# LOCALLY BASED APPROACH FOR PREFABRICATED HOUSING – CASE STUDY: INDONESIA

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## INTRODUCTION

On May 27, 2006 a 6.3 magnitude earthquake struck Yogyakarta, Indonesia killing more than 5,000 people.[1] More than 100,000 homes were destroyed and another 200,000 were damaged. Hundreds of thousands of people were left homeless. Shelter was needed for the homeless people, and many countries and organizations provided assistance in the form of food, medicine, shelter and also housing. Dome for the World Foundation, a nonprofit organization from the USA donated a total of 81 new buildings for earthquake victims in Ngelepen. Ngelepen, a village in Yogyakarta, was relocated because of landslides caused by the earthquake. The basic building shape is a dome, which up until the earthquake was foreign to Indonesia.

Figure 1. New Ngelepen Village with dome houses.

Moreover these structures were built in a rural locale, a place where most of the buildings are of traditional rectangular vernacular form. Houses in Yogyakarta typically are built as a box-like form with gable or hip roofs. Common materials for these houses are wood, brick with clay, and ceramic tile roof.

This novel dome shape of the relief effort was surprisingly accepted by the inhabitants. This acceptance has played out over the five years these dome houses have been in use. All are occupied and many residents have added components to their houses to make them more suited with their needs. Data from site visits, previous research, book, and website reports are used for this case study paper.

Two lessons can be learned from these studies. Concrete factors facilitate acceptance of these buildings particularly the opportunities for modifications such as new canopies and extended room additions. Evidence points to functional and socio-culture reasons for the success of these modifications. Second, owners add these components themselves. From these two observations it may be possible to imagine architects designing such components, perhaps as mass produced units or as features that follow a product-oriented model. Such products might be based on local customs and skill levels. This paper proposes an initial step to identify local customs and suggest how designs could be proposed based on these findings. A site specific approach is important in such a proposal since a building that works well in one place may not work as intended in another.

More than 30 years before the Yogyakarta earthquake, on December 23, 1972, a 6.2 magnitude earthquake occurred near Managua, the capital city of Nicaragua.[2] Approximately 50,000 houses were heavily damaged and 250,000 people were left homeless. The West German Bayer Corporation with the Red Cross developed and built 500 polyurethane *"igloo"* dome house for the earthquake victims. Two years before a third earthquake occurred in Kutahya, Turkey on March 28, 1970.[3] More than 10,000 houses were severely damaged and approximately 90,000 people were homeless. Bayer with the Red Cross established 400 polyurethane igloo houses for these victims as well.

These three cases are based on similar conditions: people were without shelter due to an earthquake and a house or temporary shelter was provided as a replacement. But the Yogyakarta dome houses were far more successful than those in Managua or Kutahya. All of the Yogyarkarta houses have been occupied since April 2007. Moreover, the inhabitants are satisfied and have accepted the dome houses as permanent homes. In Managua of the 400 igloo houses built only 24% were occupied. In Kutahya, all of the igloo houses were converted for use by animals and storage, even though they were originally built for people.

**A HOUSE IS NOT (ALWAYS) A HOME**

A dwelling needs to be a home, even though it might be temporary and in extreme condition in the aftermath of a disaster. A home is always a home. A house may not be enough. Marcus and Sarkissian in their 1986 text, *Housing as if People Mattered,* illustrate that every house shares the function of being a space place for eating, sleeping, loving, playing, socializing, and raising children.[4] On the other hand they also believe that a house is personal because it is about people living in it. It can be said that every house is used as a place to engage similar activities, but at the same moment, it reflects the user's individual thought. Prefabricated housing, in the three cases mentioned, had the same shape-form based on common house functions but without the Turkey and Nicaragua "igloos" did not allow for individual and personalized habitational attributes. This created a problem since people, particularly those from different cultures, have their own living patterns and preferences. In the Yogyakarta situation, the inhabitants accepted the house since they were allowed to modify and customize it.

**HISTORICAL BACKGROUND**

Yogyakarta Special Region is a province in Indonesia. It is called "Special Region" because it is the only province in Indonesia, which is still led by a king. Other provinces in Indonesia are led by a governor. The royal culture impacts social life in Yogyakarta and this in turn is reflected in the area's house design. Though modern buildings are built in the city, most structures are vernacular. Ngelepen, where the dome houses were built is a rural area located approximately 15 miles from Yogyakarta City. Most residents farm.

