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Digitally fabricated housing: tracking the evolution through two decades

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Abstract: The author is investigating the ability of digital fabrication tools to provide an alternative method for creating affordable flexible single family residential units as a part of an ongoing PhD research. This paper presents a review of previous attempts within the time frame of twenty years with a thorough analysis and breakdown of the prototypes. It provides a time line tracking with milestones of the usage of digital fabrication tools in housing construction. The analysis will include but not limited to: Design/construction time – overall cost – materials for primary/secondary structure – tools for virtual design/actual fabrication – special design methods/considerations (when applicable). The case studies are organized in a comprehensive chronological table. The paper suggests there are three main trends for digital fabrication in housing.

Keywords: Digital fabrication; housing; low-cost; low-impact.

1. Introduction

There is an incremental increase in the demand for housing units with the growth of the population especially in poor and developing countries(UN, 2005). Many countries face very high risks with the spread of informal housing settlements around large cities. Moreover, according to United Nations Higher Commission for Refugees global trend report (UNHCR, 2015) an estimated 13.9 million individuals were newly displaced due to conflict or persecution in 2014. This includes 11.0 million persons newly displaced within the borders of their own country, the highest figure on record. The other 2.9 million individuals were new refugees.

It’s undoubtedly a global crisis that is formulating with almost 60 million persons living in camps or currently homeless. Putting these factors into account, a novel rapid low cost housing methodology needs to be created as the practice of construction industry in these countries lacks efficiency and is one of the economic sectors with the lowest productivity and industrialization rates(Alvarado and Turkienicz, 2010).

Meanwhile, with the rise of personalization and individualism, mass customization is becoming an important business strategy for several types of industries. The unstable and unpredictable demand levels; heterogeneous desires; price, quality and style consciousness; high levels of buyer power; competitive intensity; product differentiation; and market saturation are among the forces shifting the focus of manufacturing from mass production to the new paradigm of mass customization (Pine, 1993). In order to implement mass customization, it is necessary to integrate various manufacturing technologies into a structured framework capable of combining human and technological factors in addition to old and advanced technologies.

Various modernist architects have been fascinated with the concepts of pre-fabrication and industrialization of the building industry specifically in the field of housing. Numerous attempts were made during the last decades to design and construct houses with a notion of "one size fits all"; a strategy that had its motivations and justifications after WWI and II. More recently, with the integration of parametric design tools with robust digital fabrication technologies, a new paradigm has started in which these technologies promise to address the design and construction of housing units with more flexibility and variation, hence a more customizable approach.

2. Aim and Objectives

The aim of this paper is to analyze the previous trials and built prototypes of digitally fabricated housing in order to understand whether they would qualify as long-term solutions to the shortfalls of housing units in developing countries. The paper also discusses the degree of success of the precedents in providing adequate solutions for their intended purposes. The discussion is made on the basic characteristics relating to cost, flexibility, convenience and environmental responsibility.

The selection of the case studies in this paper aims at displaying a representative sample that covers the spectrum of digitally manufactured housing not only from a time-progression point of view but also highlighting the trends and milestones in the development of this specific housing construction methodology. Table 1 provides a timeline of the selected projects and their analyzed aspects. It is challenging to draw a precise line between "prefabricated" and "digitally fabricated" housing, as prefabrication occasionally includes parts or assemblies that were constructed using digital fabrication tools. The case studies in this paper represent prototypes that used digital manufacturing technologies for the major part of the construction, e.g. primary/secondary structure.

Due to the novelty of some of the case studies and the difficulty of finding reliable published information, the author established direct communication -when possible- with parties involved in design and construction in order to guarantee the accuracy of the information provided. The data gathering techniques included but were not limited to emails and inquiries through official websites.

3. Trend 1: Social orientation, democratization of manufacturing

A common trend that is community enabling and socially oriented can be deducted from the following case studies. We can also note that these prototypes were defined as post disaster interventions and basically reliant on the end-user as an active contributor not in the design process but more in the construction phase. Since the community is at the heart of the process; open source digital information, Hackerspaces (*Hackerspaces*, 2015) and Fablabs (*http://www.fabfoundation.org/fab-labs/what-is-a-fab-lab/*, 2015) become the core of this trend for housing development. The highlighted examples used a puzzle like, do-it-yourself approach as a means to reach an efficient, rapid and affordable construction. The degree of success in reaching these goals is yet to be evaluated.

