

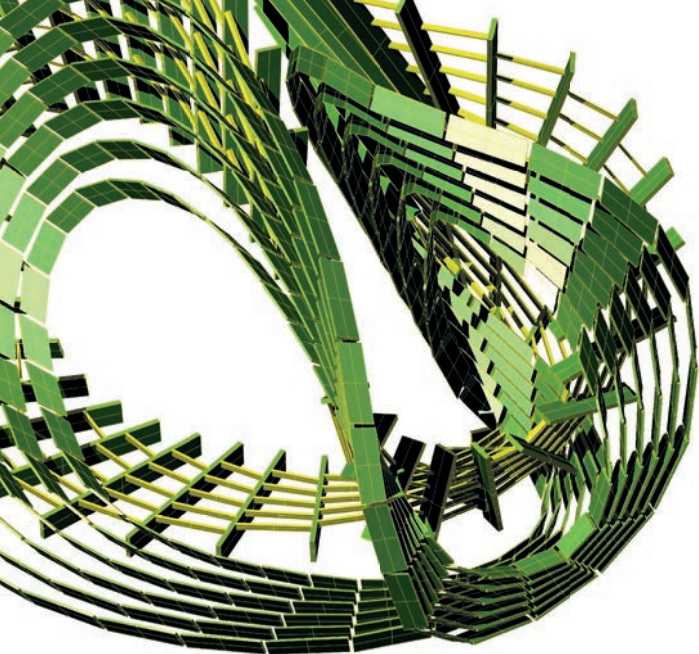
Marie Davidová: Doctoral Thesis

WOOD AS A PRIMARY MEDIUM TO ARCHITECTURAL PERFORMANCE

**A Case Study in Performance Oriented Architecture
Approached through Systems Oriented Design**

Reviewers: Birger Sevaldson, Cyril Říha, Peter Buš, Miloš Florián

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WOOD AS A PRIMARY MEDIUM TO ARCHITECTURAL PERFORMANCE

A Case Study in Performance Oriented Architecture Approached through Systems Oriented Design

The present research considers wood as a study material for a wider question on architecture's environmental interaction. It aims to explore its potential for architectural performance and atmospheres as well as to broaden the discussion on this problem area by accessing the public space. My project researches such interactions through practical experiments as well as theoretical reflections, including examinations of other scientific, artistic and crafts disciplines and honestly discusses both the successes as well as the failures and weak points to develop a strong background for architectural and urban design practice. The methodology Research by Design while full scale prototyping is covered by the Systems Oriented Design to interpret and develop complex environmental relations.

This is an article based thesis, where the texts of the articles have not been changed and serve as an addendum covered with an exegesis. Most of the repeating images were removed from the articles. If there is an exception this is reasoned through its important relation to the present text.

All the substantial contributions are mentioned within the text and/or summarized in the Thanks section. To mention the main institutions and practice/NGO's respectively, this research has been developed at the Faculty of Art and Architecture at the Technical University of Liberec, the Faculty of Architecture at the Czech Technical University in Prague, Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences in Prague, the Academy of Art, Architecture and Design in Prague, the Architectural Institute Prague, the Oslo School of Architecture and Design, the University of Chemistry and Technology in Prague, Collaborative Collective, Defio, Oximoron, re.code.nature and reSITE.

The publication of the thesis was kindly supported by EEA and Norway Grants through the project Systemic Approach to Architectural Performance, is printed on paper with 100% of recycled fibre and is dedicated to my family, friends, colleagues, students and everyone interested in the field.

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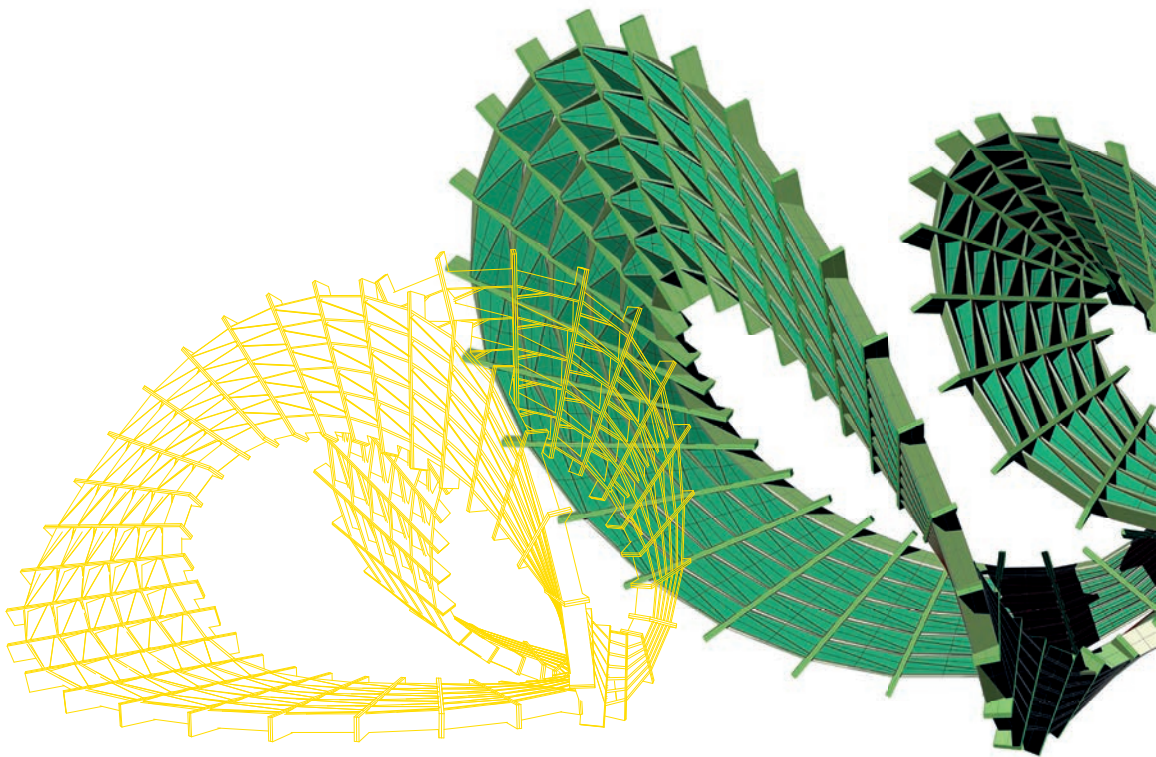
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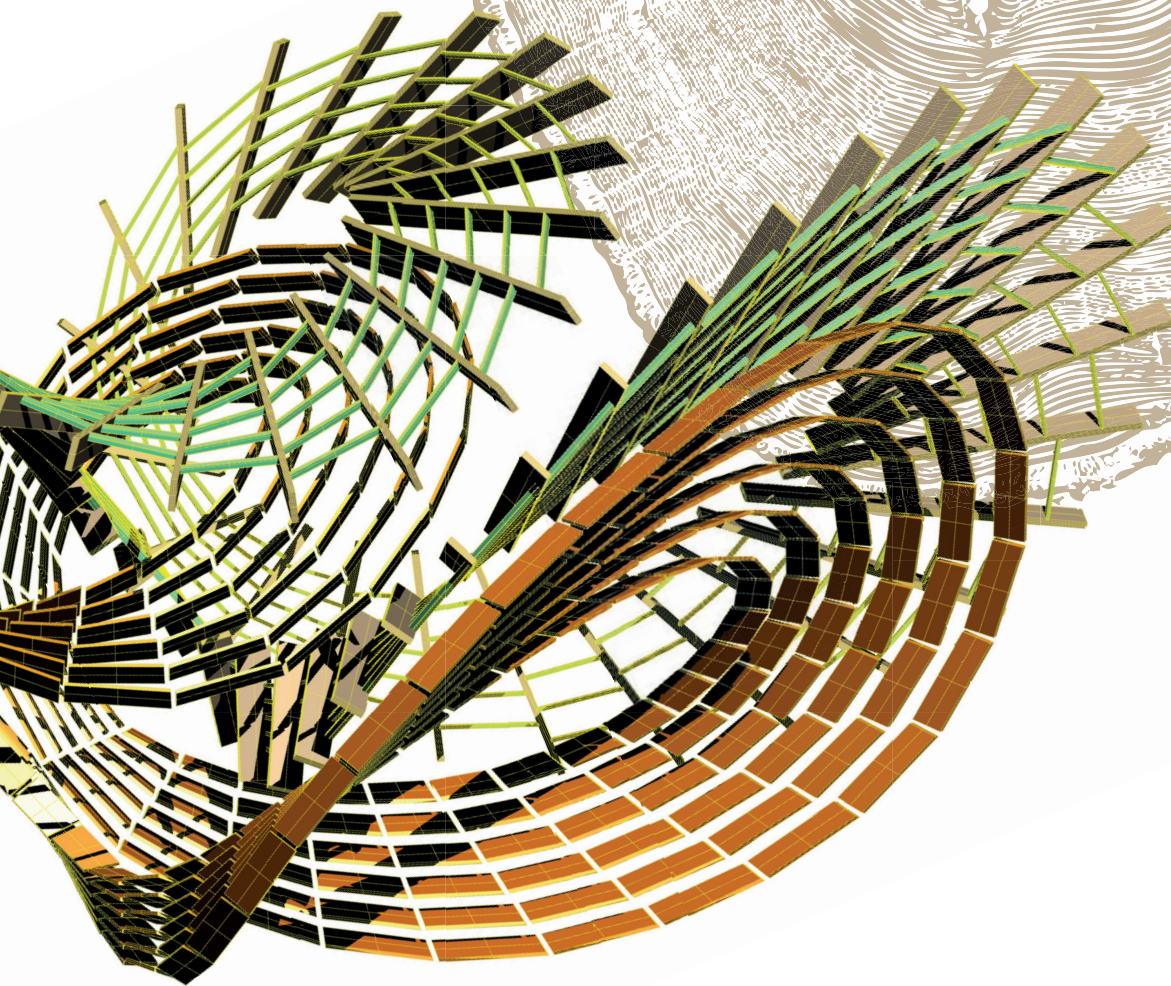
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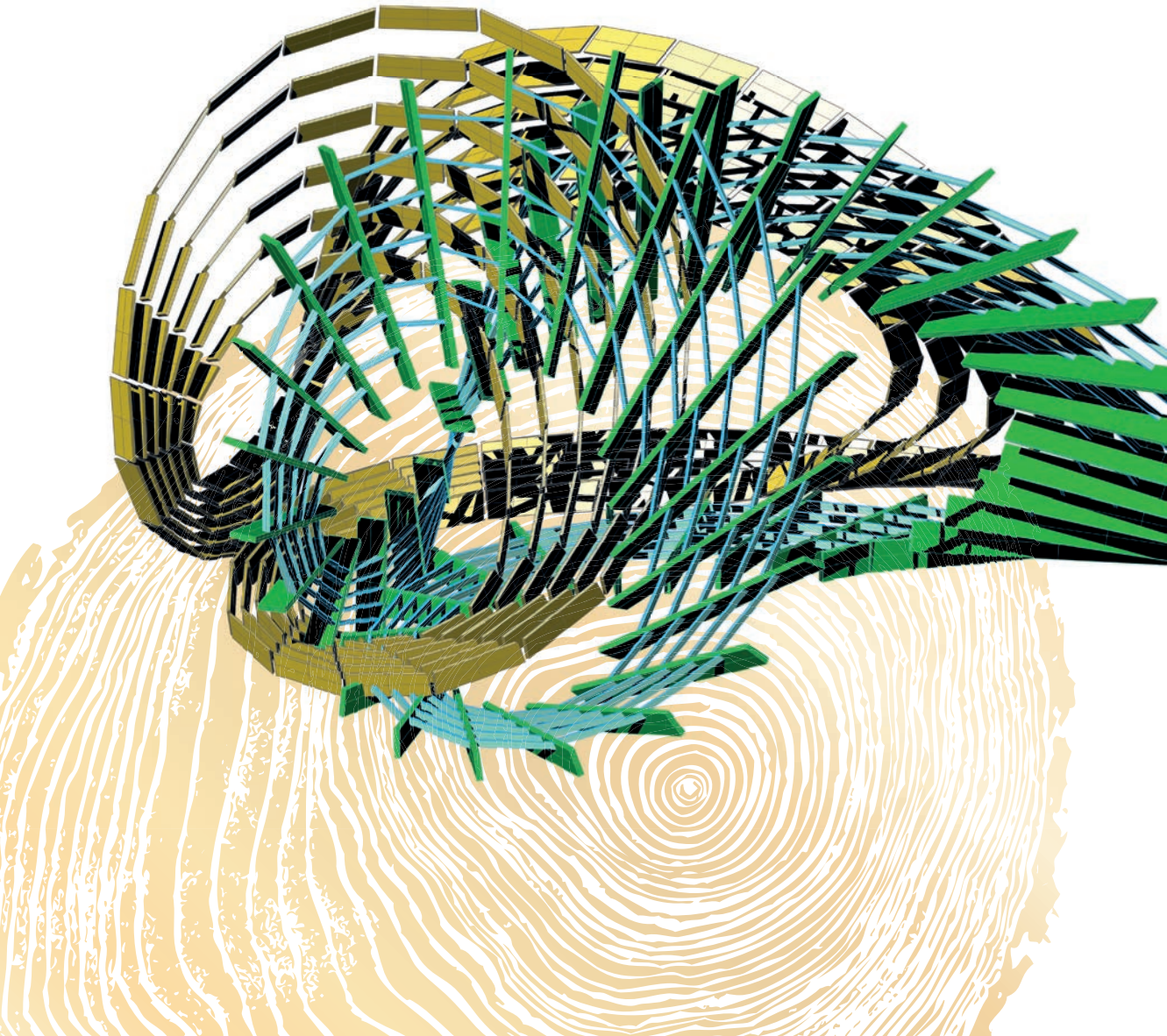
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2/ *Introduction*



The research is seeking answers to the question of what is a solid pine wood's environmental interaction and how it can be used in Performance Oriented Design (Michael U. Hensel, 2015a) applied in Czech locations. Inspired by the performance of traditional architecture from locations with more extreme climate histories, this case study mainly focuses on performative potentials of solid pine wood cut in tangential section; to be precise – its warping – and particularly how this might be applicable in the specific climatic conditions of Czechia. With today's climatic change in our region, there is a necessity to search for the adaptation of our local architecture in different places where such conditions have been present.

The Czech National Strategy for Climate Change Adaptation document clearly states that it is necessary to promote research and development of new materials and technology in reference to anticipated effects of climate change, such as strong gusty winds, extreme rainfall or snow totals or temperature extremes. The main issue in the urban environment mentioned is humidity extremes – long periods of very dry weather or extreme rains (Czech Republic Ministry of the Environment & Czech Hydrometeorological Institute, 2015). In this issue, the architecture is not considered. It is important to note that architects and urbanists were excluded from the document preparation. This research claims that architecture, especially its experimental field, may bring new perspectives to the discussion, joining climatic, material and biotic (including social), sciences.

The work covers two sub-projects resulting in four built prototypes: Performative Screens Ray and Environmental Summer Pavilions, where prototypes Ray 2, Ray 3, pareSITE and LOOP pavilions benefit from each other's ideas, observations and results. The Ray project that was inspired by Norwegian traditional panelling and oriental screens called 'mashrabiyyas' is proposing a screen that is airing and improving the environment by evaporating humidity in warm, dry weather while being resistant and sorping moisture in high relative humidity. The pavilions were mainly focused on evaporation such as in 'mashrabiyyas', while using the idea from Norwegian traditional panelling of warping for humid air movement. These architectures were improving/may improve outdoor-indoor climatic comfort by providing shading and wind sheltering but also sorping moisture in high relative humidity level that is mainly at nights, while evaporating it on hot summer afternoons, when the relative humidity is on average the lowest. According to Banham, humidity has been the most pestiferous, subtle and elusive of control for most of architectural history, either too much or too little of it in certain climatic conditions (Banham, 2009). These prototypes wish to take this discussion further, applied for the location with both extremes and their increased expectations.

This research on solid wood cut in tangential section was greatly inspired by contemporary research on plywood and laminates, conducted by Michael Hensel, Achim Menges and others and research of Sustainable Environment Association (Michael U. Hensel, 2011b) co-founded by Michael U. Hensel, Defne Sunğuroglu Hensel and Birger Sevaldson that recently joined the Ocean Design Research Association (Michael Hensel, 2015). In the September/October 2015 issue of Architectural Design it was revealed that the research at the Institute of Computational Design at the University of Stuttgart led by Achim Menges is also planning to take the direction of research on solid wood cut in tangential section. (Menges & Reichert, 2015). This work has not yet been published.

Implementing 'Bottom-Up' approach starting with the material research, the 'Top-Down' method was slightly combined with ongoing speculations about possible applications as well as the pavilions were having their separate mission of being public architectural objects through which other observations started. At the same time, the need for such performative capacities was discussed several times through many projects in my practice, Collaborative Collective (Collaborative Collective, 2012), the most striking example of which is shown in the DCA2016 paper, Ray 3: The Performative Envelope (Davidová, 2016c). Though the project Pà Vei (Collaborative Collective, 2011) is not situated in the Czech Republic but Norway, the relevance of this possible application was so important that it was included into this otherwise very site-specific, thesis. For the project's purposes, a sister NGO of the same name was established in conjunction with my colleagues from the practice.

The 'Research by Design' thus joins not only academy with practice, but also an investigation on how radical architectural research by design can be organized in the format of the NGOs.

Besides literature studies on different topics like forestry, dendrology, wood material science and technology, climatology, algology, mycology, architectural history and conservation, today's research in the field of responsive wood, environmental art, urban design and landscape architecture, etc. the project's main research approach is based on Research by Design with 1:1 Scale prototyping and practical experiments directing towards sustainable applications in architecture and urban design. This main research mode has been supported by the methodology Systems Oriented Design (Sevaldson, 2013b). The approach helped to keep an overall view of the project and to address the systemic implications and connections. This also implied development of the methodology through its application into the specific design needs. Throughout the process, the GIGA-maps (Sevaldson, 2016a) were tools for this transdisciplinary project that was mapping hard data together with tacit and subliminal knowledge and experiences, targeting the architectural and urban design practice.

The thesis first chronologically positions my prototypes into the perspective of other research that has been done in the field and reasons why the root of solid wood has been taken through LCA comparison, modelled for the Czech Republic's environment on the example of one of the prototypes.

The methodology chapter introduces approaches and/or development in all the methodologies involved. This covers Systems Oriented Design, Research by Design through full scale prototyping and the relations of Academy, Practice and NGO as well as transdisciplinary cooperation in the project. The last subchapter called Systemic Approach to Architectural Performance is discussing and introduces visions for merging digital design tools with prototyping, while handling different interrelated large amount of data as a designer in relation to GIGA-mapping. The research also covers the full scale prototypes observations that are also discussed in this chapter. The chapter on material covers the study of forests of the placement of the research for selecting species related to closer observation of the material and its environmental interactions.

The projects section, after first speculations discussion and introduction, explains each prototype subproject in detail. This is divided not chronologically but by the two main projects sections Ray and Environmental Summer Pavilions.

The thesis is concluded in reference to the projects' application, taking its role in social, or generally biotic, physical environmental perspective in reference to climatic change in the targeted location. It places the research case study into the context of larger range of different options of exterior-interior boundary conditions that I experienced in my practice or earlier in my studies, arguing for relevance of this application in practice. Some of the elaborated topics here are already proposing new explorations rather than fully closing the discussion.

This is an article-based thesis that covers entire articles published in press or submitted in a role of addendum glued together with exegesis that is richly referenced in my other articles that were not selected for full text. The selection of full articles was adapted to the suitability to different chapters of the thesis, such as methodology and specific projects' developments and explanations.

The full articles cover:

a) Full articles on method of selection of the used material and methodology:

- Davidová, M., & Kočí, V. (2016). Choosing the Material for Environment Responsive Screen Ray: The LCA Comparison. In I. Press (Ed.), *Architecture In-Play 2016*. Lisbon: ISCTE – University Institute of Lisbon.
- Davidová, M. (2014b). Generating the Design Process with GIGA-map: The Development of the Loop Pavilion. In B. Sevaldson & P. Jones (Eds.), *Relating Systems Thinking and Design 2014 Symposium Proceedings* (pp. 1–11). Oslo: AHO.



Davidová, M., & Sevaldson, B. (2016a). 1:1, A Transdisciplinary Prototyping Studio. In ASK.the.Conference 2016. Warsaw: Warsaw University of Technology, Faculty of Architecture.

Davidová, M., & Sevaldson, B. (2016b). NGO, Practice and University Driven Research By Design on Performative Wood. In M. S. Uddin & M. Sahin (Eds.), 2016 DCA European Conference (p. N/A). Istanbul: Özyeğin University.

And recently submitted article to FORMakademisk's systemic design III special issue: Davidová, M (2016). Systemic Approach to Architectural Performance: Handling Data in Creative Design Process: Mixing Physical with Digital

b) Full papers on separate subprojects' prototypes:

Davidová, M. (2016b). Ray 3: The Performative Envelope. In M. S. Uddin & M. Sahin (Eds.), 2016 DCA European Conference (p. N/A). Istanbul: Özyeğin University.

Davidová, M., Šichman, M., & Gsandtner, M. (2013). Material Performance of Solid Wood : Paresite , The Environmental Summer Pavilion. In E. M. Thompson (Ed.), Fusion – Proceedings of the 32nd eCAADe Conference – Volume 2 (Vol. 2, pp. 139–144). Newcastle upon Tyne: Department of Architecture and Built Environment, Faculty of Engineering and Environment, Newcastle upon Tyne.

