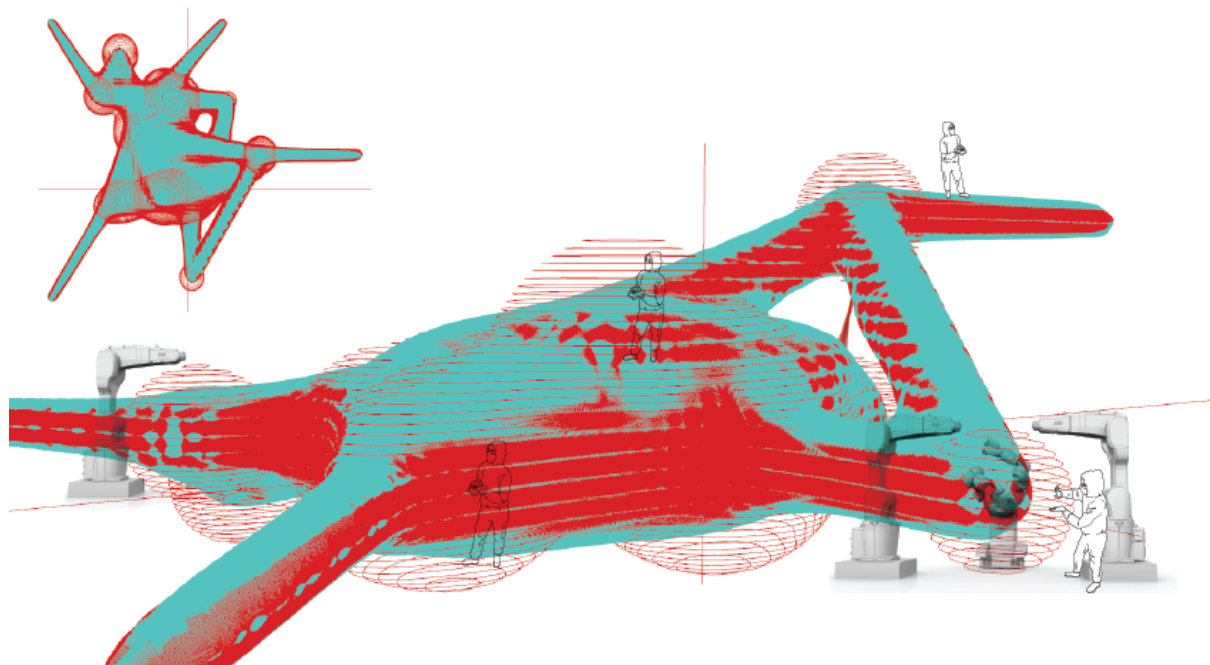


# REFLECTION PAPER

Robotic Building TU Delft

**DM&RC [Disaster Management and Research Centre]**  
*Robotic Landscapes for Natural Disaster Environments*



M.R. Galli  
4322185  
28/06/2018

## **ABSTRACT**

This paper discusses the definition of the role of the architect, specifically focused on the aspects of digital technology regarding research for production for long-duration architecture solutions. The aim is to re-settle post natural disaster environments through digital driven design methodologies and robotic production technologies. These new technologies and research-methodologies also requires the users (inhabitants) to be involved in the design and building process, therefore re-defining the role of the architect and possibly the tectonic culture of architecture.

## **INTRODUCTION**

I believe that, as architecture students, we should broaden our horizons and look into future ways of practicing architecture, while taking into consideration the upcoming climate, social and energy changes, technological advances and the new industrial revolution.

Traditionally, architects are trained following a combination of historical models, with many schools of architecture still following the “beaux-arts” theory and failing to offer training into fields like sustainability or new means of production. To prepare future architects with the set of skills needed to answer contemporary issues in an ecologically and socially responsible way, a change in the structure, content and methods of teaching in architecture schools needs to happen.<sup>1</sup>

### **Paradigm Shift in Architecture**

Over the past couple of decades, a paradigm shift in architecture towards nonstandard, intelligent, and digital architecture has emerged. As we are at the beginning of the age of digitalization, where computational logic has become integrated into the field of architecture, we need to clarify how and why these techniques and technologies, such as programmed architecture and robotic production, are to be incorporated in the design and building processes.