3.1. Case study 1: The instant House, Massachusetts, USA

This prototype was a research initiative by Professor Larry Sass in the department of Architecture at MIT in 2006. The aim was developing a novel design and fabrication process for mass customized emergency, transitional and developing contexts(Botha and Sass, 2006). The Instant house process produces a customized, habitable mono-material plywood structure, assembled manually with rubber mallets and crowbars. The materials are connected with a limited number of joint types that sustain their assembly through friction, such that nails, screws or glue are not needed during assembly.

The process proposes the development of an automated generative system, first for shape design and secondly for fabrication through a generative subdivision based on the Wood Frame Grammar(Sass, 2005). Sass (2006) proposed a framework for the design and fabrication process associated with the instant house which is basically divided into 5 different stages: shape design, design development, evaluation, fabrication and construction.

According to Sass (2006) the parameters for the initial shape design are defined based on regional criteria with a set number of variations assigned to each parameter. Parameters include climate, location, spatial constraints, vernacular influence and stylistic variations. Afterwards, the selected iteration goes through a preliminary evaluation process. The design development phase involves the subdivision of the initial surface model in CAD using Wood Frame Grammar (Sass, 2005). After the design development process produces parts for fabrication, a scaled laser cut model is produced using the same geometry for full-scale house. This scaled model is used for the confirmation of construction sequence and subjective design evaluation in real space. The fourth stage “Fabrication” is the stage in which machine G-Code generation, nesting, cutting, post processing and packing are performed. The fifth and final stage is “Construction” in which two people construct the one-room cabin in three days eliminating the need for cranes and scaffolding due to small component sizes that can be easily handled.

3.2. Case study 2: The Shotgun House, New Orleans, USA

As a progression based on the previous work done by professor Larry Sass in MIT on the instant house, the digital design and fabrication unit lead by Sass developed another prototype for the New York MoMA exhibition: “Home delivery, fabricating the modern dwelling” in 2008. The design was based on a classical style New Orleans house known as the “shotgun house”. The intent was to show diverse potentials for using digital fabrication technologies for building a fully ornamental legacy house in a post disaster area like New Orleans that was hit by Hurricane Katrina in 2005. The house was assembled of 5000 plywood components all held together by friction, with no nails or glue. This structure used the same system of wood joining used to construct the instant house out of plywood(Sass, 2005). Secondary components (ornamentation, doors and windows) were also sustained by friction/snap-fit.

3.3. Case study 3: ECOnnect, Delft, Netherlands

Pieter Stoutjesdijk and Hugo Nagtzaam, two Dutch architects based in Delft, initiated a small company called “ECOnnect” with the main aim of developing an open source platform for exchanging design and fabrication information related to building digitally fabricated houses. They partnered with ECOboard, a company that produces bio-based panels from agricultural residues such as straw and reeds(Stoutjesdijk, 2014). Their motivation was to provide an adequate housing solution for the exponentially increasing population through democratization of the manufacturing process. Stoutjesdijk (2013) argues that the direct connection between atoms and bits offered by digital fabrication enables the creation of buildings in the same way software is created. Digital, customizable blueprints of physical building parts could be shared and developed globally like pieces of source code for a script, before directly being constructed locally with digital fabrication devices.

One of the first applications was a post-disaster mid to long term shelter designed for Villa Rosa; an informal settlement in Haiti. In February 2014, ECOnnect started producing the first full scale house in the Netherlands. The estimated budget for the construction of the house is 10,000 US dollars in developing countries and twice as much in the United States and Europe. They claim to have reached a concept that perfectly fits its climatic, cultural, technological and historical context. The final results of these efforts are yet to be seen and evaluated with the final constructed house.

3.4. Observations

Since these prototypes were basically designed for post-disaster situations, they do not offer large spaces with flexible layouts. The surface area is a demanding requirement when it comes to long term living (excluding New Orleans shot gun house which offered a reasonable living surface area of 55 m^2). When it comes to cost, the three case studies did not include wet and technical spaces which significantly reduces the complexity of the design and construction and thus the cost. However, it can be easily understood that in a refugee or post disaster camp using private amenities attached to or integrated in each unit is considered a luxury. The use of a monolithic material such as Plywood or ECOboards in addition to end user involvement for assembly on-site also contributes to cost savings.