Davidová, M., & Prokop, Š. (2016). Advances in Material Performance of Solid Wood: Loop, the Environmental Summer Pavilion II. In M. S. Uddin & M. Sahin (Eds.), 2016 DCA European Conference. Istanbul: Özyeğin University.

c) The thesis is concluded with recent Relating Systems Thinking to Design 5 submission: Davidová, M. (2016). Socio-Environmental Relations of Non-Discrete Spaces and Architectures: Systemic Approach to Performative Wood.

The referenced articles mainly cover:

Davidová, M. (2009). Exploring Environmental Dimensions : On Sustainability as an Architectural Problem ; Why It Is Not Enough To Discuss Space and Time Only. In Nordes 2009 – Engaging Artifacts (pp. 1–4). Oslo: Oslo School of Architecture and Design.

Davidová, M. (2013). Ray 2 The Material Performance of a Solid Wood Based Screen. In E. Thompson (Ed.), Fusion – Proceedings of the 32nd eCAADe Conference – Volume 2 (Vol. 2, pp. 153–158). Newcastle upon Tyne: Faculty of Engineering and Environment, Newcastle upon Tyne.

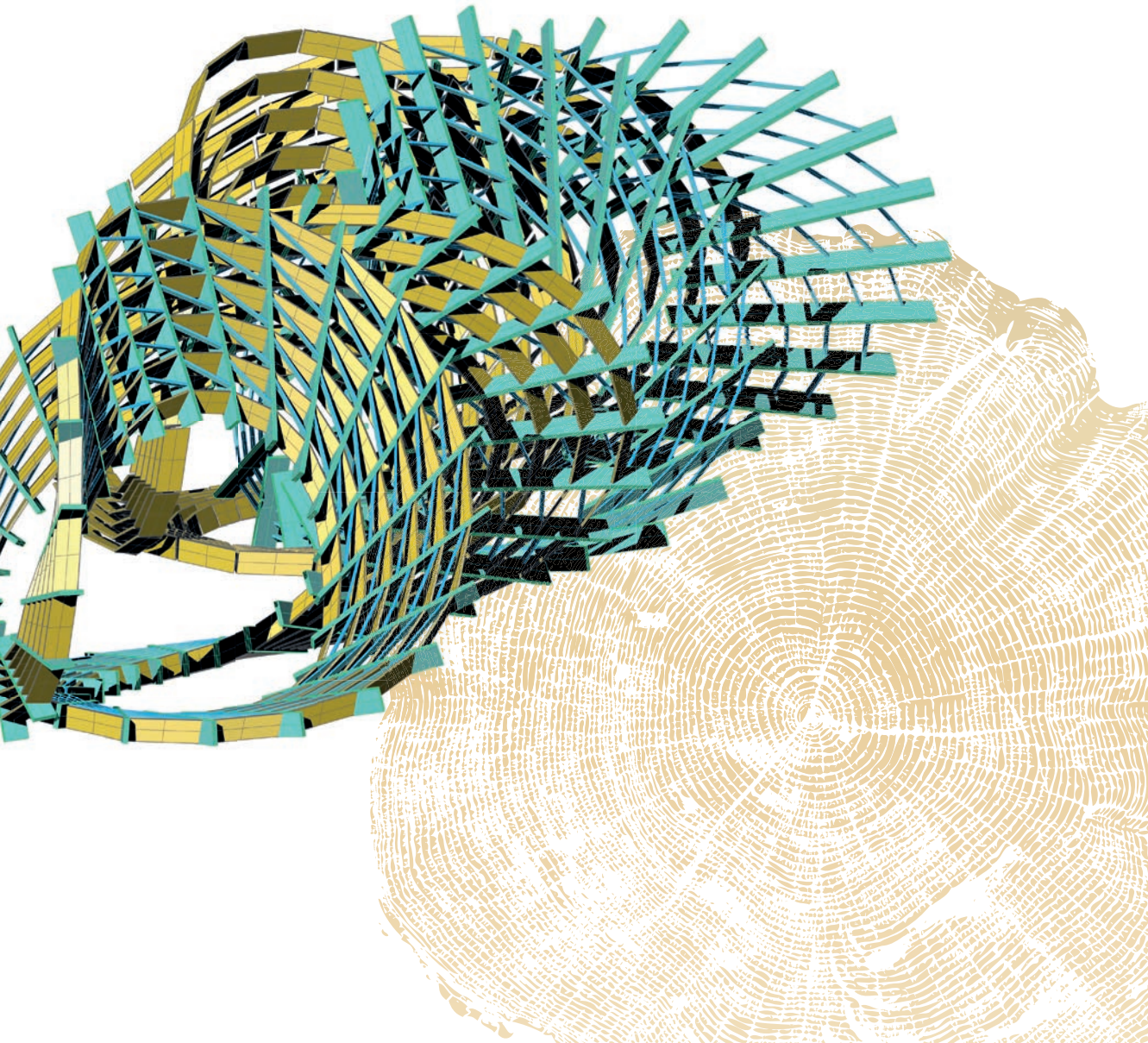
Davidová, M. (2014a). Environmental Material Performance of Solid Wood: pareSITE: The Environmental Summer Pavilion. In R. Cielatkowska & D. Jankowska (Eds.), Wooden architecture, tradition, heritage, present, future – Proceedings1 (pp. 87 – 92). Gdansk: Wydział Architektury Politechniki Gdańskiej za zgodą Dziekana.

Davidová, M. (2014c). Wood's Material Performance: Ray 2. In Wooden architecture, tradition, heritage, present, future – Proceedings1 (pp. 93–99). Gdansk: Wydział Architektury Politechniki Gdańskiej za zgodą Dziekana.

These were not included as full papers in the thesis for the reason of not complying with the logic of the structure: a) background and position of the research; b) methodology and its development; c) material in relation to environment; d) prototypes; e) discussion and conclusions.

3/

*Placement of My Research
in Reference to Performance
Oriented Design and Systems
Oriented Design*



This research is a case study in a broad area of Performance Oriented Architecture (Michael U Hensel, 2010a, 2010b, 2011a; Michael U. Hensel, 2012b; Michael Hensel, 2013), as a subfield of Performance Oriented Design (Michael U. Hensel, 2015a) ratified and commenced in 2008 (Michael U. Hensel & Sunguroglu Hensel, 2013), focusing mainly on material-climatic-biotic performance and its sustainable application in architectural and urban design practice in the researched location. It is approached as a 'figuration of fields of relationships' (Michael Hensel & Menges, 2009). By doing so, the methodology, namely Systems Oriented Design (Sevaldson, 2013b) and Research by Design through full-scale prototyping (Davidová & Sevaldson, 2016a; Michael Hensel, 2013; Sheil, 2008) and its use in observations and gluing Academy, Practice and NGO through Research by Design (Davidová & Sevaldson, 2016b), had to be applied, updated and developed. The research also covered hard data measurements of micro-climatic conditions in relation to moisture content of the wood and its placement, but these data are not elaborated in detail in the thesis. It just served as a tool for the design development. This is the reason that the thesis covers a wider spectre of issues while aiming towards durable application and sustainability in all its meanings. A similar view is argued for in the paper: Sustainability from a Performance-Oriented Architecture Perspective – Alternative Approaches to Questions regarding the Sustainability of the Built Environment, proposing holistic systems approach (Michael U. Hensel, 2012b).

The notion of performance in architecture was reformulated by Hensel as a reconsolidation of form and function into synergy of dynamics of natural, cultural and social environments (Michael U Hensel, 2010b). In 2013, the topic of Computation and Performance was assigned to the eCAADe conference, naming functional facilitation of its occupants' activities, aesthetics, economy, provision of thermal, light and acoustics comfort, sustainability with respect to material, energy and other resources, and so forth as a focus (Stouffs & Sariyildiz, 2013). Generally, performance is often related to computation, which could be seen by the fact that it became a topic of the conference related to computer-aided architectural design, but also it is clearly stated in the editors introduction in the Performatism publication (Grobman & Neuman, 2012). Though the research was often touching this field, it was not really its research area. Unfortunately we often encountered its limitations, especially when it came to simulations of single or interrelated complexity such as fluid dynamics, structural capacities or generally transdisciplinary relations, without even mentioning the relations of tacit knowledge. More than this, samples and full scale prototypes and architectures in relation to environmental observations and GIGA-mapping were largely employed.

Commonly, the architectural performance is being referred to in many different meanings in relation to interaction with environment, but mainly as structural optimisation in relation to gravity, natural ventilation or material performance (Davidová, 2014f). Starting from the point of the last one named in the meaning of biological material 'active agency' (M.U. Hensel, 2009; Michael U. Hensel, 2012a), the project soon employed phenomenological and social observations of the performance. Such interaction of material and human aspects is mentioned, i.e., in article Material Performance already in 2009 in relation to culture (Michael Hensel, Sunguroglu, & Menges, 2008). While largely focused on human interaction, the project is not really anthropocentric and is creating a suitable environment for many species. Namely algae or birds were considered and in the same time the prototypes were inhabited by them on their own will (see Figure 1, Figure 11, Figure 54 and Figure 55). Also the natural biodiversity of forests in the researched area for the material use and therefore the impact on forestry was elaborated. In this sense, the thesis is joining the key concepts of Performance Oriented Architecture, 'non-discrete' architectures and 'non-anthropocentric' architectures, defined by Hensel (Michael U. Hensel, 2015a) and believed to represent its integrated approach (Michael Hensel, 2013).

This project joins full-scale prototyping with the Systems Oriented Design introduced by Sevaldson in 2005 (Sevaldson & Ryan, 2014), both as a research tool to complexity that is involved in the project. The GIGA-mapping involves relations of soft and hard data (Sevaldson, 2015) and was generated in transdisciplinary and transorganisational Rich Design Research Space (Sevaldson, 2008, 2012b). As the methodology is mainly used



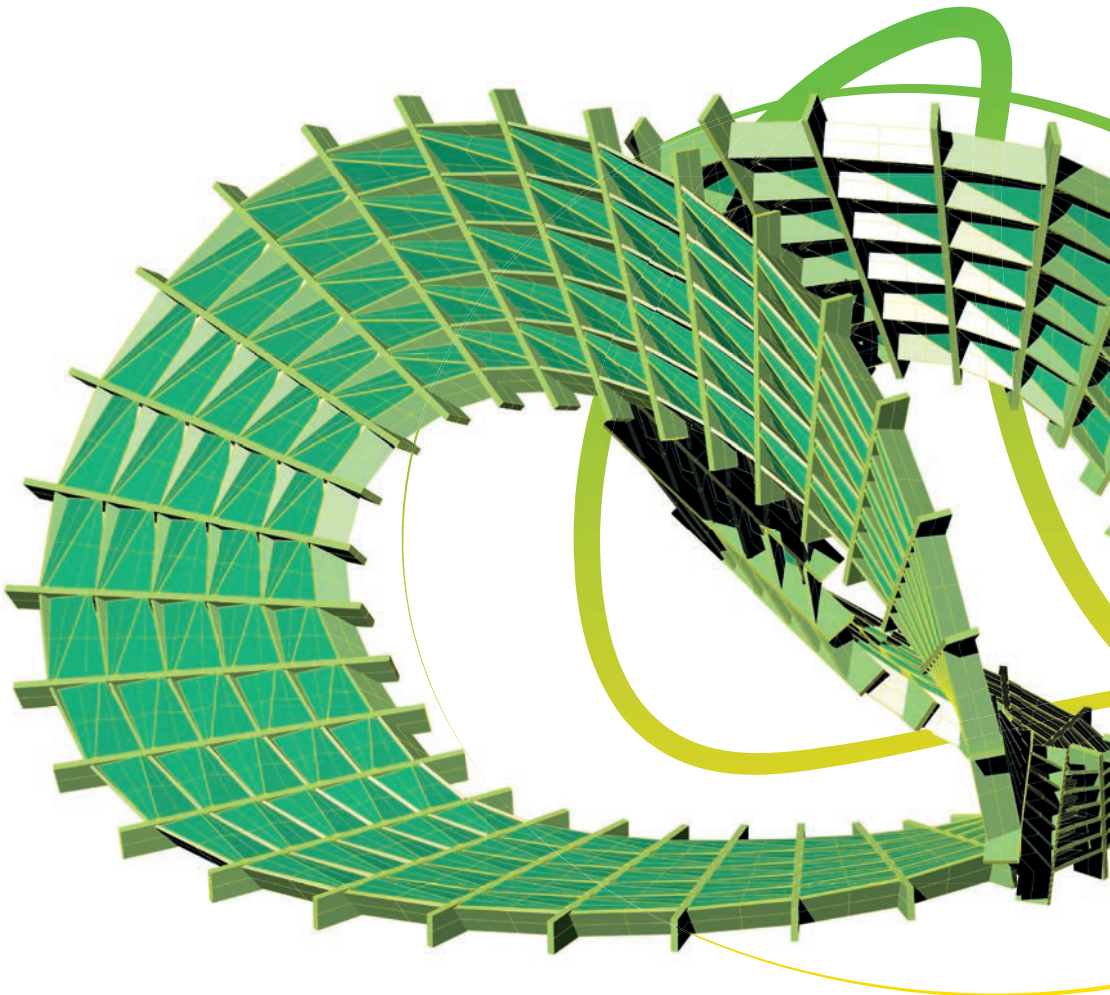
Figure 1: Our Everyday Mate at the EnviroCity Festival Sitting on the Loop Pavilion That Became a Symbol for the Festival's Events Announcements Graphics (photo: Škuta 2014)

in Service Design field (Wikipedia, 2016), my project developed its own tools for GIGA-mapping (Bjørndal Skjelten, 2014; Davidová, 2014d; Michael Hensel, 2013; Michael U Hensel & Sørensen, 2014; Romm, Paulsen, & Sevaldson, 2014; Sevaldson, 2011, 2013c, 2015, 2016a; Singh, 2013) related to the project's conditions and agenda. This involves use of a) images for employing parametric models, samples, prototypes, architectures and tacit knowledge through photography, b) its own libraries that also use degrees of curvature and gradient placements, c) matrixes and feedback loops. The GIGA-maps are thematic – one zooming into problem of the other, thus developing extended ZIP-analyses proposed by Sevaldson (Bjørndal Skjelten, 2014; Sevaldson, 2016d).

GIGA-mapping in this field of research requires much more exploration and unfortunately not even in this thesis all the themes that are discussed were mapped. The fact that the methodology is fully relevant and enriching to the field of Performance Oriented Design was previously proved through my personal experience of undertaking my master's course and diploma thesis at the Oslo School of Architecture and Design supervised by Birger Sevaldson and Per Kartvedt in 2006 and 2007 in this context but is also argued for by Hensel and Sørensen (Michael Hensel, 2013; Michael U Hensel & Sørensen, 2014; Michael U. Hensel, 2012b). It proved to be a data organizer and thus also an evaluation and design generator, discussion board as well as a presentation tool during the overall process. The rapid learning feature (Sevaldson, 2013a) gained its special meaning when it

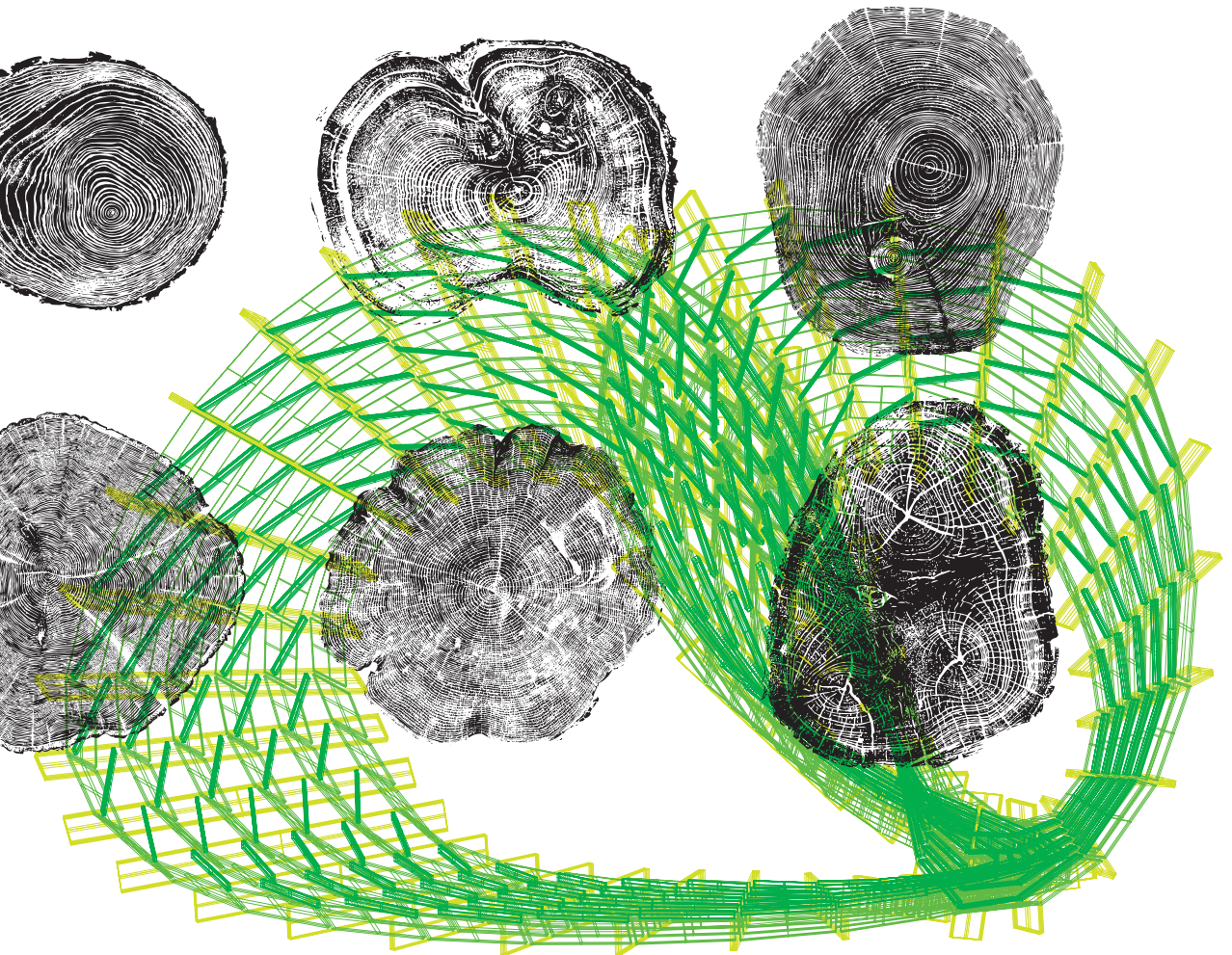
came to communication within the transdisciplinary teams as referred to by Sevaldson as a tool for collaboration (Sevaldson, 2011). This I namely explored at the very tight schedule of public furniture for communities prototyping workshop, Mood for Wood (Polish Architectural Association in Poznan, 2015) lectured by me and Šimon Prokop as Czech representatives within Visegrad countries, which involved both social and fabrication perspectives (see Figure 89).

This research proved that GIGA-maps can also serve as a presentation tool, which had been previously questioned. Our GIGA-maps developed in the course Environmental Summer Pavilion II (Davidová, 2014d; Sevaldson, 2016b; Slavičková, 2014) were publicly exhibited at the students' competition and exhibition Ještěd F Kleci (x-fatul, 2016) and next to the pavilion at the EnviroCity Festival (Davidová & Kernová, 2016; Kernová, 2014) at Cargo Railway Station Žižkov, showing the complexity of the design research process leading to a full scale prototype. Especially in relation to the physical pavilion prototype, the GIGA-map attracted an audience who became interested in the background of the project. This argues for the need for the connection of GIGA-mapping and prototyping discussed in the concluding paper of the methodology chapter.



4/

*Placement of My Research
into State of Art in Reference
to Material, Types of Prototypes
and Location*



This chapter covers the key concepts within the state of art and is setting my own research into its relation, while concluding on the selection of the material through LCA comparison of solid wood and plywood applied on my prototype Ray 2 for the location of Czechia. The selection is covering prototypes that have substantive contributions in the responsive wood field in the meaning of material research or the type of prototype application in relation to the environment or both.

The contemporary research on performative/responsive wood is mainly held by Michael Hensel and Defne Sunguroglu Hensel at the Research Centre for Architecture and Tectonics (Michael Hensel & Sørensen, 2016; Michael Hensel, 2012a) Oslo School of Architecture and Design (Oslo School of Architecture and Design, 2016) and by Achim Menges, Steffen Reichert, Dylan Woods and others at ICD University of Stuttgart (Menges, 2013).

The State of Art section generally suffers from lack of enough clear or deep information that has been published. While many examples can be found, explanation and/or significance towards the material research, dates and contributions of different persons and institutions involved are published insufficiently. In some cases, the memory of the authors, audience or even personal observations had to be used.

4.1 KEY DESIGNS – STATE OF ART

4.1.1 Traditional Norwegian Panelling

A natural property of wood is warping. When the material is cut in tangential section (see Figure 2) it generates so-called ‘cup’ across the grain (Knight, 1961).