Ngelepen was once located on a hill but it was destroyed by the landslides that were created by the earthquake. Since the old location was unbuildable, the government moved the town to a 1.5 ha new location in the flats a third of a mile from the old location. The Domes for the World organization brought the dome design as a solution for a shelter. The simple, inexpensive dome shape resists fire, tornados, and earthquakes. At first, due to the unfamiliar shape, people were reluctant to accept the temporary housing. But the distance between the donor's good intentions and the mindset of the earthquake victims was bridged by a team from Gadjah Mada University that served as a local partner. The University and Domes of the World worked in collaboration to find a design and construction scheme that fit the condition and promised acceptance by the user group. Pandelaki and Shiozaki in their paper "Social Sustainability of New Ngelepen Dome Housing as Post-Disaster Housing Reconstruction of Central Java-Yogyakarta Earthquake 2006" studied inhabitant participation from the beginning of the design process until the final construction was completed[5].

In the beginning, Domes for the World only planned to build 72 units that included six publicly shared service facilities for shower, laundry, and toilet (*MCK*).[6] The construction cost was lower than the original estimate after they added more public facilities such as a mosque, primary school, and medical clinic. These cost reductions most likely occurred due to the inhabitants and their participation in the construction of the houses through the Indonesian concept of mutual assistance known as *gotong royong*, a spirit that also animated the modification and alteration activities that followed the original dome construction.[7] Due to the unusual building type and shape of the dome Ngelepen village attracts researchers and has become a place to study how inhabitants adapt to new environments, especially in the case of dome design.

**TRANSFER OF KNOWLEDGE: A TECHNOLOGY THAT ENCOURAGES INHABITANT PARTICIPATION**

Although the dome house in Yogyakarta can be built off site, the decision was made to build it on site. Such construction scenarios are a way of empowering local workers as well as residents. Construction workers in Yogyakarta are familiar with reinforced concrete, although dome construction was new in both building technique and formal qualities.

Local vernacular buildings are built of brick load-bearing walls and reinforced concrete decks. The dome house uses a reinforced dome that serves as both wall and spanning elements over a concrete floor. The Dome for the World Foundation combined advanced technology – an inflatable "airform" inflatable formwork – with simple materials commonly known to the residents in the region. The workers had little trouble transferring their building knowledge to this process. The construction process began in October 2006, taking 370 local workers to finish the construction process by March 2007.

In Managua and Kutahya, in contrast, not only the shape of the house but also the material – polyurethane – was unfamiliar to residents. In Kutahya, the Bayer Company hired 13 workers to build the polyurethane (Styrofoam™) domes in a temporary tent facility near the construction site.

The polyurethane foam required specially trained workers in the construction process. Oxfam, another corporation using the same technology at the time, shows that the development of using polyurethane igloo has several serious problems. Oxfam built polyurethane igloos for the Pakistan flood in 1970 and the Turkey earthquake in 1975. Howard and Mister, in "Lesson Learnt by Oxfam from Their Experience of Shelter Provision 1970-1978," argue that construction cost, transfer of technology, and the new materials lead to several problems that ended the use of polyurethane igloo house.[8]

The access to understanding and working with new technology in the Indonesian example is thus key to understanding the success of this new housing type. The Domes for the World had in place a social program to engage local workers and provide the necessary support to teach as well as to oversee and empower local labor to complete the new concrete construction process. The transfer of such knowledge was one of the most important factors to the success of these units. In the Managua and Kutahya situations,

which lacked this type of technological support, the results were more uneven.

### ALTERING THE INITIAL DESIGN TO COMPLY WITH LOCAL HOUSING MORPHOLOGY

According to Ikaputra in his 2008 paper "People Response to Localize the Imported Culture," we can follow how the initial design of the Indonesian domes changed in a relatively short time after their initial construction and occupation.[9] As cited by the author's research, these adjustments occurred mainly due to the difference between Western and Eastern living patterns. For example, the original design unified the kitchen and living room areas. In Indonesia, a kitchen is considered a "dirty space" that should be separated from the living areas. Such conditions led the residents to modify and alter various culturally defined parts of the house.

The layout for the village on the other hand was derived from studying the local conditions. Ikaputra observes that the housing layout is based on a shared service area known locally as a MCK. This layout follows the known living norms of the village that allows houses to share a common service area located in the rear of the house.