When it comes to environmental performance, there were no environmental analyses performed through the design of the above mentioned prototypes, at least in published work. Claims made by their authors for reducing carbon print and being environmentally driven was not substantiated by early design analyses or ecological foot print calculations. However, their main focus was more oriented towards speed, cost and ease of construction in hazardous situations.

This work opens up an interesting line of research but it remains unclear how it can be applied to larger housing types. It might be difficult to maintain a straight correspondence between design and building components beyond a certain scale.

4. Trend 2: Seeking technological efficiency

In the middle of the spectrum lies another group of case studies that combine an economy and efficiency stand point with technological automated tendency in search for efficient, allegedly affordable long term housing. The core value here is not “affordability for all”; in contrast, it is more related to the exploration of potential savings in materials, resources and construction time.

4.1. Case study 4: System 3, New York, USA

Two Austrian architects: Oskar Leo Kaufmann and Albert Ruf designed a prototype for the Museum of Modern Art exhibition in New York held in 2008. The exhibition “Home Delivery: Fabricating the modern dwelling” aimed at showcasing diverse procedural, formal and technological innovations in prefabricated architecture. Kaufmann had designed System 1 and System 2 with a kit-of-parts approach instead of modules or blocks in 1997 and 2001 respectively. System 3 used a different approach to the design and construction by dividing the house into two basic zones: Serving space and naked space. The serving space comprises wet spaces, vertical circulation element and technical spaces for electricity and heating and was completely manufactured and assembled off-site while maintaining its size within a standard container. The naked space is the rest of free space that can be configured based on personal needs and preferences of end-user. It is also digitally fabricated off-site and flat-packed into a container.

The prototype presented in MoMA exhibition(2008) was considered by Kaufmann and associates to be the nucleus of the system and the simplest form of what could be achieved through its use. The aim was developing a system that is expandable, movable, affordable and for lifelong use. The elementary material used for the whole building was timber which gives the building a monolithic feel extending from inside to outside.

4.2. Case study 5: Micro Compact Home, Munich, Germany

A team of researchers and designers based in London and technical university of Munich (2001 to 2005) developed the concept of the Micro compact home in response to growing need for short term living accommodations for students, business people, leisure use and weekenders. The inspiration for the design of this micro house was basically taken from Japanese teahouses combined with efficient space planning usually deployed in aircraft, yachts and cars manufacturing(2015). The main structure is timber framing with Polyurethane foam for insulation covered by Anodized or Polyester powder coated Aluminum external cladding. The house is planned for basic human needs within a space of 2,4×2,4×2,4 m.

4.3. Observations

Despite the very small surface area of Micro-Compact Home (6.75 m²) which definitely translates into cost savings for running costs of maintenance and operation, the initial cost for construction is surprisingly high. According to the official website, the price provided for a single unit and frame (excluding delivery, installation, connection to services, consultants' fees and taxes) is 43 000 USD. The inclusive guide price is from 56 000 to 100 000 USD subject to site conditions. The average price per unit meter in this case is almost 10 000 USD, which is definitely high compared to average construction prices in Europe. Space efficiency and compactness is a strong feature in this house design, which might be logically tied to affordability, but on the contrast, this house provides a striking example on the higher end of the economical scale of digitally fabricated houses.

On one side, building a customizable system using dual zoning approach adopted in System 3 has a great potential. The flexibility offered in the use of naked space opens different configuration possibilities including vertical stacking and future extensions and more flexibility for end users. On the other hand, using timber as a monolithic material for the façade and interior finishes with perforations in the exterior skin is highly questionable from an environmental performance point of view. Although exterior timber panels were covered with insulation paint, it would surely be a concern in more extreme weather conditions. The cost for this prototype was not available as it was financed by different sponsors for MoMa exhibition. However, compared to other prototypes it can be projected that the budget is not on the higher end of the spectrum.

5. Trend 3: Process-driven

With an obvious lean towards the process, these prototypes showcase explorations and conceptual investigations towards how buildings are to be constructed. The motivation for authors of the following prototypes was always the process and know-how and the expansion of possibilities and potentials of digital fabrication tools with small or no regard to economical drives.