Humidity-responsive panelling systems based on the tangential section were used in traditional Norwegian architecture with long boards nailed one on the top of each other in one orientation and were compared to today’s common solution by Larsen and Marstein in Figure 3:



Figure 2: This block of Douglas-fir was cut to show three planes: the transverse or cross-sectional surface (X), the radial surface (R), and the tangential surface (T) (photo by Randy O'Rourke from Hoadley, 1980 with the courtesy of Taunton Press)

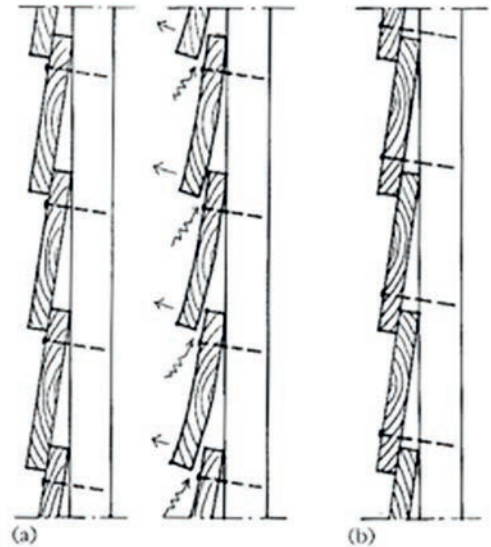


Figure 3: (a) Traditional wooden panelling in boathouses, Nordmøre, Norway. The boards are nailed towards the upper edge, just below the joint where they overlap. In dry weather, the lower board ends bend outwards, allowing dry air into construction. In wet weather the boards close again.

(b) Modern wooden panelling, Norway. The boards are nailed at the lower end. This ensures weather-tight panelling in all conditions.'

(Larsen & Marstein, 2000 with the courtesy of Larsen)

Unfortunately, there is not any further literature or knowledge possessed by the staff of the outdoor museums in Norway on this topic. From my observations, this panelling was also used in many variations on the cladding of the buildings with different use and as a screens on its semi-interior spaces 'svalgangs', discussed in the conclusion of the thesis on the west coast of Norway that is known for an oceanic climate with high humidity and rain (see Figure 4). It is important to note that some of the panelling I have seen was implemented in opposite performance.

The traditional structures are making airing gaps in the terms of millimetres.

From my observations, the triangular shape warps almost twice as much as the rectangular one.

In long boards there is even more difference.



Figure 4: Panelling of Storehouse from Nes, Øvre Valdsaroy in the Open-Air Museum in Oslo (photo: Davidová 2016)

Figure 5: Study of Asif Amir Khan (from M Hensel & Menges, 2006; with the courtesy of Hensel)



4.1.2 Morpho-Ecologies Project at AA School of Architecture

The first current example illustrating pine wood-humidity interaction is the study from 2004-05 by Asif Amir Khan (see Figure 5) in the studio of Michael Hensel and Achim Menges at the AA School of Architecture that provides more extreme performance organisation system towards openness and closeness, while also showing a relation of scale/size in two directions (M Hensel & Menges, 2006).

This project is not only mapping the material, but also the design in the means of size of the sheets/cells in relation to performance. According to the confirmation of the audience's observations when exposed in public space at Bedford Square, this prototype was based on laminated veneer, which showed great performance but seemed to be very fragile for any application. However, it has a great significance as a first basic research prototype in this field.

Within this studio other responsive wood projects had also been conducted, such as Aleksandra Jaeschke's Continuous Laminae project (2004-05), using hygroscopicity for creation of building elements, where a speculation on salt in relation to wood's conservation, that has been developed in this project, is mentioned (Jaeschke, 2006) and Joseph Kellner's and Dave Newton's project Metapatch (2004), related to plywood elements responsive screen through bending by force (Kellner & Newton, 2006). Though crucial and inspirational in the field, these projects are not elaborated in detail, for they don't directly relate to discussed performance.



Figure 6: Warped Project (from Khan, 2011 with the courtesy of Hume)

4.1.3 Warped

In 2008 Matthew Hume at the Centre for Architecture and Situated Technologies Department of Architecture, University at Buffalo in New York developed a humidity responsive screen based on plywood with a grain running in different direction, generating surface to curl (Khan, 2011) (see Figure 6). The overall research design process is presented in Hume's thesis, where he clearly states in the conclusion that the full programmability of the behaviour was not in focus (Hume, 2008). The screen was not designed for any specific use but to demonstrate the capacity of the composite material. To my knowledge, it is the first prototype using this type of performance of plywood. Thus, as the keystone basic research prototype, also in reference to durability, is of high significance.

4.1.4 Responsive Wood Architectures Studio

The Responsive Wood studio was held by Michael Hensel and Defne Sunguroğlu Hensel at the Oslo School of Architecture and Design since the year 2008. Within the course in 2009, the student Linn Tale Haugen experimented with odd numbers of layers to control the warping and directions of the fibre in the laminate to reach double curvature. (Michael U Hensel, 2011a; Michael Hensel, 2010b) .

Haugen took her project into diploma thesis in 2010 and also explored the performative plywood production process. She used two layers of beech veneer in the tangential direction for shrinkage and one in the opposite direction either from oak, which has lower tangential shrinkage, or beech veneer treated from the bottom side. With this composition, she managed to operate the bending of the composite (Haugen, 2010) (see Figure 7).

The thesis seems to be very substantial when it comes to composite material research that, thus far, has not been elaborated so explicitly in any available material and seems to be well durable. But her proposed projects are limited to the application within the field of product design. The potential of applications when it comes to performance within the field of architecture are not explored, as she points out in the thesis. The application



Figure 7: Haugen's Double Curved Plywood (from Michael Hensel & Sørensen, 2016 with the courtesy of Hensel)

of this on moulds suggested by Hensel seems to be an interesting topic to explore (Michael U Hensel, 2011a). It seems to me this would have to be performed at the first steps in climatic chambers and the relation of filling material interaction would have to be studied; at the second step it would be very interesting to see all three: a) the climatic conditions, b) the mould material, c) the filling material, in symbiosis.

In 2010, structural capacities of moist wood were explored in the same studio. The outstanding example was Wing Yi Hui and Lap Ming Wong's full-scale construction of a small pavilion for the Oslo Architectural Triennial in 2010 (see Figure 8), which demonstrated exploration of the use of moisture content for structure made of bent 0.75 mm veneers. (Michael Hensel, 2010b)

The pavilion exhibited basic research in structural capacity of moist wood and it is a crucial prototype in the meanings of curved light weight structures in relation to moisture content. It seems to me from my personal experience, that the 0.75 mm thin pine veneer would be too fragile for long-lasting structural application, but this requires more exploration. Our pavilion *pareSITE*, discussed later, used similar performance for locking torqued solid wood planks in a triangular structure. At some places the stresses were too high and also the use of screws joinery is not required for use on green wood. We experienced problems in the most stressed cells after a year of exposition to climatic conditions, some of them caused already through the winter. Also the assembly required much human physical force. I believe this area requires separate research towards this performance application.

Figure 8: Wing Yi Hui and Lap Ming Wong: Completed Pavilion for the Oslo Architectural Triennial 2010 (from Michael Hensel, 2010b; with the courtesy of Hensel)

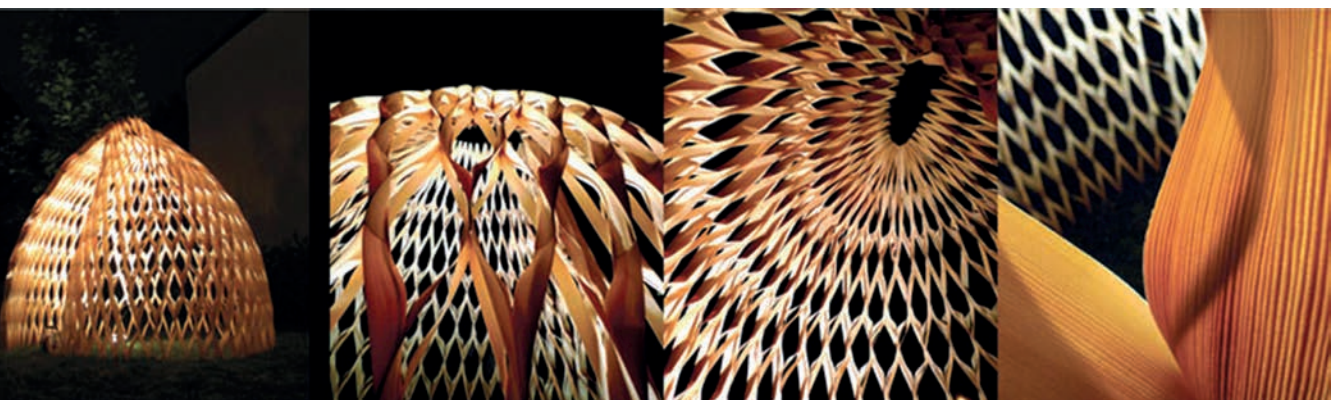




Figure 9: Achim Menges with Steffen Reichert: HygroScope – Meteorosensitive Morphology, Centre Pompidou, Paris, 2012 (from Menges, 2012; with the courtesy of Menges)

4.1.5 Responsive Surface Structure

In 2006 Steffen Reichert started to work on his Responsive Surface Structure project under the Department for Form Generation and Materialisation (Achim Menges), Hochschule für Gestaltung (HfG), Offenbach, Germany (Michael Hensel et al., 2008). Since then he has been continuing his research under the leadership of Achim Menges at the Institute of Computational Design at the University of Stuttgart.

As published in 2012, he managed to program different behaviour of veneer composites in relation to humidity by lamination. (Menges & Reichert, 2012) To my observations, such behaviour can also be programmed by the wood moisture content when solid wood is cut. The Responsive Surface Structure is a basic research which is not yet addressing rain resistance and industrial solutions for which, based on my observation, the suggested systems are far too fragile. But the, not fully explained, programmability seems to be crucial in the field. The project is still being developed and has resulted in several installations such as the HygroScope – Meteorosensitive Morphology pavilion (see Figure 9) discussed below and HygroSkin Pavilion in 2013. The planned research on solid wood has not yet been published.

In 2012 Achim Menges and Steffen Reichert built the humidity-responsive ‘Meteorosensitive Morphology’ pavilion at Centre Pompidou, Paris (see Figure 9), which seems to be the first public humidity responsive pavilion employing wood warping in interaction with environment. However, it appears to be basic research exhibiting pavilion, while not involving performance purpose or any human behavioural aspect, though it seems it had been inhabited anyway. It is also unclear if it worked as a prototype for its performance observations in relation to the environmental complexity of the location.

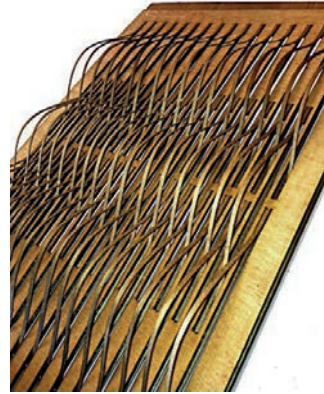


Figure 10: Microloop Panel
(from Weston & Greenberg, 2013
with the courtesy of Mark Weston)

4.1.6 Microloop Panels

Mark Weston and Dan Greenberg developed composite plywood Microloop panels (see Figure 10) that serve as a passive lighting control where the movement of two sheets is causing the attachments to bend. (Weston & Greenberg, 2013)

The authors claim the performance variation (Weston & Greenberg, 2013), however it is not clear how the lighting control relates to relative humidity of the air. It could be that the relative humidity is high when it's cloudy, so the sun radiation does not require shading while the wood composite reacts to it. At the end the authors discuss the performance in all the situations arguing for allowance of light penetration and diffused daylight while blocking direct sunlight. (Weston & Greenberg, 2013). It is therefore not clear how the material performance is used in another way than for aesthetic reasons. Furthermore, it is not clear in which circumstances the situation with the screen closure is at all wanted.

The authors state that the Microloop panels are produced in enough thickness for industrial production (Weston & Greenberg, 2013). This seems to be a step forward within the development for application.

4.1.7 Ray 2

Produced in summer 2013 according to my design, to my knowledge, Ray 2 (see Figure 11) is the first responsive prototype made of solid wood. It is the first prototype of project Ray, whose first concept was not physically prototyped, just digitally simulated.

Ray 2 is an environment-responsive screen made of solid wood. Through its 0.8 cm thick pinewood panels cut in the tangential section's material properties, combining the left and right side of the panels, the screen is airing in dry and closing in humid weather (Davidová, 2014e). The system is generating airing gaps in terms up to 16 centimetres in distance in 10%RH and 21°C. Ray 2 is one step more durable and/or sustainable in comparison to other prototypes in the field. In the case of sudden rain, it does not immediately react to the increased humidity level, but at the same time, it immediately resists direct rain.

The system was first simulated in Grasshopper for Rhino 5 based on the data from measured samples. Afterwards, a 163 × 163 cm prototype was produced from 16 rectangular pieces.

The prototype performed in a similar way as the initial simulation. The upper triangles warp outwards and the lower triangles inwards thus generating large gaps within the system. In the wet conditions the structure closes again. The prototype required further tuning as the system closes only in wet conditions and not in the case when the relative humidity is high. It is for that reason that the prototype was built from green wood.

For more information, go to the Projects section.



Figure 11: Ray 2 Prototype after Three Years of Being Exposed to Weather and Biotic Conditions
(photo: Yildirim 2016)



Figure 12: Closure after Artificial Wetting
(photo: Yildirim 2016)

4.1.8 PareSITE, the Environmental Summer Pavilion I

This interdisciplinary project involved students from the Architectural Institute in Prague (ARCHIP, 2016) and the students of the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences Prague (FLD CZU – CZU, 2016), tutored by studio course leaders: Marie Davidová – wood, Martin Gsandtner – coding, and Martin Šichman – structure.

PareSITE – The Environmental Summer Pavilion (Nam, 2013) designed for the reSITE festival (Barry, 2016) is a Möbius shaped structure built from torqued pine wood planks in triangular grid with half cm. thin pine wood triangular sheets that provide shadow and evaporate moisture in dry weather (see Figure 14). The solid wood sheets, cut in a tangential section, interact with humidity by warping themselves, allowing air circulation for the evaporation in arid conditions.

Fabricating studios building wooden pavilions already became common when it comes to plywood, i.e., pavilions at Bedford Square by AA School of Architecture in London or at the University of Stuttgart by Institute for Computational Design (Fleischmann, Knippers, Lienhard, Menges, & Schleicher, 2012; Menges & Reichert, 2015; Menges, 2012b; Self & Walker, 2010). This prototyping studio was exploring the performances and structural capacities of the hygroscopicity of solid wood cut in tangential section. PareSITE, as well as the later

mentioned Loop pavilion, was built as a prototype for complex environmental interaction observations, including overall biotic (also social) and physical aspects, as well as a methodology generator.

By being freely inspired by the performance of both, the warping of wood in the tangential section in Norwegian traditional panelling and oriental screens called ‘mashrabiyyas’ (Figure 13), this project aims towards generating a pleasant build up environment as an urban design through the concept of evaporating moisture and thus humidifying the air such as in orient. Today, European cities also suffer from arid conditions during the summer seasons. The principle of wooden ‘mashrabiyyas’ operates on the hygroscopicity of the material and its environmental conditions. At night, when the relative humidity is high, the wood absorbs moisture which is evaporated during the day (Davidová, 2014b). This is also often supported by cans with evaporating water (Fathy, 1986). The performance of these systems were often discussed by Michael Hensel, pointing out their overall complexities such as light passage, airflow, temperature, humidity of air current and visual penetration regulation between interior and exterior (Michael Hensel, 2013).

The project utilized the warping of 5 mm pine wood sheets in the tangential section for supporting circulation of humid air. The form of the pavilion did not allow subdivision into planar surfaces, but anisotropic properties of the material support torsion. The angles of cuts held the boards’ torsion together in the joint. 20 x 150 mm planks of green wood were used for the structure. (Davidová, 2014b)

The pavilion generated a pleasant environment for its visitors during the hot days of the festival and resisted wear from public use. But as mentioned above, we experienced troubles in most stressed triangular cells joins after one year of weather exposure.

For more information, go to the Projects section.



Figure 13: Wooden mashrabiyyas at the Mausoleum of Sultan Oljeitu, Sultaniyeh in Iran (source and with the courtesy of Wade, 2013)



Figure 14: pareSITE (photo: Zapletal 2013)

4.1.9 Loop, the Environmental Summer Pavilion II

This interdisciplinary project involved students from the Faculty of Art and Architecture at the Technical University of Liberec (FUA TUL, 2016) and the students of the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences Prague (FLD CZU – CZU, 2016). Studio course leaders were Marie Davidová – wood, Šimon Prokop – coding and Martin Kloda – structure.

The Loop pavilion (see Figure 15) follows the concept of the previous pareSITE project (Nam, 2013). This time the performance was increased by its spatial organisation, combination of the left and right side of the panelling and the overall form. The solar analysis affected the size of the sheets in relation to the wood's expansion due to humidity, as the panels were placed inside of the structure. The concept needs further research for extreme weather situations and structural capacities. The prototype became a centre of the EnviroCity Festival, becoming both a discussion generator as well as an observation tool for biotic-climatic environmental interaction.

For more information go to the Projects section.



Figure 15: Loop (photo: Davidová 2014)

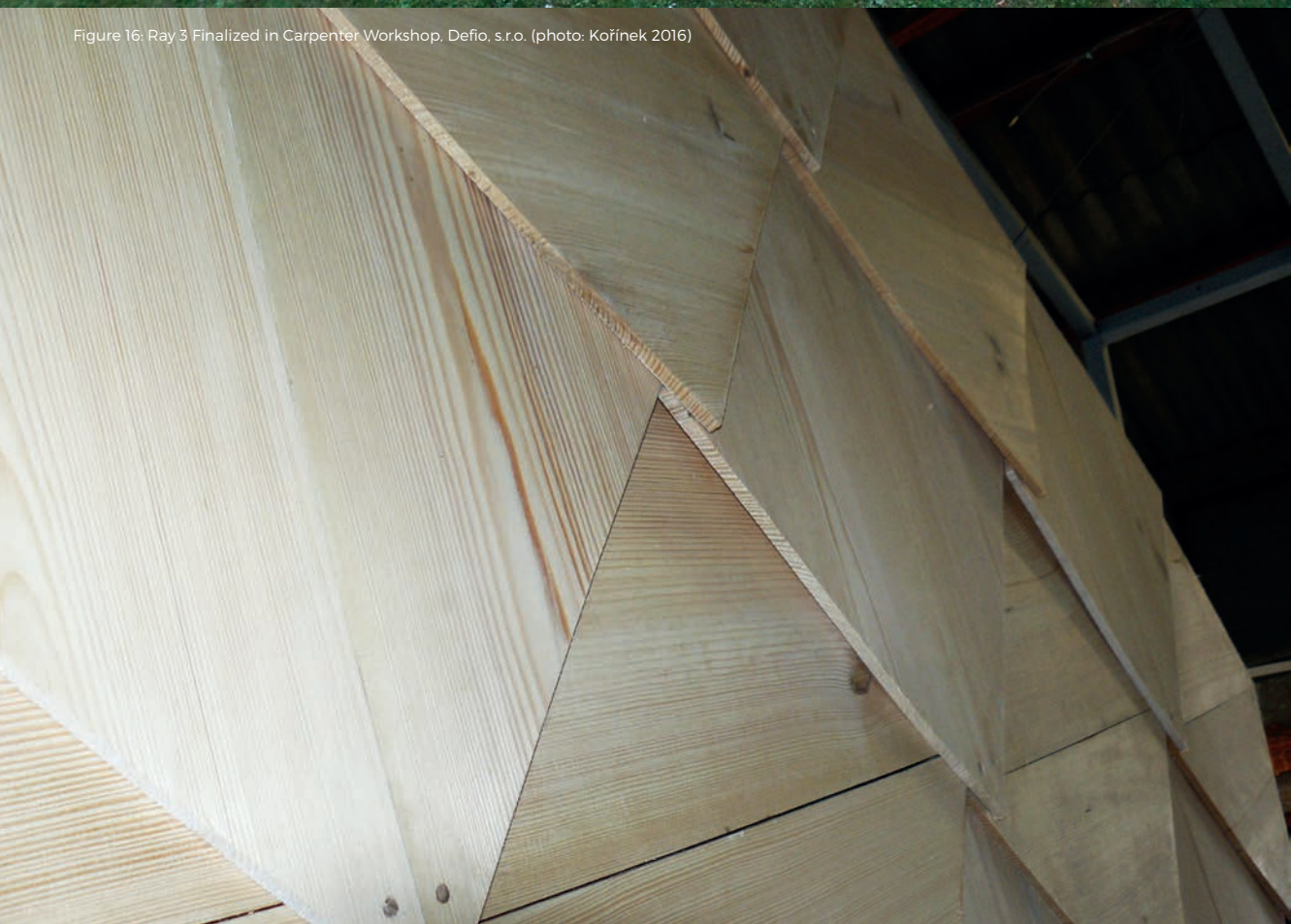


Figure 16: Ray 3 Finalized in Carpenter Workshop, Defio, s.r.o. (photo: Kořínek 2016)

4.1.10 Ray 3

Ray 3 (see Figure 16) is my second prototype of project Ray, whereas the first concept was not prototyped. It has proposed answers to the questions of durability of the 0.8 cm thick panelling and joinery and added a thermo-reflexive surface for better comfort of the semi-interior space. Its programmed warping will be observed over time. By now, it seems to be the closest prototype when it comes to application in architecture however, longer observations are necessary.

For more information, go to the Projects section.