The Robotic Building studio examines the intersection between the physically built robotically augmented environments and robotically supported building processes. Reconfigurable, robotic environments can incorporate sensor- actuator mechanisms that enable buildings to interact with their users and surroundings in real-time. Design to production-, assembly-, and operation-chains are supported by robotic means.<sup>2</sup>

The skills acquired in the studio can be the starting point of a professional or research career for the “architect of tomorrow”. It also helps in developing a critical thinking that can be applied to the contemporary architectural discourse, as well as incorporating all the advantages that the technological advancement brings into solving contemporary issues.

---

<sup>1</sup> DeKay, Mark. “Systems thinking as the basis for an ecological design education” Proceedings of the 21st National Passive Solar Conference, American Solar Energy Society, April 13-18 (1996)

<sup>2</sup> Mostafavi, S. and Bier, H. (2016) ‘Materially Informed Design to Robotic Production: A Robotic 3D Printing System for Informed Material Deposition’, *Robotic Fabrication in Architecture, Art and Design 2016* (International: Springer), pp. 338-349  
Bier, H. "Robotic Building(S)". *Next Generation Building 1.1* (2014): n. pag.

## Natural Disasters

One issue that society faces nowadays is that of a sustainable development. Sustainability is defined as meeting our current needs without compromising the needs of future generations. In mainstream literature, sustainability often deals with green buildings or with green technologies, natural resources and how to avoid depletion, but very rarely is the subject of sustainable rebuilding of disaster-struck areas being covered. Floods, earthquakes, tsunamis, or volcano eruptions are only a few examples of natural disasters that have a long-lasting effect on communities and the environment they inhabit. <sup>3</sup> ONU established that over the past 20 years, natural disasters have killed more than 1.3 million people, affected 4.4 billion and resulted in huge economic losses.

Because such events are impossible to predict with accuracy, defined strategies on how to react still do not exist. Such disasters generate crisis situations, but they also offer great opportunities in terms of future development. In examining disasters of such magnitude, it will become imperative for architecture to transform its pedagogy and expand its expertise in order to provide sustainable solutions that will preserve humanities existence. <sup>4</sup>

### How should we respond to a natural disaster?

In the wake of such events, there are a few critical stages that need to be tackled: assessment (up to five days following the event), shelter (five to 60 days) and settlement (after 60 days). Usually, authorities and communities are unprepared to deal with such events, which often leads to an increase in damages and an unclear way of future redevelopment. These periods are preceded by a prevention period, before the occurrence of a major event, in which all factors involved should make necessary preparations.

Design to Robotic Production (D2RP) and the paradigm shift from mass production to mass customization can present great potential if used in the redevelopment of such areas. Robots are already being used in the industry and research fields, but they are not being used to their full potential in the building and architectural industry, even though nowadays there are a lot more developments in the research field. The tasks they are most commonly given are repetitive and focused on the mass production rather than the mass customization or they are more focused on the research than the implementation in field.

## DESIGN ASIGMENT

### Crisis as a starting point

Throughout history, Chile (where I come from) has constantly been hit by important natural disasters actually it shows to be the most seismic country at world-wide level, as well as the one that has registered the greater seismic event (earthquake) in the world, that took place the 27 of February 2010. In the case of Coquimbo - Chile, the site of my graduation project, an 8.8-magnitude earthquake followed by a tsunami led to a death toll of 525 people in 2010, 81 of them after a tsunami struck with no warning from the government. It also led to 1.5 million people being displaced.

---

<sup>3</sup> Richards, Michael. *After The Civil War*. 1st ed. New York: Cambridge University Press, 2013. Print

<sup>4</sup> "Architecture At The End Of The World". The Huffington Post. N.p., 2017. Web. 22 Jan. 2017.

Frustrated by the lack of preparation and response towards this catastrophe I wanted to understand further the complexity of the social re-settlement and research into new design methodologies that could re-think how architect approach future events.