5.1. Case study 6: Cellophane House, New York, USA

At the higher end sits this built prototype designed by Kieran and Timberlake, two American architects based in Pennsylvania, USA. They took part in the New York MoMA exhibition: "Home Delivery: Fabricating the modern dwelling" held in 2008. Despite the fact that this house is not entirely digitally fabricated, it is safe to conclude the involvement of digital fabrication devices in many aspects of construction. A strong link was established between design and construction activities through extensive use of Building Information Modeling tools. The building was entirely modelled to very high levels of detail, and the model was used to communicate the development of the project with different manufacturers(2015). Designers claim to have used a paperless process from conception to final assembly. Construction was broken down into "integrated assemblies" defined as "Chunks" and wholly manufactured and assembled off-site then delivered via trailers to the site.

5.2. Case study 7: Facit Homes, London, UK

Facit Homes is a London based Studio and workshop designing and manufacturing custom designed digitally fabricated housing. They claim to be the first company in the world to use a purely digital design and production process from conception to final fabrication(*facit-homes.com/making-it-happen/budgets-prices-costs*, 2015). They registered a trade mark for the process called "D process" in which a "Mobile manufacturing unit" is delivered for the construction of the house on-site. Their design and construction process starts with preparing a full detailed 3D model in a CAD environment. Designed parts are then nested and cut using a computer numerical control milling machine on-site. The milled parts are then assembled into bigger building blocks (cassettes) that can be handled by one or two unaided people. The cassettes are assembled like pieces of Lego with high precision tolerances. They argue that this process is more efficient and consumes less time compared to standard construction methods. Despite using digital fabrication technologies for the manufacturing of the majority of components of the building, Facit Homes team still relies on professional carpentry experts for manual work(*facit-homes.com/making-it-happen/budgets-prices-costs*, 2015).

5.3. Case study 8: Embryological House, California, USA

Within the time frame defined for the scope of this paper, "Embryological House" (1997-2002) by architect Greg Lynn signals a milestone in digital design and fabrication of housing units. Although it was highly theoretical and chronologically precedent compared to other case studies, it offered a novel notion of house typology beyond the modernist "kit of parts" model to an organic, flexible, genetic and generic prototype from which an infinite number of iterations can be generated(Lynn, 1998). The project was developed with geometrical modeling and character animation software (MicroStation and Maya), as well as digitally-generated physical mock-ups(*Greg Lynn: Embryological House*, 2007). One of the most prominent aims of Lynn's creative process is pushing the capabilities of existing automated manufacturing technologies for the production of non-standardized architectural forms.

The Canadian Centre for Architecture (CCA) houses the physical mock-ups and digital files associated with the project. And while a number of its iterations have been sufficiently developed to allow their construction potential to be tested to a certain extent, a constructed architectural version has yet to be built. Embryological House remains a conceptual project as originally designed - existing entirely in digital format.

5.4. Case study 9: 3D Printed Canal House, Amsterdam, Netherlands

This is an ongoing three years research activity initiated in 2014 by DUS Architects, an Amsterdam based architecture office founded in 2004 by Hans Vermeulen, Hedwig Heinsman and Martine de Wit. The aim of their research is to explore potentials of 3D printing for building industry through building an actual full-scale house on one of the canals of Amsterdam. Canal houses have a big significance and symbolism to the history of Amsterdam. They try to investigate what this traditional architype can be in a 21^{st} century context showing how to combine traditional local values with new innovative ideas(*http://3dprintcanalhouse.com/construction-technique*, 2013). The DUS team is performing many trials and building prototypes using different materials for 3D printing with a main focus on bioplastics. They aim to print with a material that is sustainable, of biological origin, melts at a relatively low temperature, and has structural capacity. They are also researching the possibilities of printing with recycled materials like plastics, but moreover looking into using wood pallets and natural stone waste.

5.5. Observations

It can be seen from these case studies that cost savings were not the driving force for development of these prototype. For instance, the overall cost for Cellophane house was within one million US dollars for a house that is 168 m^2, resulting in an average of 6000 US dollars/m^2 which is definitely higher than the average construction costs of 1500-2000 USD(Dol and Haffner, 2010). However, very useful lessons can be learned from this specific prototype; just to name a few:

- The use of controlled factory environment for construction provides better control on overall quality of constructed assemblies.
- Robust planning using BIM tools resulted in an ease of assembly and disassembly of a relatively large multistory building.
- Almost all parts can be reused in different configurations as they were disassembled with no material loss.