4.2 LCA ANALYSIS COMPARING SOLID WOOD AND LAMINATES

(Davidová & Kočí, 2016)

The use of solid wood instead of plywood or laminates was coming out of the speculation on better sustainability and a healthier environment. Laminates don't really seem durable for architectural application. At present, for wood warping in plywood, a polyurethane glue is necessary. For that reason, the product is unrecyclable and may have a negative effect on the health of the environment. However, as more factors might be involved, I decided to evaluate environmental impact through Life Cycle Assessment analysis comparison for both solutions on case study of Ray 2 conducted for the environmental conditions of Czechia. This study was elaborated in our paper co-authored with Vladimír Kočí being in the press of the proceedings of Architecture In Play 2016 conference: 'Choosing the Material for Environment Responsive Screen: The LCA Comparison'. It is important to note that the study is site specific, using data for the Czech Republic or European Union when it is generally applicable for the year 2015. This kind of analysis doesn't consider speculations of future development, so the events expected to be applied in the far future are evaluated through present data. Therefore, the comparison serves as an argument for the current state in its location for a specific product, while different directions might be equal or even preferred in the future.

4.2.1 Abstract

Wood performs based on its material properties by shrinking, expanding or warping due to the changes in relative humidity and temperature. This property intends to be utilized in architecture for purposes such as ventilation or thermal comfort. This concept was developed in the design of Ray 2, a screen that airs in dry and is resistant in humid weather. Two material options are available. Following contemporary research, plywood could be used demonstrating the 'bi-metal' principle of different shrinkage of different wood species. In reference to the past, the tangential section applied in traditional Norwegian panelling, where different fibre density on opposite sides of the plate cause warping, was proposed for the prototype. The plywood research shows better programmability. However, our paper claims that the use of solid wood, at least in the Czech context for the particular product of Ray 2, is more sustainable and therefore it is in our best interest to explore past knowledge in the field. The data from the local manufacturers, as well as from the related universities, were utilized to compare both of the cases in LCA analysis (see Figure 17 and Figure 18) among all showing the energy savings and lower carbon emissions for solid wood.

Keywords: performance-oriented architecture; responsive wood; life cycle computer modelling; simulation of production complexity; solid wood versus plywood; sustainability

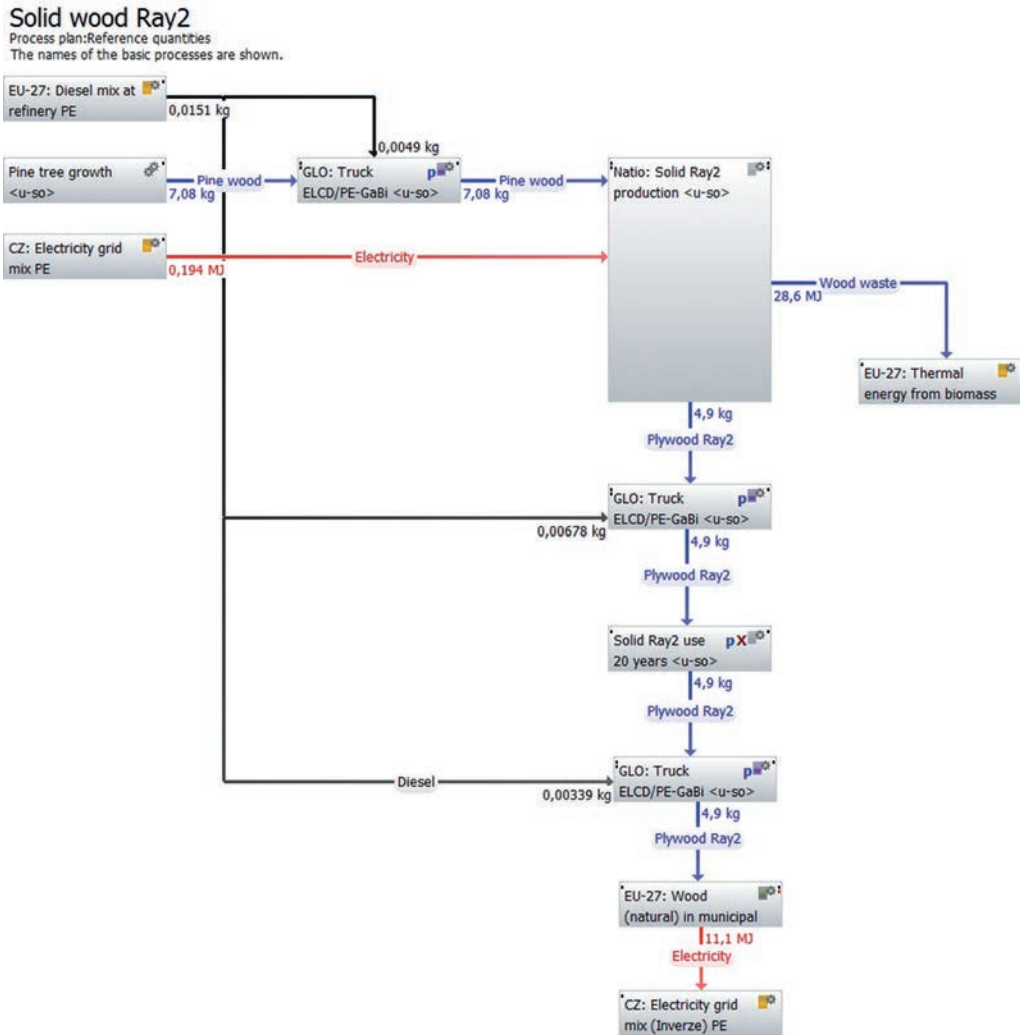


Figure 17: LCA Model for Solid Wood Based Ray 2 Screen Produced in Czech Republic (Kočí 2015)

4.2.2 Introduction

Wood is the main renewable and recyclable building material that has been tested over generations, though administratively rejected due to the fire issues in many countries. Our study compares two ways of its use for design of performative screen Ray 2 that reacts to relative humidity and temperature of the environment. It is worth noting that no analysis is able to predict the future and account for all the circumstances. However, we decided to compare solid wood and plywood material in LCA analysis for this particular design. The screen is designed to be used on buildings and therefore is not a conventional product. This difference for Life Cycle Assessment is explained by Bribián et al., stating that LCA was mainly targeted at other low environmental impact products than buildings. Reasoning the difference in long life span, frequent changes, multiplicity of functions, inclusion of many different components, local production, uniqueness, causing of local impact,

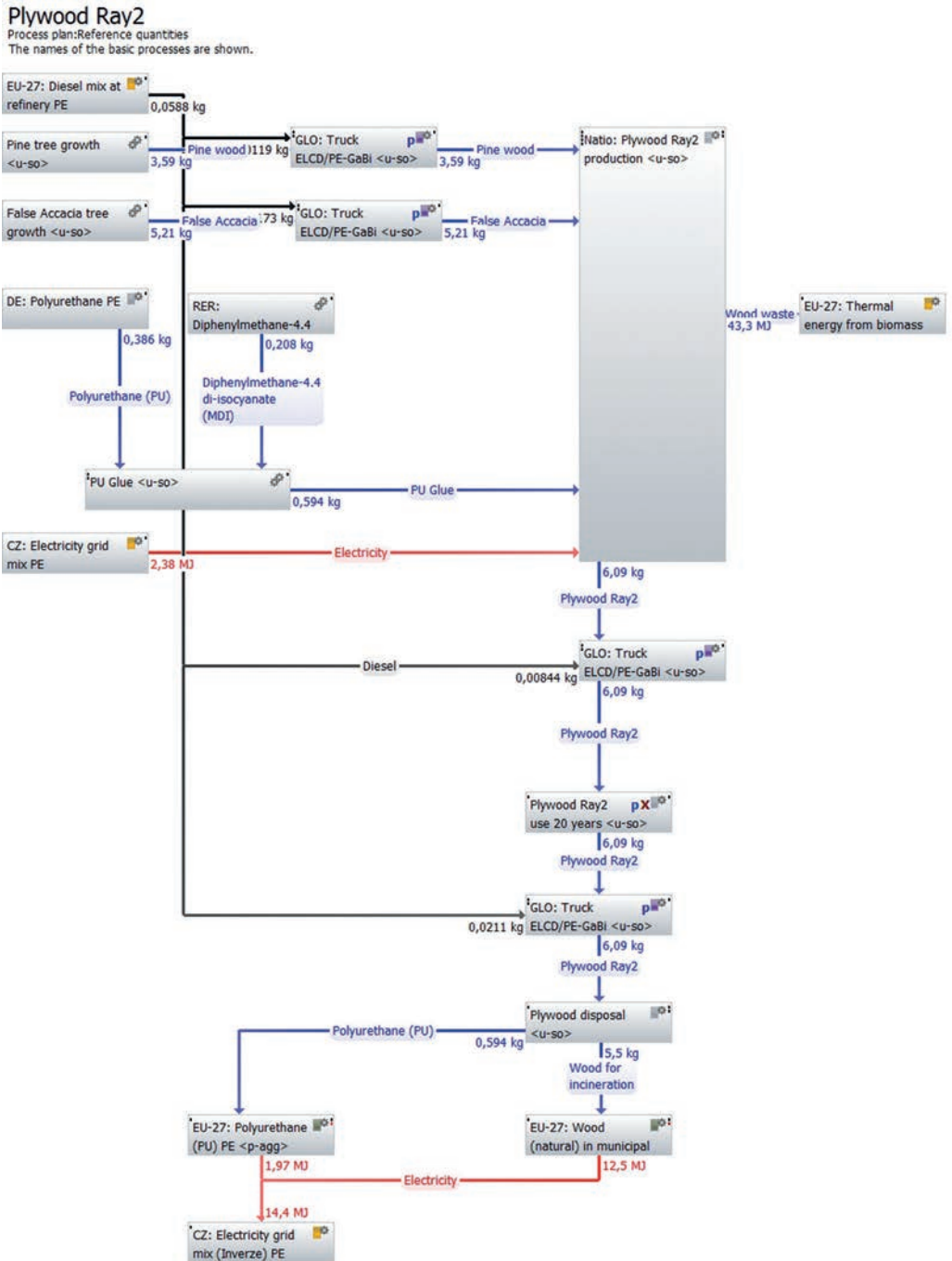


Figure 18: LCA Model for Plywood Based Ray 2 Screen Produced in Czech Republic (Kočí 2015)

integration with infrastructure, unclear system boundaries, etc. (Zabalza Bribián, Aranda Usón, & Scarpellini, 2009). All these facts have to be taken in consideration when discussing our results and utilized data. Our focus was in the comparison of two materials for one product in a certain location over an established period of time. The following summary explains the application for both of them.

4.2.3 State of Art

While the current research in the field has been conducted on laminates or plywood, the traditional architecture was applying solid wood, cut in tangential section, for the performance. Therefore the paper's research question is which approach is more sustainable for the particular first author's design in certain location.

The natural property of wood is warping. When the material is cut in the tangential section it generates a so-called 'cup' across the grain (Knight, 1961). Humidity responsive panelling systems based on the tangential section used in traditional Norwegian architecture were described by Larsen and Marstein:

'The boards are nailed towards the upper edge, just below the joint where they overlap. In dry weather, the lower board ends bend outwards, allowing dry air into the construction. In wet weather the boards close again.'

(Larsen & Marstein, 2000)

The first example in today's research, when the installation of Asif Amir Khan illustrated pine wood laminate-humidity interaction at the AA School of Architecture under the supervision of Michael Hensel and Achim Menges under Morpho-Ecologies project (M Hensel & Menges, 2006). The prototype provides more extreme performance in the organisation of the system towards openness and closeness, also showing the relation of scale/size in two directions. A Master thesis of Linn Tale Haugen supervised by Michael Hensel at the Oslo School of Architecture and Design proposed a way more durable plywood, performing on the different shrinkage of plies of different wood species (Haugen, 2010). Ray 2, the design by the first author, returns to the roots of Norwegian traditional panelling. It uses the fact observed on the samples that the tangential cut panels in the shape of triangles warp twice as much as squares. The system was explained as:

'...wooden environment responsive screen system that reacts to changes in relative humidity. Based on the material properties of wood cut in the tangential section, the system opens in dry weather, thus airing the construction, whilst in the humid conditions it closes, not allowing the moisture into the structure.' (Davidová, 2014e)

This refers to Berger et al. (Berger, Guernouti, Woloszyn, & Buhe, 2015), stating that moisture has an impact on the indoor air quality and the hygrothermal comfort of the building's occupants. From their observations on laminates, Holstov et al. (Holstov, Morris, Farmer, & Bridgens, 2015) conclude and suggest that the thickness of the active layer (means wood) is also the main factor affecting the response speed. Composites with comparatively thick active layers can be applied where the response to longer term changes in the surrounding conditions is required (i.e., daily, monthly or even seasonal changes), whilst thinner composites can react rapidly to hourly changes of ambient humidity or sudden rain. The thickness of the panels was selected at 0.8 cm as a compromise between amount of warping and reaction speed contra durability of the panel.

Samples observations prior to the decision were made hourly within 24 hours with the changes ranging from 10% to 90% RH on plates with the thickness of 0.3; 0.5, 0.8 and 1 cm when 1 cm was considered to perform too little and too slow and 0.5 cm was considered too fragile during the summer storms.

4.2.4 Conclusion for Material Selection Chosen for Comparison

This resume shows that current research at the other institutions has been done on laminates and plywood. Compared to the laminates, the plywood seems to be much more durable when it comes to vandalism, as it can combine the directions of the fibre. The laminates are very thin veneers with textile laminates that break

Figure 19: Ray 2 - Prototype after Three Years of Being Exposed to Weather (Davidová 2016)



very easily. Therefore, the plywood option was used for comparison with solid wood in Life Cycle Assessment analysis on the case study of the Ray 2 concept.

From the forest analysis of Central Bohemia, where the research is located, it became reasonable to use the combination of pine wood and false acacia. The solid wood model comes from pine wood. Pine wood is native to Central Bohemian forests (or Czech forests in general, as it grows there in all the places with low nutrients), therefore it is good to support its growth and harvest. At the same time it has very high performance when it comes to warping in the tangential section. On the contrary, false acacia is a dangerous, invasive species with no local enemies. False acacia should be harvested and its roots excavated, as it is the way it reproduces, poisoning the soil, thus disabling natural biodiversity. Pine wood and false acacia have reasonably different tangential shrinkage, therefore its veneers would perform well on the concept of so called 'bi-metal'. As a result, the species for both of the Ray 2 concept products were chosen, on one hand for its suitable material properties, on the other hand for its positive impact on local ecosystems with low carbon footprint during its transportation.

The speculation of the advantages of solid wood considered the energy and carbon emissions, but also the evaporation of poisonous chemicals. As Wójcik & Strumillo puts it:

'Today, remanufacture of timber, i.e., the production of timber derived sheet components and glulam beams, is a way to meet the needs of modern economy. That is not without an impact on the environment. Processing a material means energy expenditure and may have an impact on health risks posed by this material, and also on its recycling.' (Wójcik & Strumillo, 2014)

4.2.5 Method – LCA

The methodology of life cycle assessment used in this project was based on ISO 14040 (ISO 14040:2006(en), Environmental management — Life cycle assessment — Principles and framework, 2006) and ISO 14044 (ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines, 2006) with detailed specification according to EN15084 (EN 15804:2014 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products, 2014), that can be used as product category rules for construction products. For detailed evaluation of environmental impacts, not only were impact categories required in EN 15804 was calculated, but additional impact categories based on USETox (Henderson et al., 2011) and ReCiPe (Goedkoop & coll, 2009) were calculated as well.

The aim of the Life Cycle Assessment based comparison of the panelling compared to the Ray 2 design concept was to evaluate environmental burdens and/or benefits of having the panelling made of solid wood and or plywood. The functional unit chosen was one square meter of panelling possessing its fully-functioning ability for a reference lifetime of 20 years. In this study, the Life Cycle Assessment was principally performed on the production of panelling, its application including repair, and finally on waste management and energy utilisation of used wooden parts. Used system boundaries include wood production and atmospheric CO₂ utilisation and incorporation into wood biomass, panelling production, transportation, production of the ancillary materials and energy carriers, consumption of fuel and water, as well as atmospheric, aquatic, and soil pollution produced. The end-of-life phase of the panelling Ray 2 concept was modelled as in solid wood and/or plywood-contained energy recovery and its use for avoiding emission related to the production of the same amount of thermal energy.

LCA methodology was used to calculate the possible environmental interventions (inventory profile) and characterisation profiles (results of impact category indicators) (Koci & Trecakova, 2011). The pollution from diesel consumption and electric production, as well as the relevant processes dealing with polyurethane glue, were derived from use of the GaBi 6 Professional database (thinkstep).

4.2.6 Results and Discussion

Outputs of inventory analysis are summarized for following modules of life cycle: upstream module; transport; core module; energy recovery and end of life (EoL) module. Within upstream module all processes dealing with production of materials and energy carriers are included. Transport module covers production of during transport consumed fuels and emissions dealing with transport within all life cycle. In core module in site manual production of Ray 2 panels and its estimated repair during 20 years of use. EoL summarizes inputs and outputs within waste management and Energy recovery demonstrate potential benefits of use of wooden parts as biotic fuel during end of life of panels.

Solid wood Ray 2 needs a lower amount of all consumed resources and, in the case of the energy-carrying resources and water, avoids consumption of a higher amount of resources (expressed as numbers below zero). The main resource consumption is due upstream module and end of life module. Although during the core module there is principal consuming of Pine and/or False Accacia wood as a biotic resource.

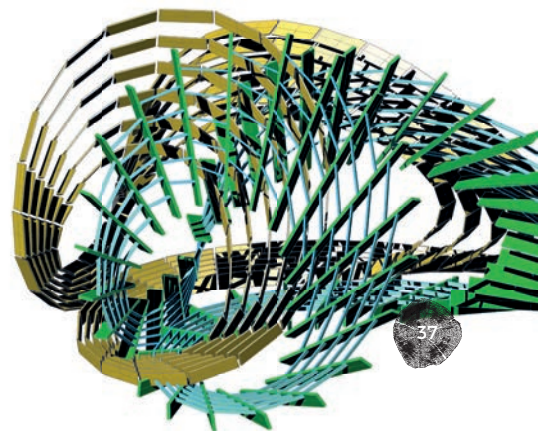
The assessment of possible environmental impacts was conducted using CML IA. USETox characterization was used for evaluating toxic and ecotoxic impacts of both scenarios. The ReCiPe characterization method was used for sensitivity analysis.

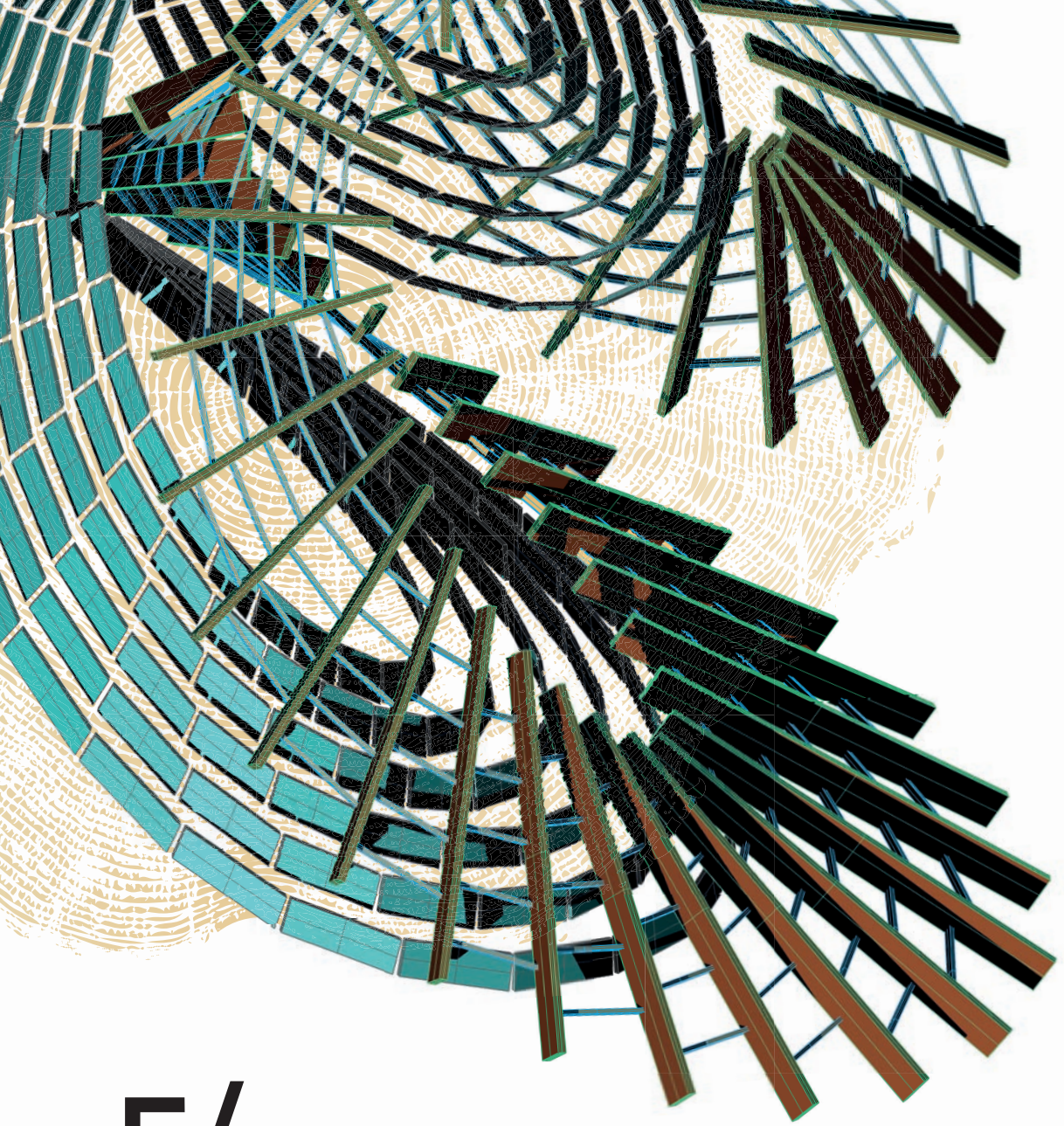
Similarly as in the evaluation of resource consumption results in impact categories due to the energy recovery of end-of-life wood and plywood express negative values, meaning the positive effect on the environment – so called avoided emissions/impacts. As the values decrease, the amount of avoided emissions rises. It seems that both of the products would be truly sustainable as the environmental impact of wood and wood products in general seems to be lower than other materials used in the building industry. This has been also concluded by a literary study comparing the results for cca. twenty years in Europe, Northern America and Australia by Werner and Richter (Werner & Richter, 2007). The LCA results argue for the use of solid wood with negative values in most of the categories. Therefore it seems that solid wood is more suitable for Ray 2 product for Czech Republic.