A crisis is a turning point, a decisive moment when tensions and instabilities come up and change becomes necessary. Crisis implies the questioning of beliefs and habits, it demands adjustment in perception and in modes of action.<sup>5</sup>

### **Digital Driven Design research to Robotic Production**

There are multiple methods in which architects can respond to these issues, specifically how can we use new technologies such as design to robotic production, to respond in a sustainable and effective way to natural disasters. In this section I will discuss three examples of using new technology systems, its application in crisis response and how it defines the role of the architect. The first one is Gramazio-Kohler's Flight Assembled Architecture, 2011-2012, developed at FRAC Centre Orleans, where flying robots assemble (prefabricated) modules into architecture. The second one is research into additive manufacturing, as developed in the Robotic Building Research Group at TU Delft, in which robotic arms are used to create 3d structures by adding material, The third one is on-site assembly production using robot arms which is currently being tested in various institutions but will focus in this paper on the Bartlett Cluster 4 research. All these are case studies for my design proposal for a Disaster Research and Management Centre in Coquimbo, Chile.

#### Flight-Assembled Architecture

The research project of Gramazio & Kohler is in its incipient stage: small-scale drones are placing prefabricated blocks to create complex spatial structures, following a perfectly-designed trajectory. The long-term goal of the research is the utopian idea of using drones to place prefabricated building modules one on top of the other, growing in height, and eventually creating high-rise building. Extrapolating this idea for a disaster-struck zone, it would mean that drones could potentially transport and position prefabricated building modules in areas where access and on-site construction would be difficult. This requires long-term planning, in areas that natural disasters occur on a regular basis: firstly, the modules would be prefabricated, and would require a pre-production process, in what is called the prevention period (period of time that precedes a natural catastrophe, in which measures can be taken to prepare for such an event). It also needs a careful design of the trajectories of the drones: how and where the modules would be placed to create temporary structures.

In this case, the role of the architect would be to firstly design the modules that would be used. Also, the architect would need to design the movement of the drones, that would ultimately create the temporary structures. As the method would offer a fast response, I would only see it as a temporary solution, planned during the prevention period and applied in the assessment and shelter periods following an event. This would offer a short-term

---

<sup>5</sup> Ballesteros, M. (2008) Verb crisis. Barcelona: Actar (Architecture boogazine, v. 6).

solution for shelter/medical facilities etc, useful to reduce more serious consequences in the long-term, and would make a transition towards the settlement period.<sup>6</sup>

### Additive manufacturing

More commonly used in robotic fabrication than drones are robot arms. What is really spectacular about these is not that they could potentially drill holes in a shorter amount of time than a human builder could, but that they could potentially fabricate entirely customized structures using, among others, additive manufacturing. This process implies the successive addition of material on a pre-designed trajectory, thus creating structures. Progress has been made into robotically 3d-printing metal structures (Joris Laarman's MX3D printing a metal bridge in Amsterdam), or optimised 3d-printed reinforced beams (research at the Chair of Digital Building Technologies, ETH Zurich). In TU Delft, the Robotic Building research group has been conducting research into additive manufacturing using different materials (clay, concrete etc.) The optimised process of production implies that structural elements can be constructed by adding material only where the stresses in the element dictate it, while reducing it in the areas where it is not needed. Overall, this leads to the design of optimised structures in terms of material use, while offering a similar structural behaviour. The process provided insight into what the technology can provide for the building industry, as well as teaching the means of designing for robotic fabrication. Research has also been conducted into the types of materials, densities, and speeds of deposition of material to reach the desired results.

In the case of responding to crisis situations provoked by natural disasters, additive manufacturing could be used in the settlement period when the community needs sustainable redevelopment. Because a design made for robotic fabrication through additive manufacturing can provide easy customisation, this technology could provide the means to fabricate countless variations of a design, thus facilitating a dialogue between architects and community, involving people in the redesign of their areas. Architects in this case would need to be acquainted with the new production method, and design with the fabrication process in mind. Through coding, countless variations for design can be provided.<sup>7</sup>

### On-Site Assembly production

On-site assembly production implies that robotic arms would be used directly on site of a crisis zone, somehow similar to human builders, but in a more efficient way, while reducing the need of people on site. The Cluster 4 of the Bartlett UCL's ongoing research into using robot arms to assemble structures using especially-designed bricks is useful in this research. They are designing optimised "building blocks" to respond to the specific needs of a project,

---

<sup>6</sup> Kohler, Matthias, Fabio Gramazio, and Raffaello D'Andrea. 2013. *Flight Assembled Architecture*. Zürich: ETH.