Another notable adjustment in the Yogyakarta village is identified by Ikaputra as a process of "dressing up the dome shape." This concept is based on additional components that embraced the aesthetics of the local culture but do not alter dome performance. This concept is also used to distinguish different building functions, something the non-vernacular shape of the dome did not offer.

In the cases of Managua and Kutahya the igloo design did not undergo such extensive revisions. The housing layout and functions also remained unaltered.

Housing morphology seems to play a critical role in the acceptance of these house designs. In Yogyakarta, an intensive set of conversations was held to find the best design solution. This design accommodated local patterns of living while at the same time accepted the new morphology of the dome shape and function. Furthermore, after the buildings were in place, the inhabitants could modify, add, or extend the house to make it more suitable for their specific needs. These alterations not only allowed adaptations to the design but also completely changed certain house functions and layout. According to three different surveys performed by Ikaputra and the team of Pandelaki and Shiozaki in 2008 and Marcillia and Ohno in 2012, inhabitants in Ngelepen felt they could adapt and feel satisfied with the dome house and its environment.[10]

### SUMMARY: A LESSON LEARNED

Prefabrication has proven to be an effective and efficient system.[11] But as a house is very personal and closely aligned with the culture it accommodates, then successful design must also reflect of the locale and people it serves.

The three case studies discussed in this paper demonstrate that a design is more likely to be successful when a dialogue is built between local concerns and foreign influence. A "win-win" solution can be achieved. Accordingly, mass produced housing should encourage its users to modify or personalize some part of it. Doing so allows individuals to personalize and find ownership in the dwelling.

While New Ngelepen Dome Village in Yogyakarta is not a perfect example, it demonstrates how prefabrication can be adaptable and accepted in a specific location. Studying what residents do after the disaster teams depart allows additional research to take place. Good house design remains adaptable to alterations and additions because it must react to dynamic human conditions. The Ngelepen example holds lessons that can be used as a starting point for the process of thinking how to improve prefabrication. These lessons include:

1. Inhabitants are interested in enhancing natural features that are available in the site or local, such as growing food or tending animals adjacent to their houses. The Indonesia example involves provisions for growing cassava, banana, mango, and chili plants. Mango tree provide fruit but also a canopy for shading outdoor public space. While large animals and herd animals such as cows and goats are kept outside the village area in a separate cattle shed or yard, small poultry like chickens, ducks, and geese are raised in and around the houses. Small buildings, cages, or semi permanent buildings are thus located within safe proximity of the house.
2. As we have seen, while the Yogyakarta dome houses are successful, all of them have been altered or modified. Some of these changes involve minor additions, such as canopy protection above the window and doors, etc. But most of the additions create additional space.

Figure 2. Additional space in front of dome house that is used for warung and terrace. Typical additions and alterations to Dome Housing.

These additions have different functions, such as storage, kitchen, bedroom, guest room, animal cage, terrace, garage, *warung*, private toilet, and hanging wet clothes/ laundry area.[12]

3. Inhabitants add these structures in order to express their social customs, *gotong royong* and *kekeluargaan,* which are identifying cultural attributes. [13]

**BASIC CRITERIA FOR PREFABRICATED COMPONENTS THAT EXTEND LIVING OPPORTUNITIES**

Prefabrication has advantages if compared with traditional construction methods. The quality can be controlled and the expense of fabrication can be less. A 35 $m^2$ dome is estimated to cost $800.[14] A traditional brick house cost roughly $100 per square meter. Prefabrication also lowers construction time and limits wasted materials. In order to take advantage of these cost savings while producing buildings that work within local cultures, this paper proposes that prefabricated designs involve modular components rather than complete buildings.

Flexibility is needed to respond to different activities that are pursued by inhabitants. One aspect of flexibility involves a way to easily create new openings in the structures. In addition, a terrace, outdoor space or a sun shading device allows a connection to the exterior that is complementary to the dome morphology.

The original Yogyakarta domes did not have canopies to protect exterior openings. But because Yogyakarta sits near the equator, high-angle solar exposure is constant throughout the year. In addition the region is exposed to the seasonal monsoon weather, which requires additional protections. Excessive sunlight and rain will easily damage window and door apertures, and water may easily enter the geometry of dome construction. At the moment, inhabitants add canopies that are made of metal or wood and covered with polycarbonate, metal, or clay tile.