4.2.7 Conclusions

The experience of vernacular carpenters, accumulated throughout generations, has been overlooked during modern times and must be revisited through 'Research by Design' in transdisciplinary teams by samples observations and the construction of prototypes in 1:1 scale. The Life Cycle Assessment of wood and plywood panelling clearly demonstrated that solid wood-based panelling of Ray 2 exhibits substantially lower environmental impacts than plywood, having lower results in almost all the values for the Czech Republic. This statement is valid for all applied impact categories and is not sensitive to the selection of impact assessment methodology. Therefore, research on performative wood should also consider the direction of solid wood.

From the designer's perspective, it is an important fact that Life Cycle Assessment is utilizing the most up-to-date data even for the calculations of the future and not the speculations of its possibilities. In this way, the system avoids failures of predictions in development, but on the other hand, it is unable to be precise in its life cycle nor accurate in the evaluation.





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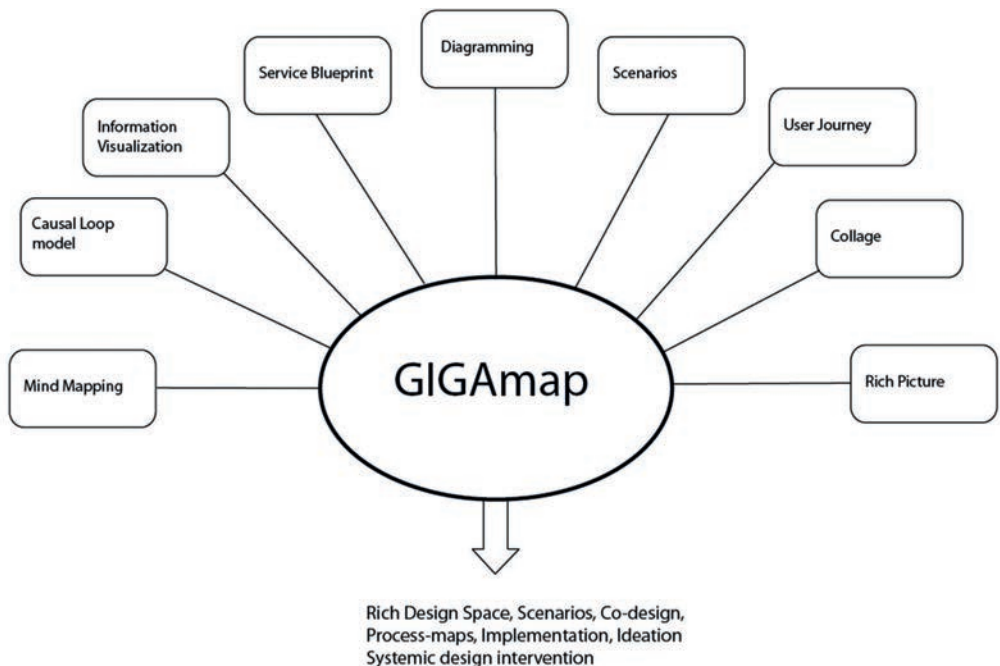
*Methodology:
Systems Oriented Design
and Research by Design
while 1:1 Prototyping*

In this section, the methodology of the research that was also explored within itself is explained. It covers transdisciplinary co-working, full scale prototyping and employment of different organisational structures within Research by Design, all utilised in Systems Oriented Design.

Systems Oriented Design was introduced by Birger Sevaldson in 2005 (Sevaldson & Ryan, 2014), is being developed by Birger Sevaldson, Michael Hensel and Defne Sunguroğlu Hensel (Sevaldson, 2013b) and others and is applied in Research by Design. It has its origin in design practice, design thinking and the complexity theory and systems thinking. Sevaldson argues that the changes in our globalized world and the need for sustainability demands an increase of the complexity of the design process (Sevaldson, 2013b). A base of Research by Design in Systems Oriented Design is the concept of Rich Design Research Space. It covers physical, social and digital space in which different actors play their role. Sevaldson shows that the design investigations are combined with cycles of observation, registration, and reflection within the research-design process. (Sevaldson, 2008)

In my case, the Social Design Research Space is represented by trans- and interdisciplinary networking of i.e., architects, coders, wood scientists, carpenters, the building industry, environment designers, structural engineers, dendrologists, algologists, climatologists, artists and art and architectural theoreticians, culturologists, stage designers, dancers, musicians and actors-some individual, some related to different organisations. The network was and still is growing based on the needs of the project and opportunities. The design is informed by transdisciplinary knowledge and skills, my personal measures of the samples, the prototypes and the biotic and physical environmental relation to it, simulations combined with the measured data, all discussed through personal experiences. The process is based on visualisations of such complex transdisciplinary relations via GIGA-mapping (see Figure 20). GIGA mapping is a diagramming of related knowledge that covers the design process. Sevaldson describes it as follows:

Figure 20: GIGA-map Map (Sevaldson 2014 – with the courtesy of Sevaldson)



'GIGA-mapping is super extensive mapping across multiple layers and scales, investigating relations between seemingly separated categories and so implementing boundary critique to the conception and framing of systems... GIGA-mapping is creating an 'information cloud' from which the designer can derive innovative solutions. While mapping in general is a way of ordering and simplifying issues, so to say 'tame' the problems, GIGA-mapping intends not to tame any problems. GIGA-maps try to grasp, embrace and mirror the complexity and wickedness of real life problems. Hence they are not resolved logically nor is the designerly urge for order and resolved logic allowed to take over too much and hence bias the interpretation of reality.' (Sevaldson, 2011)

From my observation, it is good to start with creating a GIGA-map straight during the literature study and updating it within the process. A GIGA-map certainly helps in leading the design phase in developing a complex product next to the simulation techniques, which in my case were mostly generated in Grasshopper for Rhino 5 based on the registration of the behaviour of the samples. Following a Systems Oriented Design process through GIGA-mapping led directly to the final prototypes, research conclusions, questions and discussions on further development.

My working paper 'Generating the Design Process with GIGA-map: The Development of the Loop Pavilion' explains how GIGA-mapping and online tools can be used in teamwork while designing and prototyping the Loop Pavilion and cooperating on the project in different locations. The paper introduces MINI-maps for fast concept sketching and physical GIGA-maps that can be reorganized during the overall process by using printed images, pins and threads.

The discussion in the paper 'NGO, Practice and University Driven Research By Design on Performative Wood' co-authored with Sevaldson opens the question, if the, by now only referred to, connection of research with practice in Research by Design is enough for experimental architecture. It is showing the example, how NGO's, practices and universities were joint within this project, arguing for better flexibility and potentials of such. It is also opening the discussion of observations of material performance through interactions of performers' performance and opportunistic use inhabitation, that was clearly possible through NGO's involvement.

The paper '1:1, A Transdisciplinary Prototyping Studio' co-authored with Sevaldson explores the necessity of full-scale prototyping in comparison with the results obtained through samples observations and simulations and how the transdisciplinarity can be involved in such.

The recently submitted paper 'Systemic Approach to Architectural Performance: Handling Data in Creative Design Process: Mixing Physical with Digital' is concluding the use of tools involved within the design-research processes, arguing for the present necessity of development of project specific methods and proposing speculations for their further development. Instead of today mixing media, all interrelated in one physical performative environment GIGA-map is envisioned for the future.

5.1 GENERATING THE DESIGN PROCESS WITH GIGA-MAP: THE DEVELOPMENT OF THE LOOP PAVILION

(Davidová, 2014d)

This paper was formerly published in: Relating Systems Thinking to Design 3 Proceedings 2014. It explores the potentials of GIGA-mapping within teamwork, where the GIGA-map becomes a discussion board with registered deadlines that can be reorganised several times according to the current design stage while still keeping the schedule on track. Through the hands on discussion on different data and proposals it becomes a generator and organiser of the design and its process within the Rich Design Research Space. It also introduces MINI-maps as kick offs for the project.

5.1.1 Abstract

This interdisciplinary project involved the teamwork of the students from the Faculty of Art and Architecture at the TUL in Liberec and the Faculty of Forestry and Wood Sciences at the CZU in Prague under the leadership of myself, Šimon Prokop and Martin Kloda. Various disciplines, such as mathematicians, software developer, structural engineer, mechanical engineers, urban planners and arts managers were included within the design process. The goal of the one semester lasting studio course was to build a wooden, environment responsive, pavilion that hosted cultural events in June 2014 of EnviroCity festival. The pavilion absorbed the humidity at night, while evaporated it the arid sunny afternoons. Its panelling generated the circulation of humid air.

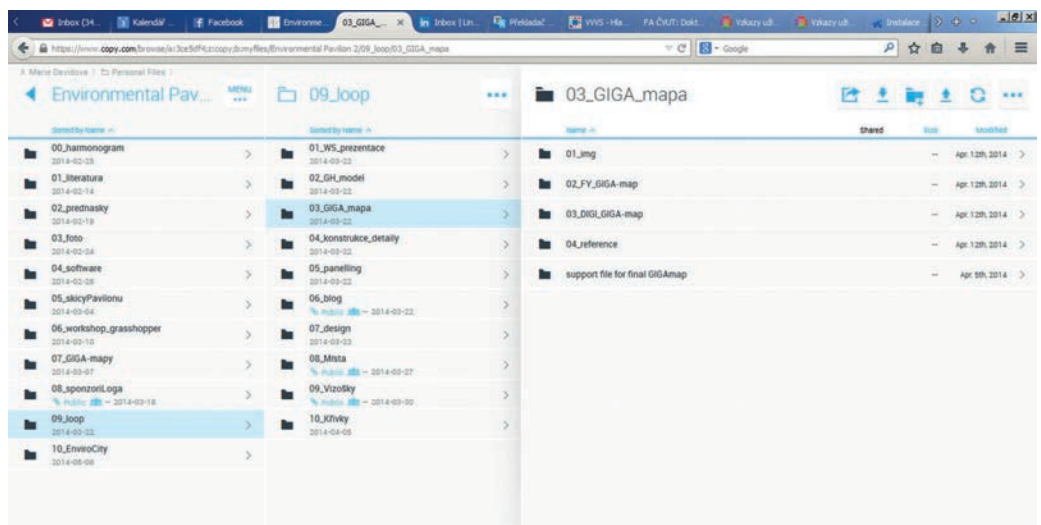
The research method was Systems Oriented Design, Physical Modelling, Parametric Design, File to Fabrication and 1:1 Prototyping, where GIGA-mapping became the all covering working tool of the design process. Besides the literature, the students used my own GIGA-map of performative wood research as a study material for the starting point. The overall knowledge was mapped on the paper board on the table. To use the table instead of wall is recommended by Birger Sevaldson for the reason of better interaction of the participants. (Sevaldson, 2012a)

After the discussion we decided to map and predict our design process. The timeline with proposed time schedule of the course and different roles and responsibilities of the participants were drafted. All the results and expectations were put on the board and discussed in the team. In that sense, the design process of the overall team was generated and controlled by the GIGA-map.

5.1.2 The First Step

Before the course started, the students were invited to online folder on Copy, used for file sharing. Copy allows more data space than Drop Box, but we were struggling with real time. There students could find there related literature and time schedule of the course. The first day started with all day lectures on the topic area and information on the first task. We established a Facebook group for the online discussion as the students were located in different cities. Whenever somebody uploaded something to Copy folder, started also a discussion on FB. Copy folder had very organized structure.

Figure 21: Copy file sharing (Davidová 2014)



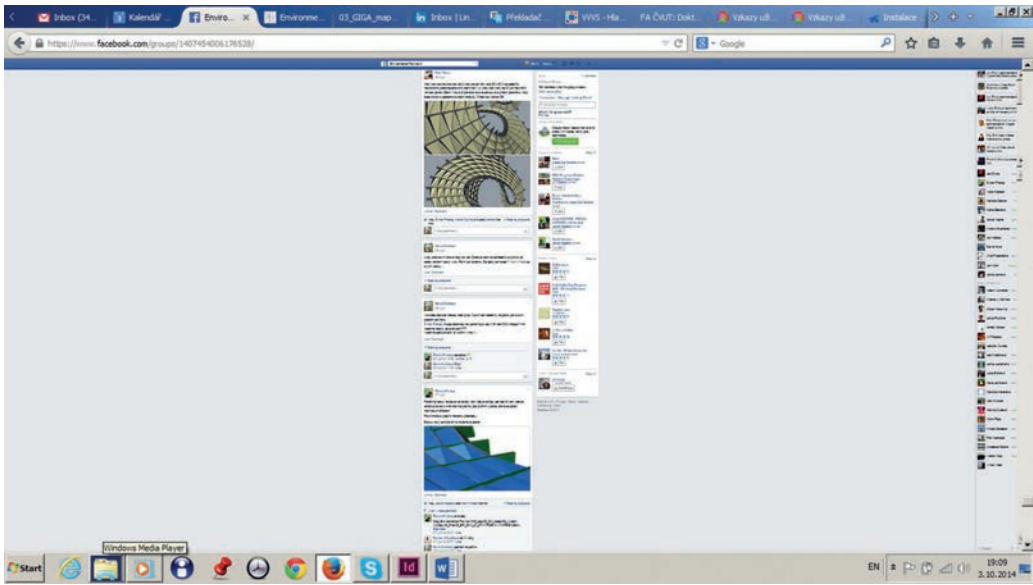
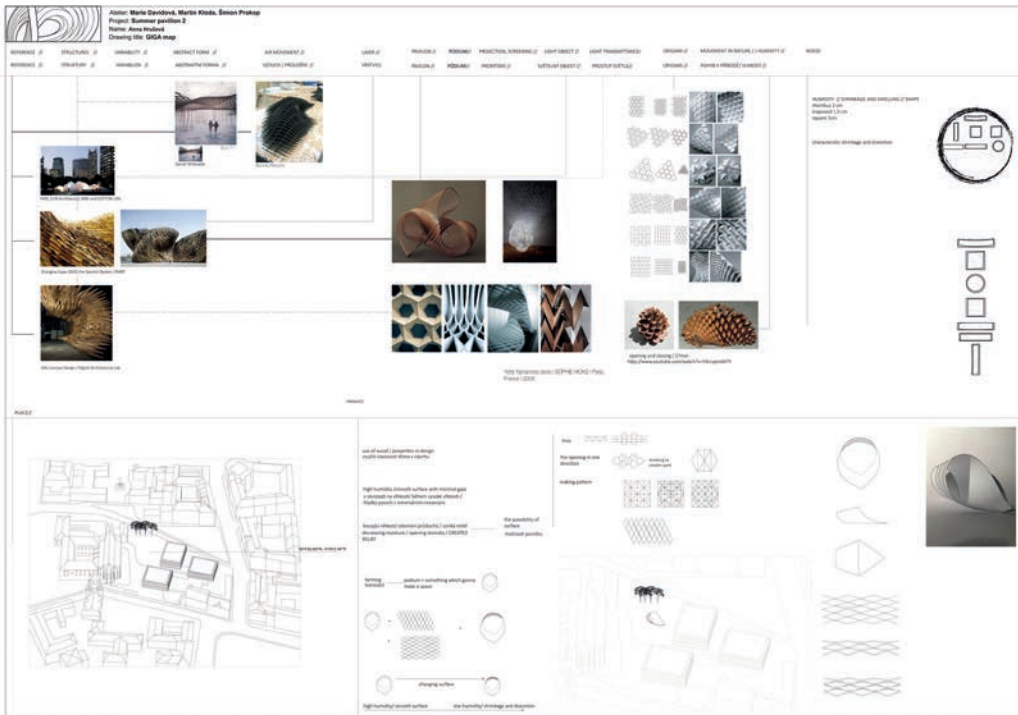


Figure 22: Discussions on Facebook group (Davidová 2014)

Figure 23: 1st stage MINI-map (Hrůšová 2014)



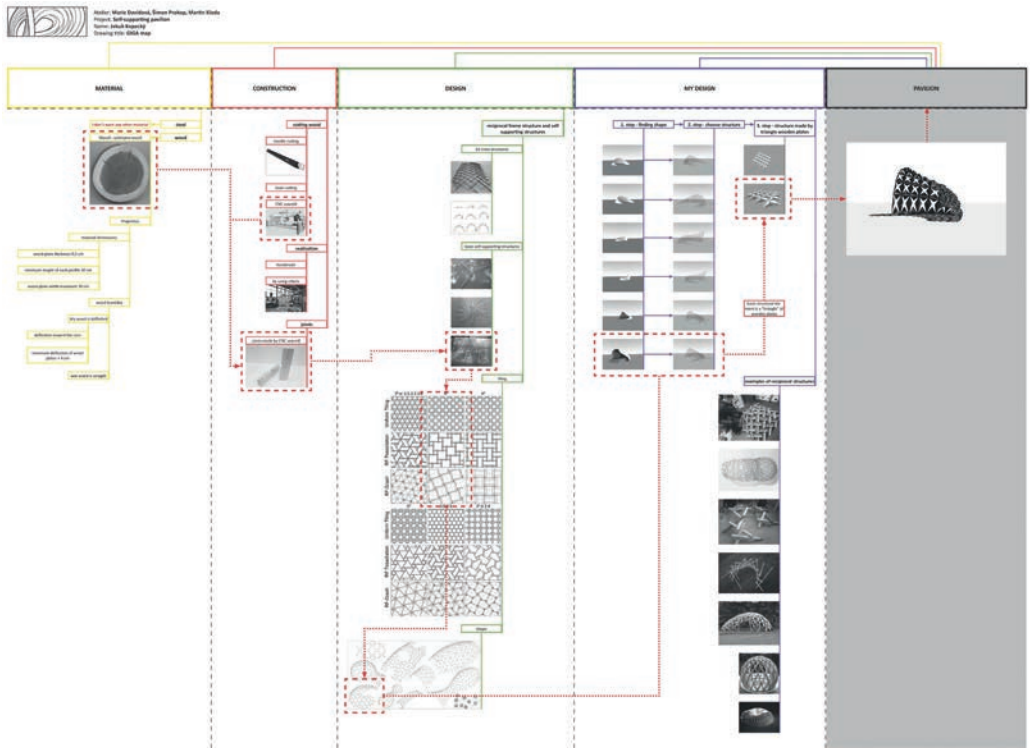


Figure 24: 1st stage MINI-map (Kopecký 2014)

The students got two weeks for designing the concept of environment responsive pavilion from solid wood and creating a MINI-map of their research and design development. MINI-map, as opposed to GIGA-map doesn't cover about 300 items but else, it has the same mission.

'GIGA-mapping is super extensive mapping across multiple layers and scales, investigating relations between seemingly separated categories and so implementing boundary critique to the conception and framing of systems...' (Sevaldson, 2011)

In the sense of Performance Oriented Architecture, which was the goal of this project Michael Hensel is adding: *'GIGA-maps can be also used when exploring different strategies and approaches to integrating the different traits of performance-oriented architecture and help maintain an overview over directly or indirectly affected conditions.'* (Michael Hensel, 2013)

It was interesting to note, that not all the students were successful with MINI-mapping and created them ex-post. However, they were able to involve themselves, working in the team on big GIGA-map. The students tested several software for generating the map but at the end, the Illustrator was selected as the main tool, allowing enough complexity in the relations. The same fact was also mentioned by Sevaldson. (Sevaldson, 2013c)

Anna Hrušová's map was covering different inspirations stages with material and site analysis that lead directly to the design.

Jakub Kopecký started with the knowledge of the material then he explored the possibilities of tools we could use, followed by selfsupporting structures study that inspired his design.