Stuart-Smith, Robert. "Behavioural Production: Autonomous Swarm-Constructed -Architecture". *Architectural Design* 86.2 (2016): 54-59. Web.

<sup>7</sup> Mostafavi, S. and Bier, H. (2016) '*Materially Informed Design to Robotic Production: A Robotic 3D Printing System for Informed Material Deposition*', *Robotic Fabrication in Architecture, Art and Design 2016* (International: Springer), pp. 338-349

Bier, H. and S. Mostafavi. "Structural Optimization For Materially Informed Design To Robotic Production Processes". *American Journal of Engineering and Applied Sciences* 8.4 (2015): 549-555.

and use robots (or Robots, to refer to the plug-in developed by Vincente Soler for this purpose) to assemble the final structures.

The role of the architect in this case is to develop new “building blocks” to be used in crisis areas (maybe using research into new materials, trying to achieve better parameters in terms of insulation, weight etc), as well as to design the rules in which robots would assemble the components. This method, similar to the additive-manufacturing method, could be used in the settlement period. A problem for this method is that currently, most of the robot arms used in research are static, the Bartlett RC4 mounting rails to make their robots flexible.<sup>8</sup>

### **A shift in the tectonic culture of architecture**

In order to develop a coherent design to production system specific to respond to natural disaster events, the first step is to implement methods of form finding derived from the innate needs and actions of the inhabitants in order to re-settle. Patrik Schumacher talks about the concept of *autopoiesis* in architecture, referring to architecture as a system capable of reproducing and maintaining itself. He mentions in one of his thesis that the evolution of society depends on architecture’s continuous innovation of the built environment and that the development of the built environment is understood as an indispensable material of socio cultural evolution and future life process.<sup>9</sup>

In crisis periods following a natural disaster, swift and clear responses are mandatory. The three examples presented offer possibilities in building that differ in a few ways: while the flight-assembly method can be mostly implemented in the period immediately following an event, contributing to a fast solution to the issue of temporary housing, the other two offer new possibilities in reconstructing the communities, mainly in the building process. The advantage of all three is that they could all be designed in the prevention period, meaning that they could all be designed in periods when they are not needed, and only implemented when they are indeed needed. This means that efficient plans can be conducted, and swiftly applied when they are required. Combining the three methods has various advantages: flight-assembly can provide temporary facilities in a very short time, even in areas that are not easily accessible to human intervention teams. Robotic fabrication offers the flexibility in design, through customization. The optimised design also means a reduction of materials, thus also cost. The use of robot arms instead of human builders can also mean reduce in cost. The easily customisable design means that communities can be involved in the redesign, facilitating the rebuilding in a sustainable way. The architect should lead the project, by designing the means in which the interventions should be made, and involving inhabitants into the rebuilding process, while, at the same time, ensuring the coherence of the project.

### **A new design system: Disaster management and research centre.**

The design and development processes of this project is on one hand, supported by various computational strategies and, on the other hand, informed by the shift from traditional,

---

<sup>8</sup> Gillesreitsin, Jimenez M., V.Soler. *Fabricate: Rethinking Design and Construction*. (London, UCL Press, 2017), pp 178-183

<sup>9</sup> Schumacher, P. (2012) *The autopoiesis of architecture, volume II : a new agenda for architecture*. Hoboken: John Wiley & Sons.

architecture towards individualized, informed architecture. The design strategy employs a solution-based approach to address complex problems after a natural disaster and also the paradigm shifts in society and culture.

The project integrates a high level of diversity in computational embedding, i.e. robotic fabrication (hybrid procedure: additive vs. subtractive manufacturing, high tech vs. local materials) and local responsive behavior. This allows for a locally informed structure that can adapt and grow on time based on the emergency response systems.

An multi Design to Robotic Production system addressed in 3 scales, from micro to macro.

- **Micro Scale:** Multi robotic agent production system. "Pack" of robots with specific building and fabrication tasks, on site and also pre-fabricated at a production facility. Here the assignment is to define an aged based parametric framework focused on the robotic production process.