A terrace or relaxing outdoor space is needed to provide a place for interaction with other families. People in Yogyakarta like to visit other families and maintain good relationships with them. They usually have a routine semi-formal meeting area such as an *arisan* and prayer space.[15] These activities can be held indoor in guest rooms, but due to limited space often times people sit in the terrace. An enclosed space can be used as a guest room, bedroom, or storage. An extension for guest rooms is often built by owners to accommodate social occasions such as an *arisan*.

The Indonesian government recommends that couples in Indonesia have two children. Based on this suggestion, the dome house provides two rooms, one for the main bedroom and another for a children's room. Nevertheless, when the children grow older additional bedrooms are needed. A 9 $m^2$ (96 $ft^2$) room is not sufficient for two children. Another additional enclosed room is often required as storage. Some of the New Ngelepen inhabitant work as farmers or merchants. They usually have a place to store their harvest or commodities. All of the inhabitants have transportation modes such as motorcycles and bikes. They need garages to store them – not for security but because of weather. Some inhabitants open a *warung* to support family economics. Although a common laundry space is provided, inhabitants require a place to dry their washed clothes. These are a few of the activities that might benefit from additions and alterations to the basic dome form.

Modifying prefabricated components is especially valuable when it can be carried out by inhabitants together with the help of their neighbors through *gotong royong*. Even though a family can build by themselves or pay construction workers, relying on *gotong royong* will strengthen a sense of *kekeluargaan* in the village. During dome construction, local construction workers are paid to erect the domes. Inhabitants then volunteer their help to work on additions and/or repairs for their neighbors. They construct additional spaces that are used for public amenities, such as playgrounds, courtyards, and *poskamling* (civil security posts). They also help one another to build additional private spaces, such as *warung*, terrace, or laundry areas. The spirit for volunteer work is strong in the community, creating strong family-to-family bonds that can be relied on in post-disaster recovery situations.

This type of social capital in such hard times is more valuable than economic assistance for these families.

**PROPOSED DESIGN**

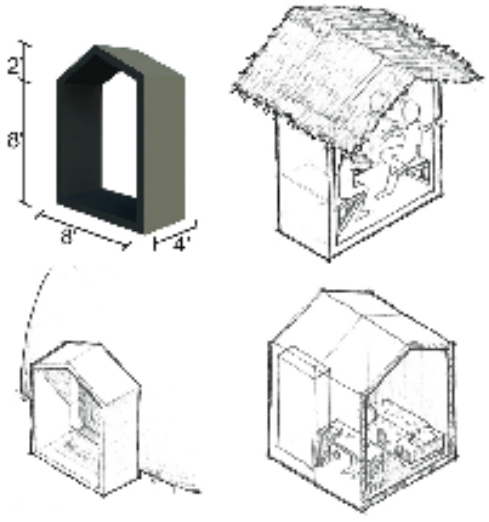


Figure 3. Basic design of proposed prefabricated component with possible configurations.

The work beyond this paper will investigate these dome structures based on the confluence between the dome itself and more traditional forms. The dome is modular and open on both sides. The module is based on materials that are available on site. Some materials like chipboard, calcium-silica board and wood have a

basic size: 4'x8'. A homemade brick is roughly 2"x4"x8". The module of the building is 3' and has a 4'x8' opening. The proposed material for this component is reinforced concrete, like dome house materials. There are three possible ways to utilize this prefabricated component, based on function, layout, and additional enclosure.

This component can be used as an open space to provide shading, terrace, or gazebo. It can be semi-open to be used as a garage, small shop, or laundry. When an enclosure is applied to the prefabricated component, it can be used as a bedroom, guest room, kitchen, storage, or toilet.

The layout of prefabricated component follows its function. If it is located in the front side of dome house, it can be used as guest room or terrace. It can be located in the backyard for "dirty space" like a kitchen or laundry. The component can act alone or be configured with other components. If there is not enough space, a side-by-side configuration can be employed to extend the spatial size.

Openings in the prefabricated component can be freely designed and constructed by inhabitants. They can build walls using available materials such as calcium silica board, wood, bamboo, and other materials. A window, door, or other features can be added to the enclosure. This is a part where inhabitants can express their style and customize the building's look.