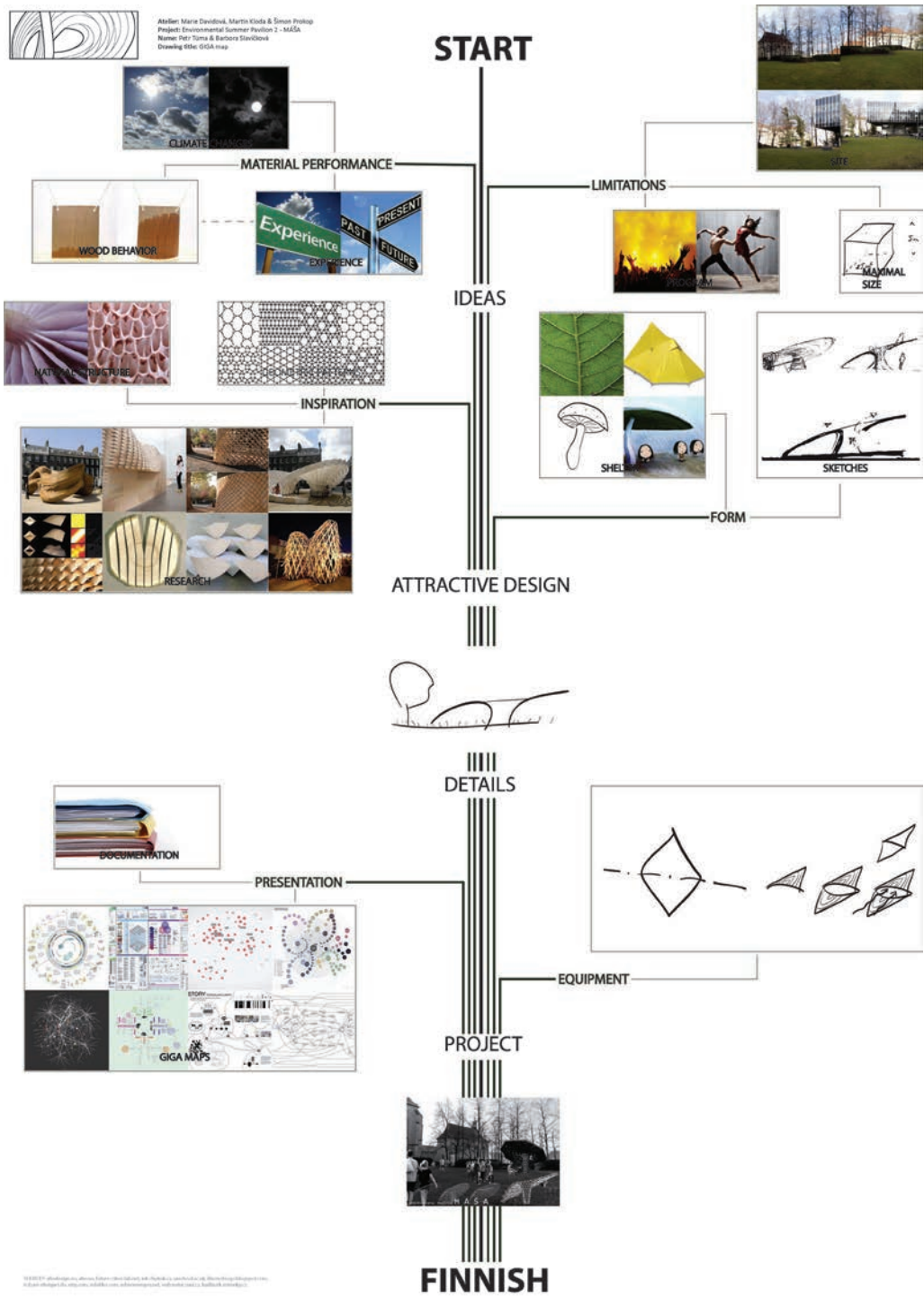


Figure 25: 1st stage MINI-map (Slavíčková & Tůma 2014)

Barbora Slavičková and Petr Tůma had a different approach from the others. Their process started with putting the stickers on the board. This method very well enabled them to collect data, on the other hand they struggled with connecting the relations. But in the end, when they were forced to make an order in their data and create the map in PC, they succeeded. Their map was showing all their design from the start to the finish of the task, covering the collected knowledge.

Sevaldson does not recommend the sticker method for the exactly same reason – struggling with relations (Sevaldson, 2012a) but the result by the translation into PC was successful. Barbora and Petr were the only students who worked in group. It might mean, that the stickers can well work as a starting point for fast communication in the team.

However, we decided to follow the recommendation and use thumbtacks further on for a big GIGA-map that was covering the teamwork on selected project that was to be built.

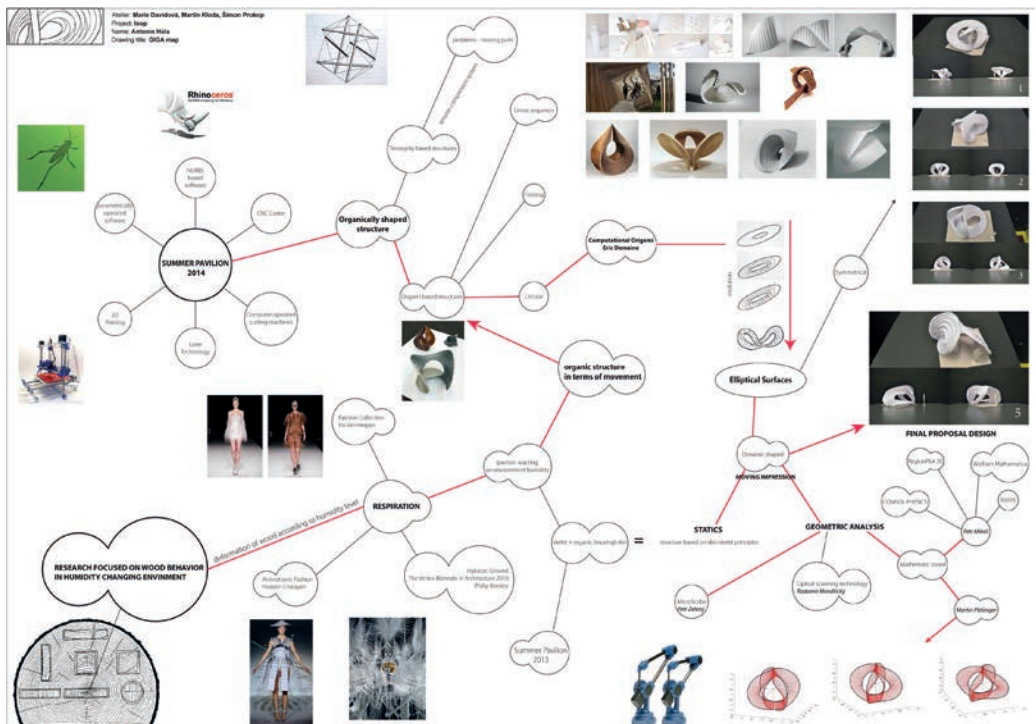


Figure 26: The winning design MINI-map (Hůla 2014)

5.1.3 Work on the Winning Design

Antonín Hůla's selected design was origami based, folded ellipse. It immediately asked for different professions who got involved in one big paper based GIGA-map. In the same time, the design of PC based GIGA-map was drafted and had an effect on the paper based one.

We decided to create time based board which was covering my own GIGA-map in wood research, all the findings from the MINI-maps from each student and started adding another professions involved. The board was set by the time line from the preliminary course schedule. This way, all the participants had an overview, in which

DESCRIPTION OF FOLDING PROCESS

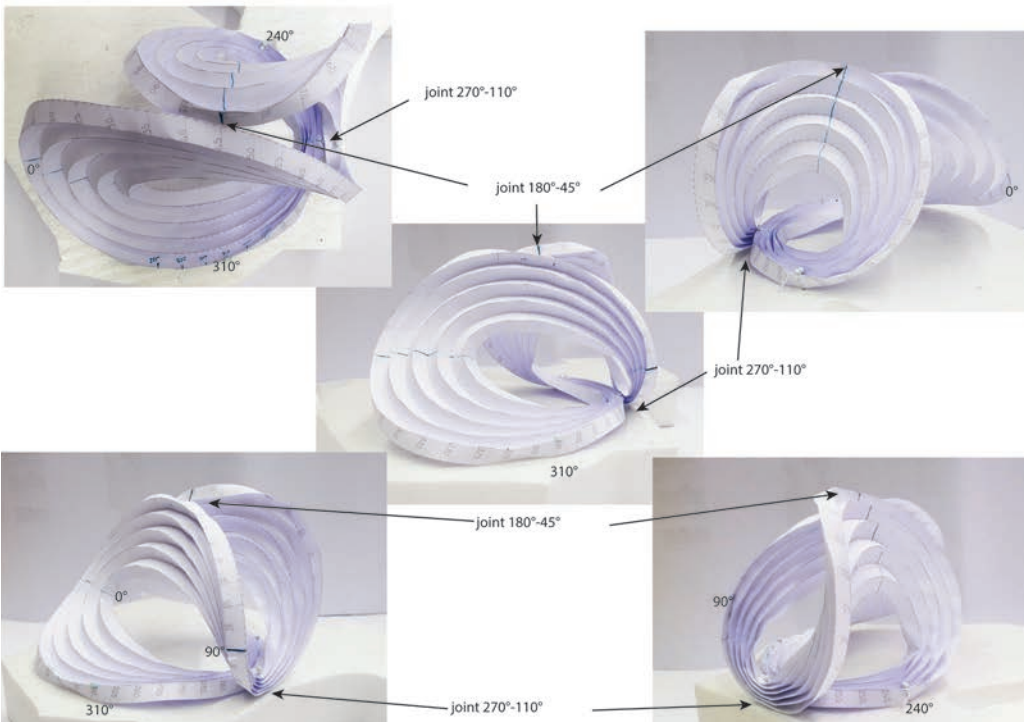
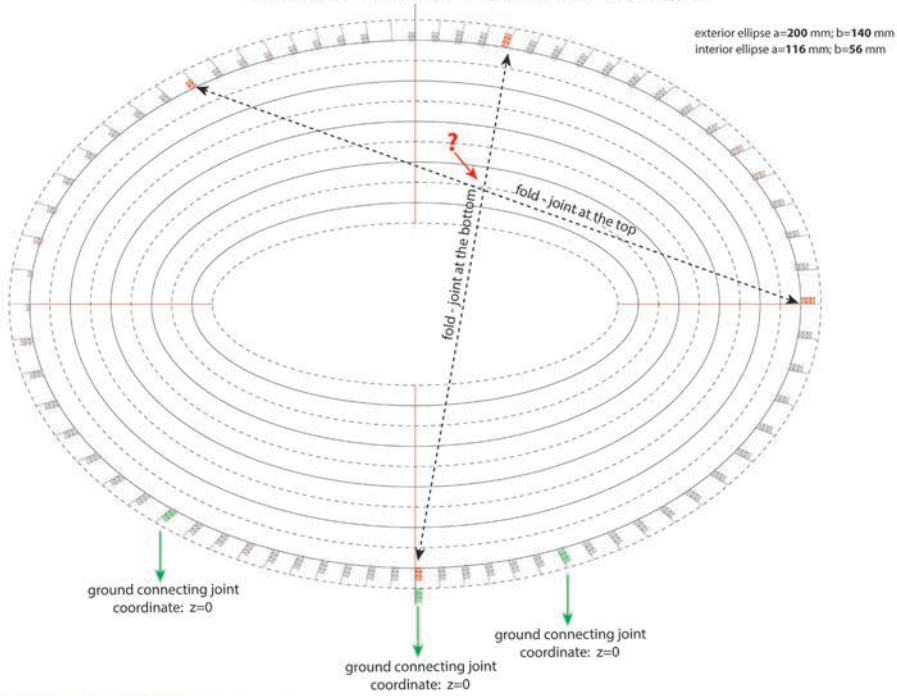


Figure 27: Loop Pavilion – the winning design (Hůla 2014)

design stage they were positioned and were aware about the deadlines. The time based mapping for the groups is explained by Sevaldson:

'Mapping in groups has an effect on dialogue. It fosters dialogues and collaboration. Especially the short workshop types developed for strategic meetings in leader groups has a very strong impact on the dialogue. These most often are time based maps that follow a timeline. The time line is used as a sorting device that is immediately understood by everybody. This sorting device allows the group to skip the agenda, as long as one has a theme to investigate. The conversation is allowed to jump back and forth. Jumping in the discussion is done easily because everybody is brought along in the jump by pointing to the time line. The conversation stays focused on the topic but remains open ended and holistic.' (Sevaldson, 2013c)

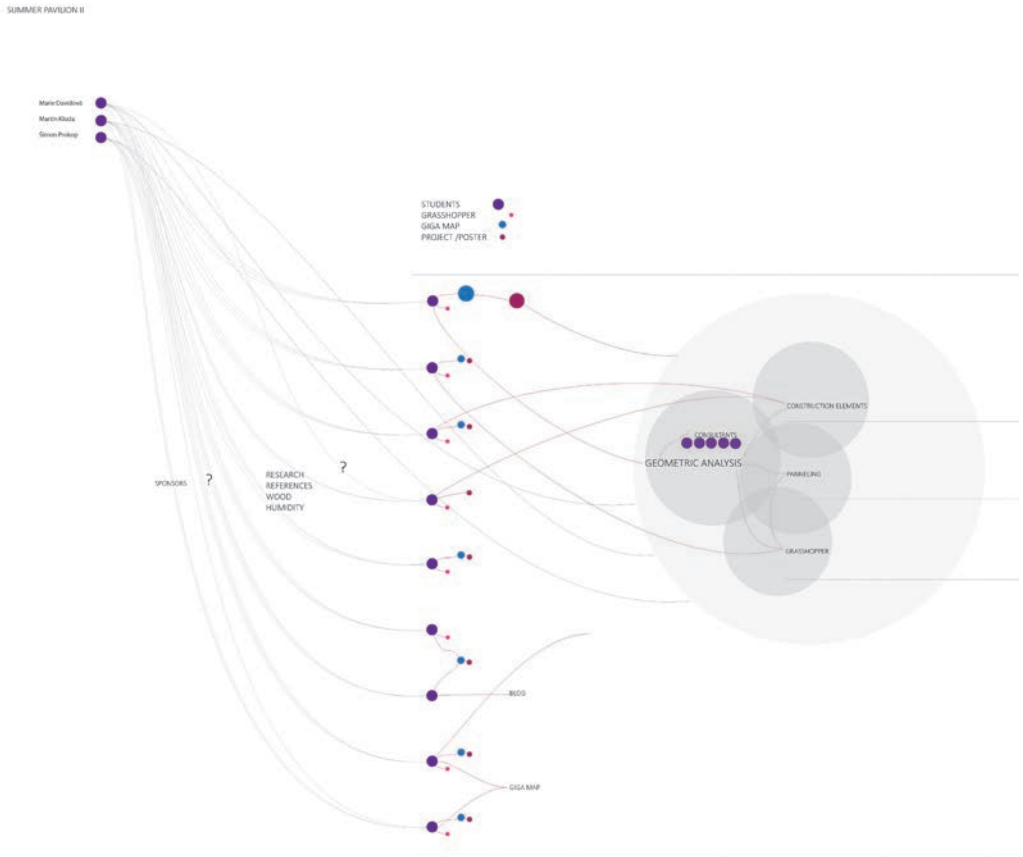


Figure 28: Draft concept of the final GIGA-map design (Hrůšová 2014)

The students were divided into six different, interrelated groups with special responsibilities and communicated among each other, as well, as with different professions through GIGA-map, where every group had its own line that was corresponding to the others. Further on, in the process of mapping, the groups were replaced by topics of research, where the roles were mixed.



Figure 29: WIP board based GIGA-map (photo: Pokorný 2014)



Figure 30: WIP board based GIGA-map (photo: Pokorný 2014)

We used pins and strings for the physical GIGA-map, so, it could be easily reorganized all the time during the discussion. All the files were printed and moved all over.

The final GIGA-map didn't respect the timeline but the research topics took the main place at the end.

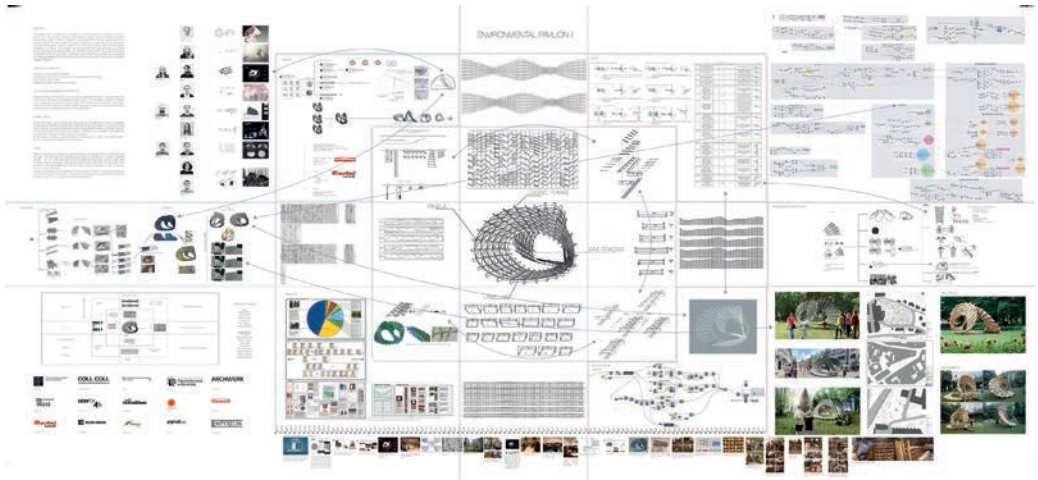


Figure 31: Final GIGA-map (FUA TUL & FLD CZU 2014)

5.1.4 Conclusions

The GIGA-map was raising new questions in the design process and therefore generating it.

Its time basis created an overview and control about the design stage and deadlines.

It was a great tool for the other professions to get overview of the project and to involve themselves more, than to be just asked questions.

It was a good tool to draft the design concept of the paper based GIGA-map in the PC first.

Creating a MINI-maps for each individual student/group was a good starting point that lead the students into the study.

The use of my own research GIGA-map gave a good study material for the students, who, thanks to the time schedule, couldn't go deep into the wood research themselves.

The time-line GIGA-map was a good tool for the process but might not be working for the final representation.

The sticker method might work, but only in the very first stage of the GIGA-mapping.

The method with pins and string was very helpful for the discussion and development.

The complex overview helped us to develop the concept of performative wood!

5.1.5 List of Participating Students

Alena Novotná, Anna Hrušová, Antonín Hůla, Barbora Slavičková, Jakub Kopecký, Jiří Fáber, Jiří Pokorný, Petr Tůma, Tereza Jílková, Radim Sýkora, Eliška Antonyová, Tereza Lišková, Filip Janata, Tomáš Kytka, Marie Kortanová, Vojtěch Holeček, Martin Vaníček, Jakub Hlaváček and Petr Havelka.

This project would never happen without a kind support of the Faculty of Forestry and Wood Sciences and the Czech University of Life Sciences in Prague, the Faculty of Art and Architecture at the Technical University of Liberec, Stora Enso, Rothoblaas, Nářadí Bartoš, Eurodach, Lesy ČR, Natura Decor, Easy Moving, Nadace Proměny and Collaborative Collective.



Figure 32: Loop Pavilion (photo: Novotná 2014)

5.2 NGO, PRACTICE AND UNIVERSITY DRIVEN RESEARCH BY DESIGN ON PERFORMATIVE WOOD

(Davidová & Sevaldson, 2016b)

This paper is currently in the press of the DCA 2016 conference proceedings. It discusses more options for relating different partners within Research by Design than just academy and practice and how their roles can be mixed and interlinked. Thanks to involving NGO's into play, it is also introducing research observations through what Uexküll defined as individual Umwelt in 1936 (von Uexküll, 2009) within interaction of enacted and/or embodied (Merleau-Ponty, 2002) field by different professions, institutional status members, gender and age agents that are engaged in social aspects. To this mix of collaborators and interactors applies in a similar fashion as to the mix of tools discussed in last sub-chapter of this chapter, in which it is not elaborated in detail.



Figure 33: Loop pavilion: Light Performance: Lunchmeat;
Dance Performance: Jana Vrána (photo: Dvořák 2014)

5.2.1 Abstract

The present paper discusses the possibilities of a relationship between academy, NGOs and practice in Research by Design on the case study of the first author's PhD research in performative wood and chairing of NGO Collaborative Collective, o.s. (Collaborative Collective, 2012). The more common link to commercial practice in this case might not reach the goal due to the long lasting sampling and prototyping compare to the timeframe of commercial projects. On the other side, academy is often not as flexible as small NGOs in its organisation and goals. While, in this case, the academic research is focused on responsive wood material, design and environmental science, the NGO can link this with society, culture, education and popularisation of science. By doing so, the project is reaching higher complexity, connecting art, science and public life. Within this project, two Environmental Summer Pavilions, *pareSITE* (Nam, 2013) and *LOOP* (Slavičková, 2014), have been built in the city centre of Prague and hosted multi-genres festivals, *reSITE* (Barry, 2016) and *EnviroCity* (Davidová & Kernová, 2016; Kernová, 2014), related to public space during summer 2013 and 2014, respectively. The pavilions themselves relate to hot and dry summer city environments by absorbing moisture at night, when the relative humidity is high and evaporating it during arid summer noon of the Prague city centre, thus pleasing the stay of festivals' visitors.

5.2.2 Introduction

Lately, it is getting more common to establish NGO next to the academic research, to create a stage for experimental practice as an alternative to practise based research conducted in, e.g., a design company. This model was pioneered amongst others by Ocean, starting as a network in 1994 and registered as Ocean Design Research Association in 2008 (Michael Hensel, 2015). In 2010, a special issue of FORMakademisk was released, discussing research related to design or otherwise. In this issue Sevaldson maps out a long range of definitions, concepts and approaches in practice research in design with emphasis on the relations between design practice and research (Sevaldson, 2010).

