-ek.com/

Lucas, R. E. (2002). Lectures on Economic Growth. Cambridge: Harvard University Press.

McCarthy, F. X. (2008). *FEMA Disaster Housing and Hurricane Katrina: Overview, Analysis, and Congressional Issues.* Washington D.C.: CRS Report for Congress.

McCosh, F. (1997). *Nissen of the Huts: A biography of Lt Col. Peter Nissen, DSO.* Bourne End: B D Publishing.

McIlwain, J. K. (2006). *Principles for Temporary Communities .* Washington, D.C: ULI–the Urban Land Institute.

McKinley, V. (n.d.). *Modular Homes Consumer Guide*. Retrieved 5 20, 2011, from Modular Today: http://www.modulartoday.com/

Port of Los Angeles, (2011). *TEU Statistics (Container Counts).* Retrieved May 26, 2011, from The Port of Los Angeles: http://www.portoflosangeles.org/maritime/stats_2010.asp

NOAA. (2005, December 29). *Hurricane Katrina*. Retrieved 5 24, 2011, from NOAA Satellite and Information Service: http://www.ncdc.noaa.gov/special-reports/katrina.html

Oakley, B. (n.d.). *Prefabrication*. Retrieved May 15, 2011, from Britannica Online Encyclopedia: http://www.eb.com: 180/cgibin/

Pawley, M. (1991). *Buckminster Fuller.* New York: Taplinger.

Pendola, R. (2010). *HUD Manufactured Home Requirements*. Retrieved 5 20, 2011, from eHow: http://www.ehow.com/list_6157761_hud-manufactured-home-requirements.html

Rivera, J. (2008). “Bob Vila” Show Documents Construction Method Using Recycled Shipping Containers. *INNOVATIVE PILOT HOUSING PROJECT IN ST. PETERSBURG*. N. Venice, Florida, United States of America.

Robertson, D. (1974). *Mind's Eye Of Buckminster Fuller.* New York: Vantage Press.

Saaty, T. L. (102). "Relative Measurement and its Generalization in Decision Making: Why Pairwise Comparisons are Central in Mathematics for the Measurement of Intangible Factors - The Analytic Hierarchy/Network Process. *RACSAM (Review of the Royal Spanish Academy of Sciences, Series A, Mathematics)* , 251-318.

Sanders, J. (n.d.). *Shipping Container Home Construction Globally*. Retrieved May 26, 2011, from Shipping Container Homes: http://www.containerhomes-info.com/

Schodek, D. L. (1975). Operation Breakthrough: the Changing Image. *Industrialization Forum*, 6(1), 3-12.

SG Blocks. (2011). *SG Blocks Building System*. Retrieved June 3, 2011, from SG Blocks: http://www.sgblocks.com/about-sg-blocks/sg-blocks-building-system/

Sherwood, R. (2002). *Trinity Buoy Wharf*. Retrieved June 2, 2011, from Housing Prototypes: http://www.housingprototypes.org/project?File_No=GB016

Sorlien, S. (2006). *History*. Retrieved June 5, 2011, from Katrina Cottage: http://katrinacottagehousing.org/history.html

Stevenson, K. C., & Jandl, H. W. (1995). *Houses By Mail: A Guide to Houses from Sears, Roebuck and Company.* Hoboken, New Jersey: John Wiley & Sons.

Swinney, L. (2007, September 26). *Lexington Homes awarded MEMA contract for cottages*. Retrieved June 7, 2011, from Small Town Papers News Service: http://www.stpns.net/view_article.html?articleId=65441031098716018

Tatum, J. A. (1987). *Constructability Improvement Using Prefabrication, Preassembly, and Modularization.* Austin: The University of Texas at Austin.

Thornton, R. (2002). *The Houses That Sears Built: Everything You Ever Wanted To Know About Sears Catalog Homes.* Alton, Illinois: Gentle Beam Publications.

Traffer, H. (n.d.). Manufacured Home Construction and Safety Standards. *Title 24-Housing and Urban Development*, p. 3280.1.

USM. (2001). *Container City*. Retrieved June 2, 2011, from Urban Spaces Management Ltd: http://www.urbanspace.com/container_city.html

Vanegas, J. (1995). *Modularization in Industrial Construction.* Austin: The University of Texas at Austin.

Wood, S. (1981). *Degradation of Work: Skill, Deskilling and the Braverman Debate.* Harper Collins.

BIOGRAPHICAL SKETCH

Nicholas R. Brow was a resident of central Florida for 21 years, since relocating with his family in September of 1990, from Leominster, Massachusetts. After the completion of high school, Nicholas attended Daytona Beach State College to pursue an associate's degree; where he completed the necessary prerequisites to attend the architecture program, at University of Florida, in the summer of 2007. Two-years after transferring into U.F., Nicholas was selected to participate with a select group of students to study abroad in Hong Kong and China for the summer of 2009.

After successfully completing his undergraduate requirements, Nicholas was granted access into the Master of Science in Building Construction program at the M.E. Rinker, Sr. School of Building Construction at the University of Florida, in the summer of 2010. Nicholas has been inducted into Sigma Lambda Chi (SLX) in the fall of 2010 and later awarded the Dickert Scholarship in the spring of 2011 for his scholastic efforts in and out of the classroom. Nicholas has graduated with honors from U.F. with a master's degree and a 3.94 grade point average. Currently, he is pursuing at second master's degree majoring in architecture at the Washington University in St. Louis, Missouri on a twenty-five thousand dollar annual scholarship. Nicholas is living with his newly wed wife and their two English bulldogs, Mr. Magoo and Lily, in St. Louis.