- **Messo Scale:** Architectural Unit based on ergonomic and programmatic functions. At this scale the assignment is to design a living unit which integrates energetic, environmental, structural and climatic conditions. This unit will be fully robotically produced.

- **Macro Scale:** Robotic Landscape intervention that will address the design system of re-settling on the urban scale. The assignment at this scale is to visualise the system growth-adaption and transformation on a time-base.

This project explores the possibility of developing an multi robotic building system and long-duration architecture solutions with the aim to re-settle un-habited or hostile environments, through digital driven design parameters, material and numeric controlled technology research and experimentation through scale models and prototypes.

## RELEVANCE

The focus of this paper is that there should be a paradigm shift in architecture towards a digital driven architecture, changing the tectonic culture of architecture. Architects should learn and make use of this new research methodologies and technological developments to become actively involved in responding to natural disaster crisis. Nevertheless, the role of the inhabitants, their social interactions and needs are also a very important input for the design and construction process, therefore the use of multiple research methodologies is necessary. In this way, random, uncoordinated response from volunteer forces that often cause more damage in the redevelopment of communities can be avoided.

We must take the opportunities this shift provides us: design to robotic production, in combination with traditional knowledge, gives us the opportunity to create effective and sustainable solutions for natural disasters. By embracing digital driven design systems and numeric controlled / robotic production technologies, as a hybrid research method system, we can have a voice in the upcoming architecture and building industry. Architecture, society and architects as part of the same self-sustaining system.

Acknowledging this reality – by researching, experimenting and innovating – is the starting point of its transformation.

## REFERENCES

- "AADRL SWARM PRINTING: AERIAL ROBOTIC BRIDGE CONSTRUCTION". Kokkugia.com. N.p., 2017. Web. 22 Jan. 2017.
- "Architecture At The End Of The World". The Huffington Post. N.p., 2017. Web. 22 Jan. 2017.
- Bier, H. and S. Mostafavi. "Structural Optimization For Materially Informed Design To Robotic Production Processes". American Journal of Engineering and Applied Sciences 8.4 (2015): 549-555.
- Bier, H. "Robotic Building(S)". Next Generation Building 1.1 (2014): n. pag.
- Bock, Thomas and Thomas Linner. Robotic Industrialization. 1st ed. New York: Cambridge University Press, 2015. Print.
- "Climate Change NASA". Climate.nasa.gov. N.p., 2017. Web. 22 Jan. 2017.
- Crompton, Dennis and Pamela Johnston. A Guide To Archigram, 1961-74 =. London: Academy Editions, 1994. Print.
- "GAD – RC4 / Computational Design Methodologies For Large-Scale 3D - Printing". CreativeApplications.Net. N.p., 2017. Web. 22 Jan. 2017.
- Guallart, Vicente. Geologics. Barcelona: Actar, 2008. Print.
- Leach, Neil, David Turnbull, and Chris Williams. Digital Tectonics. 1st ed. Chichester: Wiley-Academy, 2004. Print.
- McGee, Wes, Mónica Ponce de León, and Aaron Willette. Robotic Fabrication In Architecture, Art And Design 2014. Print.
- Oosterhuis, Kas, Henriette Bier, and Kas Oosterhuis. IA #5. Print.
- Oosterhuis, Kas. Towards A New Kind Of Building. Rotterdam: NAI, 2011. Print.
- Reinhardt, Dagmar, Rob Saunders, and Jane Burry. Robotic Fabrication In Architecture, Art And Design 2016. Print.
- Richards, Michael. *After The Civil War*. 1st ed. New York: Cambridge University Press, 2013. Print.
- Stuart-Smith, Robert. "Behavioural Production: Autonomous Swarm-Constructed - Architecture". Architectural Design 86.2 (2016): 54-59. Web.

## Videos

#GSM3 | Robotic Building | Jelle Feringa - Kathrin Dörfler - Keith Green | <https://www.youtube.com/watch?v=RvjeA3IAFQ>

Robotic Building HH Bier <https://www.youtube.com/watch?v=a7uhr1WC5IU>

Hyperbody Scalable Porosity <https://www.youtube.com/watch?v=JMVeDiVOvWA>