On the negative side, using aluminum as primary structure raises concern about embodied energy due to high energy consumed for manufacturing of profiles. The thermal bridge effect caused by high conductance of aluminum is also questionable.

On the other hand, environmental aspects of Facit Homes built prototypes were considerably better than other case studies. They include better insulation means, air tightness and overall passive design ideas. They have been designed on a case by case basis which also accounts for better fitness to context.

Although not being the only or the first investigation into 3D printing applications in construction, the canal house represents an important milestone in housing applications, due to its scale, material selection and location and the fact that it is multi-storey. Advantages of 3D printing over traditional building techniques: the possibility of using a high level of detail and ornament; variation as the process goes straight from raw material to final product, thus eliminating waste. There are no transport costs, as designs can simply be transferred digitally and printed locally. In terms of disadvantages, it is evidently a huge challenge to create a building that complies with current building regulations as there is the question of insulation, fireproofing, wind loads, foundations, etc.

Table 1: Timeline of Digitally fabricated housing from 1995 to 2015

1997 — **Embryological House – Conceptual – Architect Greg Lynn – Trend 3**

	Micro Compact Home	The instant house	Loblolly House	System 3	Cellophane House	New Orleans House
Trend	2	1	3	2	3	1
Year	2001-2005	2006	2006	2008	2008	2008
Architect	Richard Horden & students	MIT Research Larry Sass	Keiran Timberlake	Oskar Leo Kaufmann - Albert Rüf	Keiran Timberlake	MIT Research Larry Sass
Country	Munich, Germany	Massachusetts, USA	Maryland, USA	New York, USA Dornbirn, Austria	New York, USA	New York, USA
Status	Built	Built	Built	Built	Built	Built
Image						
Area in sqm	6.75	18	168	53	168	58
Time (days)						
Design		NA	NA	84	NA	NA
Fabrication	56 – 70	NA	NA	147	90	21
Construction		3	19	1	7 assembly + 9 finishes	23
Cost	43.000 to 100.000 USD	NA	NA	Planned for Auction – On hold	Estimate 1.000.000 USD	NA
Materials						
Primary Structure	Timber framing + Polyurethane foam insulation	Plywood	Anodized Aluminum profiles	Plywood	Bosch Aluminum Framing + Steel Connectors	Plywood
Secondary Structure	NA	NA	Equipped Wood Truss Cartridges	NA	Floors: Aluminum grate + 0.5 inch Polyethylene	NA
Claddings	Anodized or polyster powder coated Aluminum external cladding	Plywood	Western red cedar timber - glazing	Plywood	Skin: Transparent PET recyclable Material with PV cells	Plywood – unfinished to showcase structure
Interior finishes	Variable – unit includes appliances	Plywood	Wood Cladding / Aluminum / Glazing	Plywood – Sanitary fixtures in stainless steel	Wall panels: 8 mm polypropylene sheet	Plywood
Process	Full CAD modeling – Partial fabrication – Off-site full assembly- One module delivery	Shape generation – Scripted part and joint generation – Puzzle Approach	Full BIM from conception to coordination- integrated assemblies	Full CAD modeling – Offsite modular fabrication – Naked element fabrication	Full BIM from conception to coordination- integrated assemblies	Shape generation – Scripted part and joint generation – Puzzle Approach
Tools						
Fabrication Tools	Various	CNC Milling	Various	3 Axis CNC Milling	Various	CNC Milling
Other	Confidential	Rhino - EZCam	Revit Architecture	Rhino	Revit Architecture	Rhino - EZCam

2008 — **Burst *008 – Built for MoMA – Architect Jeremy Edmiston & Douglas Gauthier – Newyork, USA – Trend 2**

2009 — **Contour Crafting – Research - partial prototypes – Professor Behrokh Khoshnevis – California, USA – Trend 3**

2010 — **Generative House – Research – Partial prototypes – Architect Rodrigo García Alvarado & Benamy Turkienicz - Southern Brazil – Trend 1**

2012 — **Digital Vernacular – Research – Scaled Prototypes – Architect Shankara Kothapuram et al. – London, UK – Trend 3**