Most of these perspectives are more or less meant to be linked to professional practice. This has been discussed by Dunin-Woyseth and Nilsson:

‘Grillner and Stahl also presented a sketch to map the different sites where practice-based research in architecture may be related both to more conventional ‘profesional’ practices as well as to alternative, ‘academic’ practices, meaning experimental practices based in academia and pursued through teaching, exhibitions and publications.’ (Dunin-Woyseth & Nilsson, 2012)

The potentials in linking practice research to NGOs is not discussed. However, this discussion takes already into consideration not only the education and academic results, but also the popularisation of science, in the case of exhibitions. Different modes of research have been discussed by Koskinen et. al. and conceptualized as the lab, the field and the gallery (Koskinen, Binder, & Redström, 2008). The special setup with research by design involving NGOs in the cultural field might be ideal for combining the three modes of research mentioned.

The first author is taking this idea forward, by examining how research by design can benefit from a relation to a NGO. By exposing her collaboratively built prototypes, to a living public space, as a central stage of multi-genres festivals on and in public space, organized by the NGOs. The audience is attracted by the cultural events while, in the same time the prototypes are tested by the performers.

5.2.3 The Method of Cooperation between Academy, Practice and NGO

The first author originally planned to link her research with her own practise, but she didn't reach that goal. Though the work is based on one to one scale prototyping that should be applied in building industry, the time frame and targeted resources did not fit. Due to that fact, she founded an NGO, Collaborative Collective, o.s. (Collaborative Collective, 2012) with the colleagues from her practise (Collaborative Collective, 2012). There is a close link between the member's practices and the collective especially as an arena for speculation of future applications. The Collaborative Collective, and the architectural practises are presented in public as one unit and they use the same facilities. Thus the practise and the NGO get attention from different target groups, which leads them to more financial recourses and popularisation of the work. At the same time, the research has been conducted as PhD research at different institutions. During the realisation of two of the Environmental Summer Pavilions prototypes, the cooperation between the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences (CZU, 2016), Architectural Institute Prague (ARCHIP, 2016) and the Faculty of Art and Architecture at the Technical University in Liberec (FUA TUL, 2016) was established as a research based design studio course lead by the author and her collaborators. Parallel to this, the private sponsorships for the materials and outsource CNC, etc. were arranged through NGOs as well as all the festivals' events and organisation. The sponsorship is easier due to the fact, that the academy has more complex administrative responsibilities, therefore a small NGO is more flexible, at least when it comes to the laws in the Czech Republic. The festivals were public, not targeted to science or academic education in the first place. Various performance artists, musicians, VJs and DJs, anthropologists, urban planners and designers, architects and landscape

architects, theoreticians and city gamers were invited to perform an event of their wish that preferably relates to both, the pavilion, as well as to the surrounding public space. By perceiving the expressions coming from different disciplines, the authors of the prototypes got the opportunity to see their work in different perspective. The first author's research, as well as the development of the pavilions with all the participants was in both of the cases presented and introduced at the opening of the pavilions as a first festival event before the light, music and dance performances to the public.

The first pavilion, *pareSITE* (Nam, 2013), was built for a bigger event *reSITE* festival (Barry, 2016) and conference, ran by the NGO with the same name, where Collaborative Collective (Collaborative Collective, 2012) cooperated as a small part of the big event's sister arrangement in public space, while a big un-public conference was held as a main interest of *reSITE* NGO. It was concluded by both sides, that such a constellation was not suited for both of the partners, as their aims and audiences differ. Therefore the festival *EnviroCity* (Davidová & Kernová, 2016; Kernová, 2014) for the *LOOP* pavilion (Slavičková, 2014) was fully ran by Collaborative Collective and managed by Michaela Kernová and the first author with technical and financing support of the Prague Institute of Planning and Development (Prague Institute of Planning and Development, 2016) and Landscape Festival Prague (Galerie Jaroslava Fragnera, 2014) as co-organisers.



Figure 34: Loop pavilion: Light Performance: Lunchmeat (photo: Dvořák 2014)



Figure 35: pareSITE pavilion; Dance Performance: Antonie Svobodová (photo: Vajdová 2013)



Figure 36: pareSITE pavilion; Dance Performance: Nami Maria Halingten (photo: Vajdová 2013) - additional thesis author's note: In the case of the situation on this picture, the audience and performer are exchanged. The audience covers the pavilion from outside - not inside which is proving its different use options in relation to human behaviour.



Figure 37: Various Performances, Lectures, Workshops and City Games at EnviroCity Festival at Both its Locations (photo: Novotná 2014)

5.2.4 Discussion

pareSITE pavilion on reSITE Festival, navigating complex networking problems:

The pareSITE pavilion was part of the author's PhD studies at the Academy of Art, Architecture and Design in Prague (UMPRUM, 2015). As the structure of this institution did not enable her to lead a studio course there, she made an agreement with a private school, Architectural Institute Prague (ARCHIP) on holding a visiting studio at their institution. The cooperation with reSITE NGO helped in the negotiations, as both of the organisations are linked through the dean being the founding member of NGO at the same time. However,

as ARCHIP had already confirmed its study plan, we were given only half a semester for the task. The original plan of the author was that the course will involve students from various schools, which was cancelled by the argument of ARCHIP that their students pay study fee as opposed to the students from state schools, therefore the course cannot be open to them. As the initial agenda had addressed also the other students, the students from the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences got very enthusiastic and discussed the options for joining the course with their school management. It is sympathetic fact, that the first author's long lasting cooperation with the faculty was initiated by their students, who arranged the first meeting. The school offered their specialists and workshop equipment, both necessary for the project, as the transdisciplinarity of the proposal was very attractive to them. All the materials were covered by ARCHIP's major sponsor, SKANSKA and the design part was conducted in ARCHIP's studio spaces. The schools signed the contract on their transdisciplinary cooperation for the project. The salaries of the tutors were covered by reSITE and the first author received a stipend through Collaborative Collective sponsorship application from Lesy České Republiky (Czech State Forests). reSITE is a big transdisciplinary conference and has its festival as a small public event on the side of its main activities. This caused several failures. For them, our project was insignificant compared to their larger activities and responsibilities to their sponsors. The positive fact about the cooperation was that the organizers were very open to first author's ideas and she took large part in the festival concept. The unfortunate fact was that the cooperation was very difficult as the conference and festival were happening simultaneously and the first author and members of Collaborative Collective ended up volunteering for the festival's success without rights on decision making or any PR. Same difficult situation emerged with large sponsors, who supported the conference, but wanted to be exposed at the festival, as it addressed the public, with cheap, but larger attractions, overshadowing the pavilion, though it was the only stage of the festival. Lessons were learned. It was definitely not enough to agree on only a half semester lasting studio course for such project, but that time, it was our only option. The cooperation with reSITE brought an insight into the festival organizing but we learned that it is not suitable to be a small add-on of a big event. The conclusion of reSITE not to split their energy into small events seems to support the theory. The organization could have been better through establishing for instance discussion groups for all the participants with phone notifications as was done in the second case. Most likely, as all the participants were new to such large partnership, the organization was very chaotic and stressful. Thanks to this cooperation we learned how to create such projects in the future. The festival itself was very successful. Happening at largest square in Prague, Karlovo Square, it hosted about 1600 visitors just during the weekend (Davidová, Šichman, & Gsandtner, 2013). The pavilion concept was not affected by the robust organization and the performance was experienced by many visitors due to the extent of the event. The sponsors were decently engraved to pavilion's panels as it was explained to them, that this way, they get the best PR from city sensitive Prague citizens.

5.2.5 LOOP Pavilion at the Festival EnviroCity

This project largely benefited from the learned lessons. The PhD studies moved to the Faculty of Architecture at the Czech Technical University in Prague (Faculty of Architecture at the Czech Technical University in Prague, 2015) and the author was offered to host a whole semester studio course at the Faculty of Art and Architecture at the Technical University in Liberec. The same cooperation contract was signed with the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences in Prague. The studio had to be better organized, as the students were living in different cities. In addition to regular meetings with physical GIGA-map for coordinating team work, an online file sharing offered by Copy and a private Face Book group was established (Davidová, 2014d). The author decided to organize the festival, as well as the material and research sponsorship through Collaborative Collective, o.s. due to the conclusions drawn from the previous experience that this can better serve the project's goals. As for the materials small local companies were intended as suppliers of the

materials, at the end Stora Enso was sponsor for the wood, Rothoblaas for the joinery and EuroDach for CNC. It seems, that larger companies can better afford research/or PR. Smaller sponsorship was covered by smaller local companies such as tools landing by Nářadí Bartoš and moving of the materials and pavilion from site to site by Natura Décor and Easy Moving. The research stipend was again sponsored though Collaborative Collective from Lesy České Republiky (Czech State Forests).

The festival's concept was addressing the research questions of the first author, while adapting to later agreed co-organizers' who had to submit to the already created concept. The project management and coordination of the cultural program was conducted by Collaborative Collective's client Michaela Kernová, who has been connected to their practice for a long time, through collaborations with the author. Graphic design was sponsored by Škuta Design with creating strong CI. A private Face Book group was arranged for the management of the organizers and volunteers. As the Collaborative Collective was founded as a civic association for research and innovation within the field of architecture (Collaborative Collective, 2012), the NGO could also apply for grants for the dancers and musicians, because they related to research in architecture by the performance. The site, technology, facilities and partly PR was covered by the co-organizers, the Prague Institute of Planning and Development (IPR) and the Landscape Festival Prague. The cooperation between the two differed. While IPR is state institution run by the city municipality, the Landscape Festival is run by architectural gallery, Galerie Jaroslava Fragnera. While the gallery was more free and dynamic, the state institution had more possibilities, in case it came to agreement with appropriate person, such as covering the commercials on city trams. Thanks to the previous experience, the project was organized in less stressful, agile and light weight way while lasting much longer, though new lessons were learned by different settings. Thanks to the whole semester studio course, we could create more complex projects and increase the performance of previous pavilion (elaborated in separate paper for the conference). Involving a professional project manager and cultural program coordinator brought much stronger seriousness to the festival and secured its smooth process. The professional coordinator working for Collaborative Collective was also following and fulfilling the needs of the partial research goals, gained through observing and questioning an interaction with the pavilion and public space by performers from different disciplines, as well as by the visitors. Many were really targeting the connection and were getting attached to the object and its closest environment as close as possible by all their senses. The dancers were eager to explore its materiality and form in relation to the ground by laying under it or climbing it while expressively touching and smelling it or receiving its energy. The landscape architects were impressed by the humidity and fresh, wood smelling, air circulation inside of the prototype. Musicians were exploring its shape-material acoustics. The city gamers used its space for room division or board for notes, while the architectural historians used it as a meeting point for their city walks. Two different locations, one covered by greenery at IPR's gardens, the second rough at the suburbs at Freight Depot of Žižkov brought different perspective to environmental conditions of the object both, by different constellations, especially of the ground, as well as through different aesthetics. The employees in the location used it periodically for lunch breaks, commenting on its pleasant environment and expressing their worry it might be removed. It was of course loved by kids for their spatial games. It is the main author's experience from both of the cases that placing a beautiful object into a public space never leads to vandalism.

As it was its first year, we consider EnviroCity festival as successful. It reached over 800 visitors during the summer 2014. Over one hundred visitors came to the festival opening at IPR's gardens. From engraving the sponsors' logos on the panels we created an attractive offer that was a gift to the donors after pavilion's disassembly.

It seems the NGO can function as a bridge or glue between different interests because of its non-profit organization. The action diagram of Loop and EnviroCity management organisation shows clearly the NGO as the central point while all the institutions benefit from the cooperation. During the process it seemed to

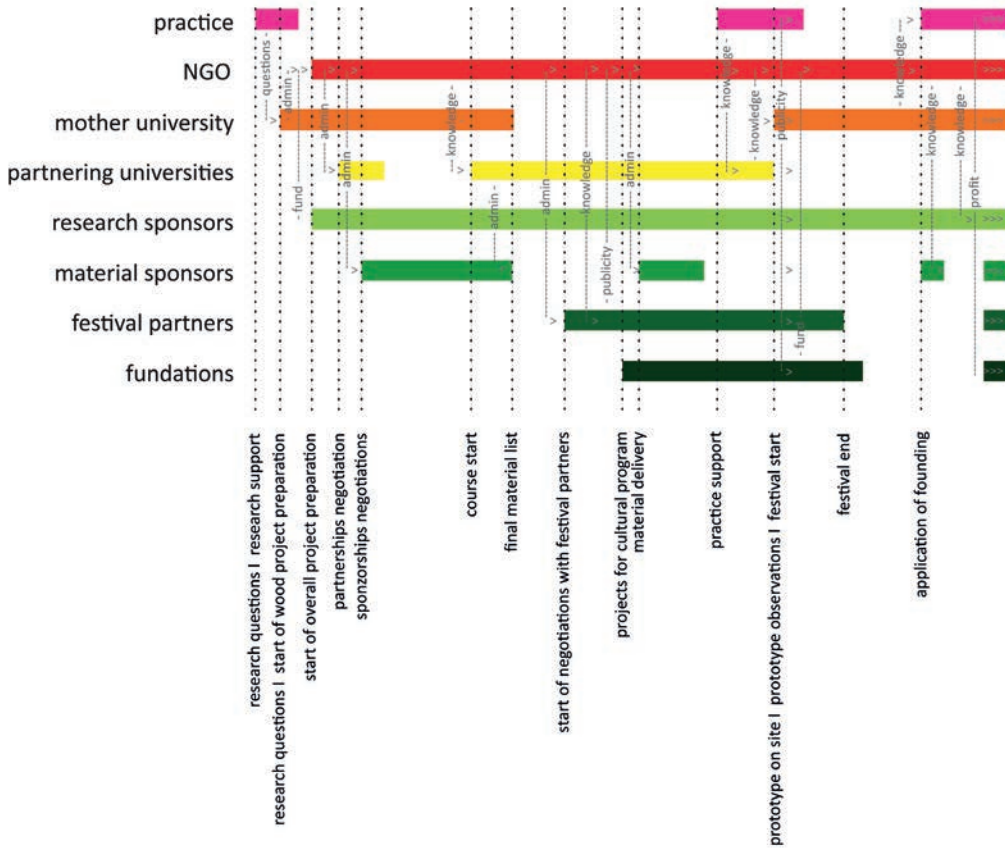


Figure 38: Action Diagram Mapping the Project Of LOOP Pavilion and EnviroCity Festival (Graphics: Davidová 2015)

be proved, that small NGO with no profit ambitions is more flexible and can be seen as a caring and kind spider in the net. On the other side, the larger, more powerful organisations operate with better resources and opportunities. However, it is strongly beneficial when most of the administration is left on the NGO.

5.2.6 Conclusions

The cooperation between a NGO and the universities worked perfectly, probably for the reason of one person sitting at both places. It has been proven that for some purposes organisations that are less and for some purposes organisations that are more complex are suitable. Without any of the type of them, even without the minor part of the practice, the project wouldn't happen.

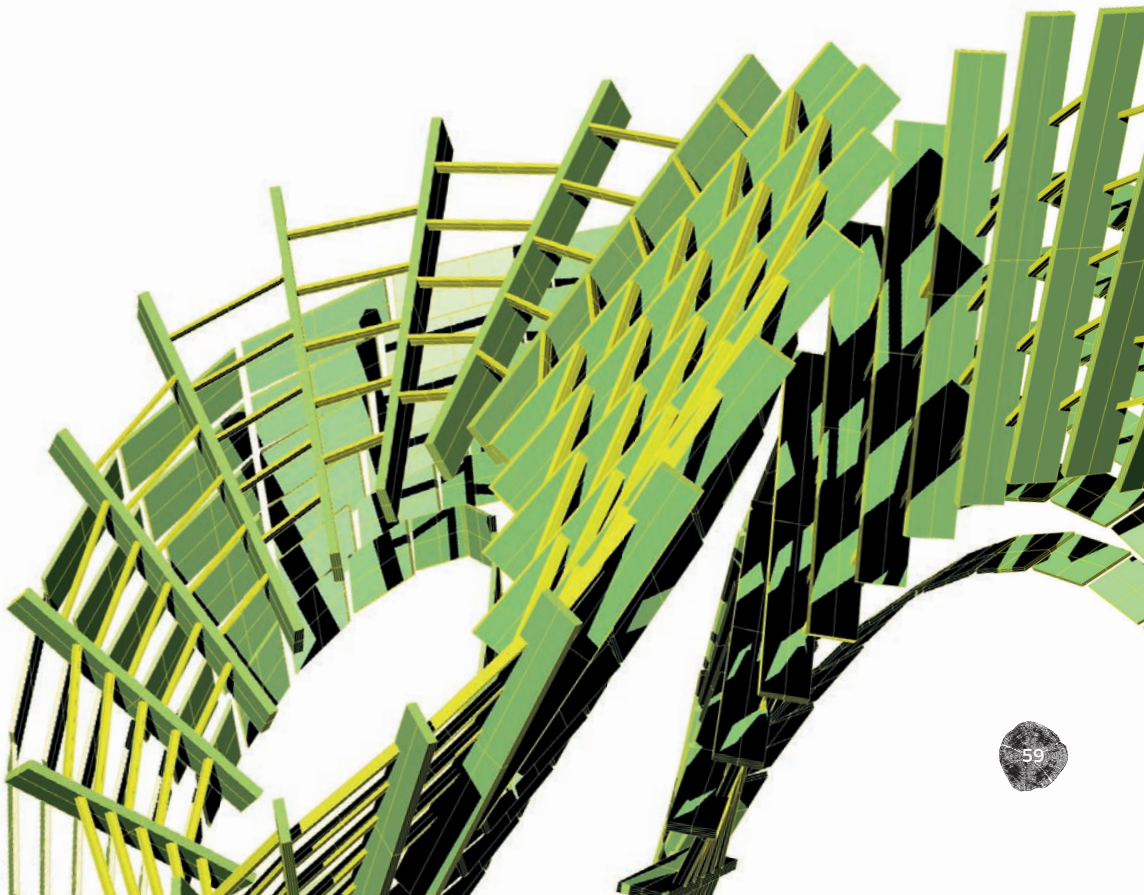
When cooperating with different types of the organisations, it is possible to reach different goals, audiences, as well as financial resources. The parts that are almost impossible to solve for one organization are very easy for others.

The introduction of NGO's to Research by Design is necessary for reaching better disciplinary complexity of the projects and thus design-research results, perceived by the authors in all the fields. Especially the dance performers were very enthusiastic about receiving new inputs from the relation of dance, material – environmental – body interaction through architectural object, public space, music; and light performance, when applicable. Similar feeling was experienced by the authors of the pavilion, seeing the performers in action. The landscape architects were very sensitively commenting the pleasant humid environment with beautiful smell of wood in hot summer days in the city centre of Prague. It is very difficult to explain the experience of observation as it happens in near or totally subliminal level. The interaction of materiality and environmental conditions, together with the enactment of the performers and visitors, made all experience the exploration of strong feelings.

The introduction of the research field of performative wood to the public, as well as to the performers and presenters, reached its audience even among people who wouldn't consider it as their focus of interest. The discussion with such people enriched the views of all of us.

It is more suitable to keep autonomy within organisation, not in the transdisciplinarity. While the first might lack the understanding for certain purposes, the second needs the equality for bringing benefits of particular field to the discussion.

The project would never happen without a kind support of Collaborative Collective, Faculty of Forestry and Wood Sciences at Czech University of Life Sciences, ARCHIP, Faculty of Art and Architecture at Technical University of Liberec, Faculty of Architecture at Czech Technical University in Prague, Academy of Art, Architecture and Design in Prague, Prague Institute of Planning and Development, Landscape festival Praha 2014, Nákladové nádraží Žižkov, SKANSKA, Stora Enso, Rothoblaas, Eurodach, Natura Dekor, Náradí Bartoš, Lesy ČR, P-Print, Škuta Design, Empyreum Information Technologies, Meloun Production, Easy Moving, Nadace Život umělce, Nadace Proměny, Paperlinx, Vinařství Sonberg, Městská část Praha 3, Nová síť, o. s., Nadace Proměny, Auto*Mat, Lunchmeat, TANEC PRAHA, Uličník, Rekola, I Need Coffee, Architekti ve škole.



5.3 1:1, A TRANSDISCIPLINARY PROTOTYPING STUDIO

(Davidová & Sevaldson, 2016a)

The topic Research by Design while 1:1 Scale Prototyping was explained by the author and Sevaldson in the article for ASK.the.Conference 2016: '1:1, A Transdisciplinary Prototyping Studio.' It elaborates on the necessity of full-scale prototyping within Research by Design and introducing how the transdisciplinarity was involved in the project through practice.

5.3.1 Abstract

The main author is using transdisciplinary studio courses as a research tool in the field of performative wood. Through sharing the knowledge between architectural, environmental design, and wood science researchers and students, we managed to develop complex 1:1 scale prototypes. The course process is a learning arena for students, teachers and researchers and the skills, competences and insights are being developed through experimental practice. The second prototype of the Environmental Summer Pavilion II course was created from reflection upon the first one while both serve as complex material-environment interaction studies for the development of responsive envelopes.

Figure 39: Loop Pavilion (photo: Davidová 2014)



5.3.2 Introduction

The theme of this paper is to present and discuss the experiences of working in a transdisciplinary prototyping studio forming a learning framework for a collaboration between two different university level institutions, working with full scale prototypes. The research guest studios have been led parallel at architectural schools, the Architectural Institute in Prague (ARCHIP, 2016) and the Faculty of Art and Architecture at the Czech Technical University in Liberec (FUA TUL, 2016) in 2013 and 2014, respectively and at the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences in Prague (CZU, 2016). In both of the cases, there were three guest tutors, the first author, being the project leader and being responsible for the material and architectural performance of wood, Martin Gsandtner/Šimon Prokop, responsible for coding and Martin Šichman/Martin Kloda, responsible for structure, detailing and realisation. In addition, different specialists from both of the faculties were available for the consultations and prototypes testing.