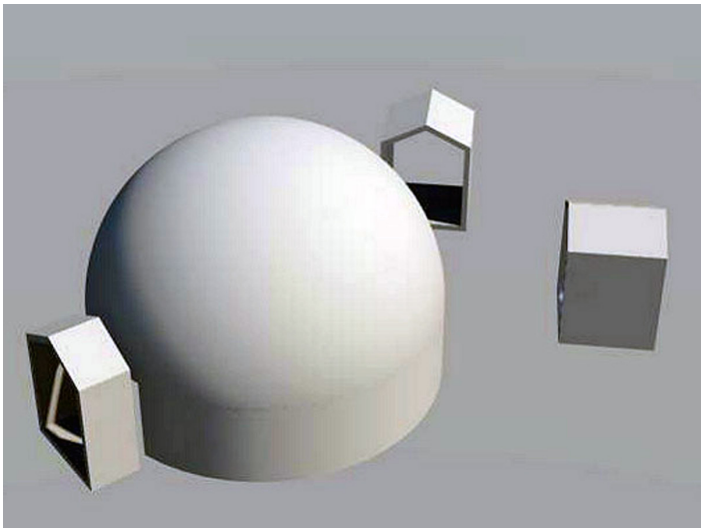

Figure 4. Possible layout of additional prefabricated components and their connection to dome house.

## Suggestion - Further Research

In summary, New Ngelepen inhabitants can work with a new Architecture for their dwelling in their own particular way. Some adjustments are made to create a more "homey" feeling for the dwelling. This is just a small example of an approach that may useful for designing a future prefabrication or mass-produced architecture. Further research from other case studies is suggested to draw more valid conclusions about customizable mass products that can be adopted to local cultures or habits. We hope this paper will help inspire that research.

## ENDNOTES

1. Magnitude 6.3 - JAVA, INDONESIA, accessed June 15, 2012, http://earthquake.usgs.gov/earthquakes/eqinthenews/2006/usneb6/
2. Historic Earthquake: Nicaragua, accessed June 15, 2012, http://earthquake.usgs.gov/earthquakes/world/events/1972_12_23.php
3. Historic Earthquake: Gediz Turkey, accessed June 15, 2012, http://earthquake.usgs.gov/earthquakes/world/events/1970_03_28.php
4. Marcus, Clare Cooper, and Wendy Sarkissian. *Housing as if People Mattered: Site Design Guidelines for Medium-Density Family Housing*. Berkeley: University of California Press, 1986.
5. Pandelaki, Edward, and Shiozaki, Yoshimitsu. "Social Sustainability of New-Ngelepen Dome Housing as Post-Disaster Housing Reconstruction of Central Java-Yogyakarta Earthquake 2006" (paper presented at the 21st EAROPH World Planning and Human Settlement Congress & Mayors Caucus, Egret Himeiji and Awaji Yumebutai International Conference Center, Japan, October 2008).
6. MCK is an abbreviation from *Mandi*=Shower, *Cuci*=Laundry, and *Kakus*=Toilet). This shared facility accommodates social interaction, especially between housewives.
7. *Gotong royong* is a mutual assistance among community member. They voluntarily work without payment.
8. Howard, Jim, & Mister, Robert. Lesson Learnt by Oxfam from Their Experience of Shelter Provision. *Disasters 3* no.2 (1979): 136-144.
9. Ikaputra. "People Response to Localize the Imported Culture Study Case: the Dome House in the Rural Culture Post Javanese Earthquake 2006" (conference paper presented at the 14th World Conference on Earthquake Engineering, Beijing, China, October 12-17, 2008).
10. Marcillia, Syam Rahma, & Ohno, Ryuzo. Importance of Social Space in Self-built and Donated Post Disaster Housing after Java Earthquake 2006. *Asian Journal of Environment-Behaviour Studies 3* no. 7 (2012): 25-34.
11. Arieff, Allison, & Burkhart, Bryan. *Prefab*. Salt Lake City: Gibbs Smith, 2002. 36
12. *Warung* is a small shop that is informal, owned by a person and usually sell basic needs such as food or appliances. It is like the informal version of circle-K or 7 eleven.
13. *kekeluargaan* (from the word *keluarga*-means family) is the feeling of being tied as one big family even though there is no family relation
14. The dome house was built in situ. This cost exclude construction worker.
15. *Arisan* is a semi formal meeting which the main function is to preserve *kekeluargaan* through money rent and saving. This will help inhabitants deal with economic problems. This meeting is popular in Indonesia until now.

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