	Facit Homes
Trend	3
Year	2012-present
Architect	London based firm – Bruce Bell
Country	London, UK
Status	Built
Image	
Area in sqm	Variable
Time (days)	
Design	120
Fabrication	
Construction	330
Cost	116 sqm – 300.000 USD
Materials	
Primary Structure	Timber Cassettes
Secondary Structure	NA
Claddings	Variable
Interior finishes	User defined standard finishes
Process	CAD detailing - Mobile fabrication facility on site-Cassette fabrication
Tools	
Fabrication Tools	CNC Milling
Other	Manual Carpentry

2012 — **The Bunkie Co.- Company – Digitally fabricated small scale cabins – Product designer Evan bare et al. – Meaford, Canada – Trend 2**

	ECOnnect
Trend	1
Year	2013
Architect	Pieter Stoutjesdijk & Hugo Nagtzaam
Country	Delft, Netherlands
Status	On-going
Image	
Area in sqm	13
Time (days)	
Design	
Fabrication	Ongoiing
Construction	
Cost	10.000 – 20.000 USD
Materials	
Primary Structure	ECOboard – agricultural residue
Secondary Structure	NA
Claddings	ECOboard
Interior finishes	User defined standard finishes
Process	Shape generation – Scripted part and joint generation – Puzzle Approach
Tools	
Fabrication Tools	2.5 Axes CNC milling
Other	

2013 — **10 smart sqm - Built prototype - small scale student residence - Tengbom Architects – Virserum and Lund, Sweden - Trend 2**

	3D Printed Canal House
Trend	3
Year	2014
Architect	DUS Architects
Country	Amsterdam, Netherlands
Status	Prototype
Image	
Area in sqm	NA
Time (days)	
Design	
Fabrication	Ongoing
Construction	
Cost	NA
Materials	
Primary Structure	Bioplastics Macromelt – industrial glue
Secondary Structure	Bioplastics
Claddings	Bioplastics
Interior finishes	Bioplastics
Process	Paperless process from model to printing
Tools	
Fabrication Tools	3D printing
Other	

6. Discussion

The paper tracked a number of prototypes and built projects (Table) that highlight different approaches and stand points towards the relationship between manufacturing technologies and construction industry. Some research initiatives and published work approach digital fabrication from a completely industrial, mechanical point of view, attempting to completely alter how buildings are conceived by applying mass production/mass customization technologies which are widely used in vehicles, aviation and other well-established manufacturing industries. Two of the strongest advocates of this approach are Stephan Kieran and James Timberlake. They skillfully demonstrate that contemporary building construction is a hierarchal process, in both design and construction, where segregation of intelligence and information is the norm(Kieran and Timberlake, 2004). Parties involved in the construction industry (architect, contractor, consultant, client, etc.) are motivated and derived by different goals which represent a process that is not as efficient as it should be.

On the other side of the spectrum lies a different approach which considers fabrication as a tool to empower people to think, build, experiment and be able to realize their own ideas away from corporate gurus, hence it takes more of a social decentralized standpoint. Supporters of this approach are trying to disseminate technology transfer and education through Fablabs and Hackerspaces which have at heart the issue of public enabling and democratization of the means of design and production.

Between these two approaches exists a great pool of opportunities and spaces to explore potential synergies between local craftsman knowledge and expertise and sophisticated new technological solutions in search for economic and efficient construction. It can be seen from selected projects that some powerful conceptual ideas are yet to be developed into more robust solutions. Potentials for future work and development in the field of digitally manufactured housing is far from conclusive.

7. Conclusions

The author will build on understandings obtained from analysis and evaluation of precedents to develop a system that is self-sustaining specifically in developing countries from an economic, social and environmental point of view. A theoretical framework will be formulated for the next stage of the research investigation in which the proposed system attempts to offer new ranges of flexibility through the following procedures:

- Merging concepts of "Kit of parts" with pre-assembled modules "Chunks" in search for more freedom in formal and spatial expression.
- Space planning with social factors in consideration; for example: open kitchens are not widely embraced due to the nature of food and cooking activities that have strong odors. It is also well-known that families in developing countries are mainly extended families with relatively high number of children which in turn necessitates gender separation for sleep space planning.
- Maintaining a maximum affordable budget with respect to construction costs in developing countries which are quite different from European and American bench marks for affordable housing.
- Exploring the use of local recyclable sustainable materials.
- On-site fabrication creates user involvement and attachment which in turn translates to a more successful housing intervention.

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