The work conducted in the presented collaboration is based on material research by design on the dynamic features of wood. Following the work of Hensel (Michael U Hensel, 2010b) and others in using the performative material features of wood, for example shrinking and warping, as a dynamic material feature from which one could benefit, the research ought to further develop this approach.

The methodology for the research is based on Research by Design (Research through Design) as described by Frayling (Frayling, 1993) and others and developed in more detail by, e.g., Sevaldson (Sevaldson, 2000, 2010).

Research by Design is in the process of being established as a solid approach and a more effective version of the practice of Research in Design, (Morrison & Sevaldson, 2010) where uniqueness, reflexivity, discourse and generalization are addressed.

All modes of modelling in physical materials and digital models are applied during the experimental design work. Full-scale prototyping is central to this method. The models and prototypes work as a dialogic platform for interdisciplinary inquiry. This way of design research had been common during the Renaissance times, for example in the work of Leonardo da Vinci. Highlighted by the most advanced structural experiments by the end of 19th and the duration of the 20th century, prototyping became a key method for material research and is used by the academy as well as by the industry.

Michael Hensel explains it as follows:

‘...The findings of the material experiments are the basis for computational modelling and analysis, which serves to further elaborate the design as it gains in complexity. In most cases, the design experiments culminate in full-scale constructions that can be further examined in order to empirically derive reliable data for the further development of the specific material system, working methods and approach to design.’ (Michael Hensel, 2012b)

From the philosophical point of view, the method is argued for by Wallner:

‘We understand what we have constructed. We cannot understand anything else.’ (Wallner, 1994)

We could add that only when our experiments are finalized can we fully understand what we have constructed and what its implications will be.

Schön is describing the design process as reflection in action, explaining the reflective conversation within the situation, while gaining the skills by experience (Schön, 1983). Reflection in action has been central to the research process, beginning with sample observations and concluding with the built prototypes. The success or failure of design actions has been central in building a body of methodological and technological knowledge. Numerous failures were unavoidable due to the lack of particularly developed methods suitable for the case. Samples, prototypes, and measuring had to be repeated because of the utilization of methods that in hindsight proved to be inappropriate. As Sevaldson stated in reference to designing with digital tools: ‘clear models and methodologies do not yet exist – these are being developed through practice’ (Sevaldson, 2005).

The same can be applied to material research by design, using digital tools and prototyping in 1:1 scale. The design problems we are discussing here are of a nature that confronts the designer with wicked problems (Rittel & Webber, 1973). There is no right or wrong answer, each problem is to a certain degree unique and it is only possible to base a resolution on prior experience to a limited degree. Therefore, the researcher needs to base her or his learning on practice, reflecting the failures that also bring the new findings. This process develops in iterations, which makes every new prototype more complex.

5.3.3 The Project: Wood as a Primary Medium to Architectural Performance

The introduced prototyping studios are part of the first author's PhD research project, Wood as a Primary Medium to Architectural Performance, where the key interest is the development of environment responsive screens/envelopes. During the spring semesters of 2013 and 2014, the courses Environmental Summer Pavilion I (Nam, 2013) or II (Slavičková, 2014) were conducted at the Architectural Institute Prague and the Faculty of Art and Architecture at the Technical University of Liberec, respectively, both in cooperation with the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences in Prague. Prior to the start of the first course, various theoretical studies, speculations, and sample observations were conducted by the first author and research questions for the first course were established in the paper for the 33rd eCAADe conference as follows:

- * The main area of our investigation lies in the material performance of solid wood: Wood – Humidity – Temperature Interaction (see section 'Material Performance').
- * A second topic is the question of how to create parametric models of the design and produce CNC fabrication data, leading to the question: Can parametric design cover all the design tasks? (See section 'Design Process in Grasshopper for Rhino 5').
- * Finally, we discuss the structural possibilities of CNC fabricated design (see section 'Structural Design'). (Davidová et al., 2013)

The course lead by the author, Šichman and Gsandtner lasted only a half semester, so much of the production data and industry negotiations had to be finalized by the tutors until the students returned to physical prototyping when their school duties finished in ARCHIP's students case, or in FLD CZU students' case it was their new course of professional practice. This situation was not ideal, but it was the only possible option. However the main focus on material performance was maintained in the course. The observation of warping of the panels and structure from torqued greenwood planks locked in a triangular structure was described as follows:

'...The pavilion designed for reSITE festival, is a möbius shaped structure, built from torsesd pine wood planks in triangular grid with half cm thin pine wood triangular sheets that provide shadow and evaporate moisture in dry weather. The sheets, cut in a tangential section, interact with humidity by warping themselves, allowing air circulation for the evaporation in arid conditions.' (Davidová, 2014b)

Along with this project, mapping the overall performance from worldwide orientations mainly focused on sample measuring, the speculation of particular application in the building industry was investigated on prototype Ray 2. The prototype developed further the combination of design with material science. This was published in 33rd eCAADe proceedings:

'Ray 2 is a wooden environmental responsive screen system that reacts to changes in relative humidity. Based on the material properties of wood, cut in the tangential section, the system opens in dry weather thus airing the construction. Whilst in the humid conditions it closes, not allowing the moisture into the structure.'

Ray 2 was developed from the concept of Ray with the fact that it resists to sudden rain. Based on the properties of tangential cuts from different position of the tree trunk, the plates are combined in diagonal directions...'
(Davidová, 2013b)

Both of the prototypes were observed and analysed and reflected upon and the findings were used as a starting point for the next pavilion course, led by Davidová, Prokop and Kloda. This time, a full semester was provided for the course so the schedule was not as tight. The resulting Loop pavilion utilised and developed further the gained knowledge to its fullest potential and increased the performance by design. The panelling was laid not only in combination of the left and right side of the tangential section, but also in spatial organisation into the structure. In this case, as it was observed on the prototype, the circulation of humid air was better. The team work was organized in a much more efficient way by arranging regular meetings with GIGA-mapping (Sevaldson, 2016a) for team work, an online file-sharing offered by Copy cloud service and a private Face Book group. This was especially useful because the two participating faculties were located in different cities (Davidová, 2014d). The GIGA-mapping method proved to be a perfect tool for interdisciplinary communication both, within the team as well as with the invited specialists. The performed sampling, as well as parametric analyses of joints, wood extension or FEM simulation, was more promising in the end than the final full-scale prototype. This speaks to the fact that full scale prototyping is necessary within architectural research.

In both cases, the pavilions were designed by the entire team – the students as well as by the tutors, after the initial concept sketch was selected through a competition. In the second case, the responsibilities within the design tasks were more clearly outlined after being discussed by the entire team over a GIGA-map. In both cases, the students followed up observations of the prototype originally made by the first author. The students with backgrounds from different disciplines were initially not assigned to particular tasks but all were coping with design, engineering or environmental issues. Later in the process, the responsibilities were assigned according to particular interests relating to the profession that they were studying. In addition, the researchers from both of the faculties were engaged to assist with particular design questions.

5.3.4 The Transdisciplinary Prototyping

The cooperation between the disciplines proved to be smooth while each of the professions followed their particular missions. The cooperation between the Architectural Institute in Prague (ARCHIP) and the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences in Prague (FLD CZU) worked well as continual prototyping and designing were interchanging. Students from both institutions cooperated well during the overall process, exchanging their skills and using their institution's facilities and studios and competences, e.g., structural engineer of ARCHIP and wood workshops and wood technologists of FLD CZU. The mature and experienced students of FLD CZU, many of them with architectural background, organized the prototyping and fabrication as well as helped with digital data.

The Faculty of Art and Architecture at the Technical University of Liberec (FUA TUL) was well-suited for concept design and this part of the project was performed there, including regular meetings over one common GIGA-map that also served for the organisation of the team work. The Faculty of Forestry and Wood Science at the Czech University of Life Sciences is well-equipped with wood workshops and testing machines. Therefore the prototyping, as well as the final fabrication, took place here. This time, we had few students from FLD CZU following the overall process but we had also a student with building engineering background in the architectural team, who could be involved full time.

The skills of the students perfectly complimented the equipment of the school. The wood engineering students had much better practical experiences with machines as well as with the materials and the architectural and environmental design students were learning such skills from them. On the other side, the architectural

and environmental design students were better in following the complexity of the overall project while still maintaining responsibility for certain tasks.

Due to the different missions of the faculties, architectural and environmental students possessed a time advantage in having the studio as the main subject. This changed when it came to the building phase, when wood engineering students were given the task as their full time exercise in professional practice.

Though we believe it would be ideal if both teams could have participated equally, the division of the work intensity according to the different professions worked well. The wood engineering students focused on material and prototyping consultancy or small tasks within the concept design phase, which was mainly executed by architectural and environmental design students. The architectural students had a perfect overview of the design and fabrication data and could organise the building process when the wood engineering students were engaged in the workshop.

5.3.5 Conclusions

The 1:1 scale prototyping is necessary for Research by Design development when it comes to material-design experimentations. Though the sample observations and digital simulations are helpful, they are not fully representative for the overall situation. So, despite that constant learning was achieved through action and analysis throughout the whole design process, the main learning input was obtained from the full scale prototype. And thus the Loop pavilion gained the most from the previous prototypes and studio experiences while it brought forth new questions for further consideration. New experiences, successes as well as errors were recognized.

The transdisciplinarity of the project played a crucial role within the process. While the wood engineering students proved to have the best experience with physical prototyping, the architectural students were better equipped for design tasks, using digital tools and handling fabrication data. At the same time, the environmental design students had the best understanding of implementing the local conditions. One of the students had a graphic design background, which was of great assistance, when deciding the organisation of the GIGA-map, as well as its finalization for print. GIGA-mapping turned out to be an ideal tool to bridge differences between the groups and for coordinating the work.

The full scale prototype generates a distinct and clear transdisciplinary understanding because all team members focus on one common product while implementing their professional background and observing and analysing the common result at the end.

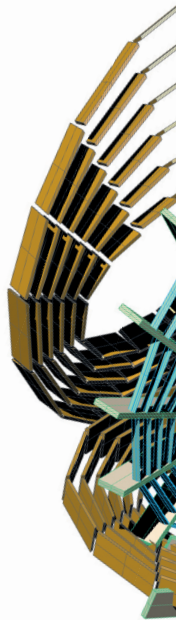
5.3.6 List of Participating Students

pareSITE:

Yuliya Pozynich, Jason Nam, Alena Repina, Daria Chertkova, Yana Vaselinko, Mikkel Wennesland, Dan Merta, Daniela Kleiman, Liv Storla, David Lukas, Christopher Hansen, William Glass, Jiří Šmejkal, Milan Podlena, Josef Svoboda, Tomáš Pavelka, Miroslav Runštuk, Ladislav Rubáš, Radim Sýkora, Anna Srpová, Ivana Kubicová, Gabriela Smolíková, Karel Ptáček, Jan Matiš, Tomáš Mišoň, Lukáš Růžička, Jan Hyk, Marian Loubal, Jan Dostál, František Juhász and Jakub Vykoukal

Loop:

Alena Novotná, Anna Hrušová, Antonín Hůla, Barbora Slavičková, Jakub Kopecký, Jiří Fáber, Jiří Pokorný, Petr Tůma, Tereza Jílková, Radim Sýkora, Eliška Antonyová, Tereza Lišková, Filip Janata, Tomáš Kytka, Marie Kortanová, Vojtěch Holeček, Martin Vaníček, Jakub Hlaváček and Petr Havelka



5.3.7 Thanks

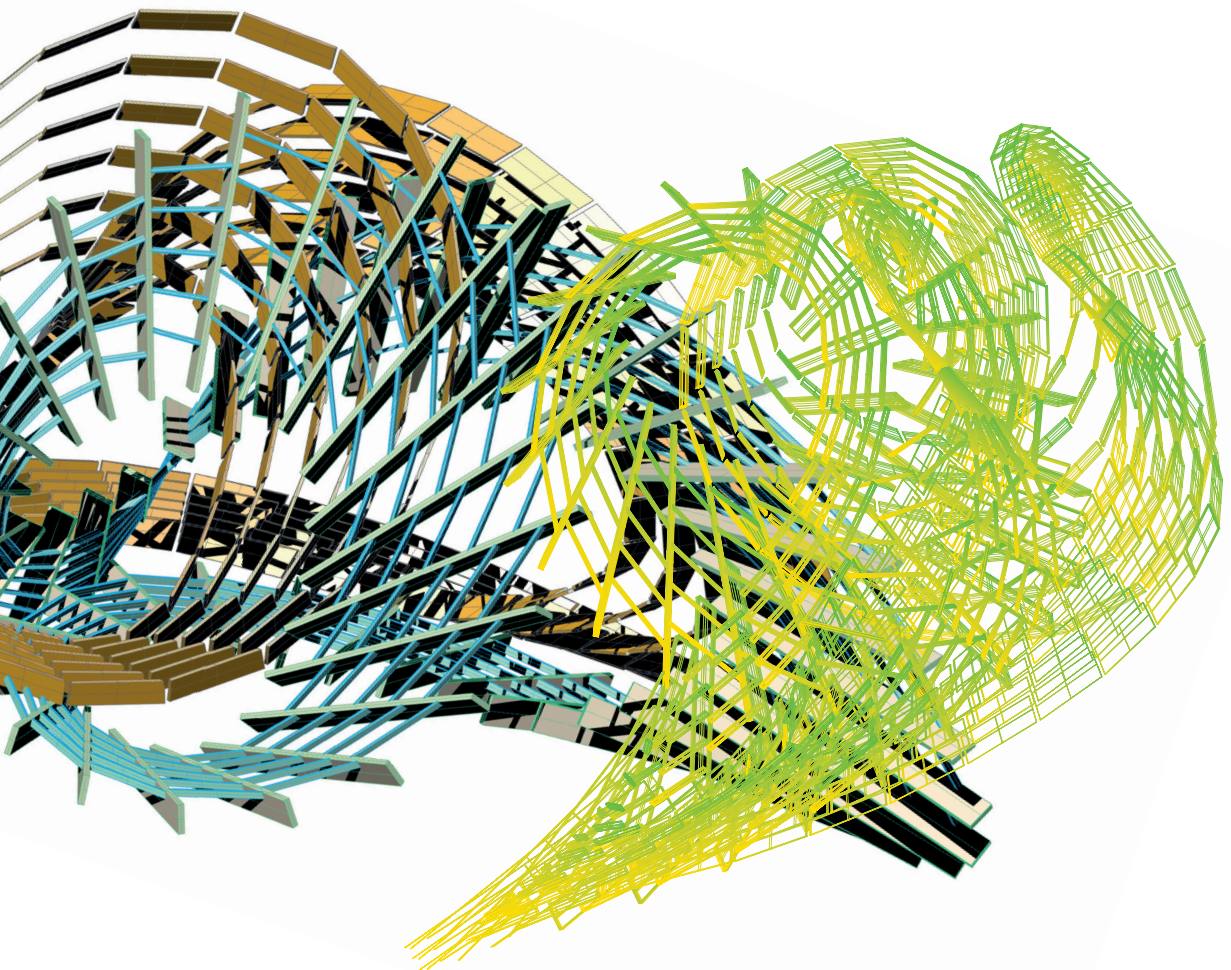
pareSITE:

The project was accomplished with the kind support of Skanska, Eurodach, Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences Prague, Lesy České republiky, reSITE, ARCHIP, Collaborative Collective and Oximoron.

Loop:

This project would never happen without a kind support of the Faculty of Forestry and Wood Sciences and the Czech University of Life Sciences in Prague, the Faculty of Art and Architecture at the Technical University of Liberec, Stora Enso, Rothoblaas, Nářadí Bartoš, Eurodach, Lesy České republiky, Natura Decor, Easy Moving, and Collaborative Collective.

This paper is a result of Systemic Approach to Architectural Performance project (Davidová, 2016e) that was kindly supported by EEA and Norway Grants (EEA and Norway Grants, 2016).



5.4 SYSTEMIC APPROACH TO ARCHITECTURAL PERFORMANCE: HANDLING DATA IN CREATIVE DESIGN PROCESS: MIXING PHYSICAL WITH DIGITAL

Davidová, 2016, recently submitted article to FORMakademisk's systemic design III special issue.

Following the submitted paper: 'Systemic Approach to Architectural Performance: Handling Data in Creative Design Process: Mixing Physical with Digital', authored by me, is concluding on use of the tools involved in experimental design research. It argues for the necessity of seeking specific methods according to the specific design's needs in reference to the borders of the tools today and in the past and envisioning the future possibilities of Systems Oriented Design tools in architecture or design in general. The conclusions and processes ferly relate to discussion published by Hensel and Sørensen in 2014 (Michael U Hensel & Sørensen, 2014), while approaching similar topics from Systems Oriented Design perspective, suggesting integration into one Rich Design Research Space (Sevaldson, 2008, 2012b).

5.4.1 Abstract

My research in the field of Performance Oriented Design (Michael U. Hensel, 2015a) is using the opportunities and mixing both digital as well as the physical concept sketches, simulations and prototyping. At the same time, the concept of GIGA-mapping (Sevaldson, 2016a) is applied to organize the data. The design process accesses the most suitable tool for the task at a certain moment and the media are mixed according to the current need. The paper discusses design methodologies of several projects and the development and trends in the tools for it. It argues, that the digital tools tend to get unified with given pre-sets and that it often doesn't correspond to the real world. This is even more significant for bringing attention to the necessity for appreciated prototyping for the creative design process. Mixing of media and transdisciplinary cooperation is unavoidable in the holistic approach to contemporary design. I argue that for bearing this complexity physical, as well as digital GIGA-mapping, is a crucial tool. Furthermore, I contemplate on the speculations of such a mixed development, proposing integration of physical and digital into one GIGA-map and through participation into one Rich Design Research Space (Sevaldson, 2008, 2012b).

5.4.2 Introduction

The computing in architecture emerged as a big move in the nineties. Offices or collaborative networks such as Ocean (Michael Hensel, 2015), Nox (NOX, 2016), Asymptote (Asymptote Architecture, 2016), dECOi (dECOi architects, 2015), FOA and others, started submitting their experimental design proposals for competitions. These projects were using computing in a highly artistic way, receiving unpredicted results from experimentations with different tools, such as animation. Sevaldson from Ocean in his PhD thesis on creative computing expresses the atmosphere as such:

'The rudimentary traces of an experimental design practice developed further when I slowly became aware of the generative potential in the machine. The machine had the ability to surprise me.' (Sevaldson, 2005)

The not yet developed tools, including a lot of bugs, both hijacked for different purposes, became a great arena of mixing media within creative design processes that were sort of soft systems based. The rise of 3D printing techniques enabled prototyping of these attempts. The method of prototyping for innovation through trial and error in the field of product design is explained by Capjon in his doctoral thesis from 2004 (Capjon, 2004). Sevaldson in his thesis talks about the hybrid process where many digital and traditional techniques and

design strategies melt together, discussing the mix of media as well as individuals in the team with different responsibilities (Sevaldson, 2005). A short time after that, he introduced GIGA-mapping which I am using for handling the data and responsibilities in teamwork of such.

In 2008 a special issue of Architectural Design edited by Bob Sheil called 'Protoarchitecture: Analogue and Digital Hybrids' calls for hybrid modes of experimentation in the post-digital age with focus on prototyping (Sheil, 2008). In the same year Sevaldson publishes an article defining Rich Design Research Space:

'The concept of the Rich Research Space includes the physical space of the design studio or research environment, the multiples of digital and analogue design media, the virtual information space, and the social, cultural and aesthetic spaces. The aim is to engage a holistic research approach and to nurture it as a skill rather than a method.' (Sevaldson, 2008)

In 2011 Neri Oxman demonstrates an integrated approach to design and additive based manufacturing promoting a direct link between virtual performance-based design and its physical prototyping of the material systems according to the performative properties. (Oxman, 2011)

Sevaldson concludes contemporary state as follows:

'Design culture indicates that we are more on the soft, fuzzy and wicked side of that landscape but reality tells us that we more than often work with, e.g., technology. Technological systems at large are 'hard' and deterministic. Our lack of grips at the hard side we compensate with interdisciplinary collaborations with, e.g., systems engineers and other experts. This is not limited to the hard end of the scale but it also expands throughout the field involving in any experts and stakeholders.' (Sevaldson, 2014)

In one way, today's digital design tools are not complex enough to simulate the real world. At the same time, they become too specialized with suggesting pre-sets, getting close to hard systems where creative design process has become truncated. Contemporary designers are computing an incredible amount of data, while when it comes to real prototyping, prove to fail their output. Furthermore, the physicality is often necessary for developing tacit knowledge.

5.4.3 The Media-Mix in Praxis

In all of my projects, I was constantly mixing media according to the suitability to the task. Starting traditionally with mixing hand drawing with model making, through mixing physical and digital modelling and animations and physical computing, I ended up with GIGA-mapping of complex, environment responsive, systems that are sketched, physically modelled, digitally designed, sampled, full scale prototyped and afterwards observed.

My first experience with prototyping was in the field of physical computing-not generating the architectures as such – but designing the tool for generating interactive architectural spaces through reading sensors with mathematics and adding randomness (see Figure 40). The tools involved Processing connected with Basic X, chip, board and various sensors that were tested for its interactive performance.

Later, I involved GIGA-mapping introduced by Birger Sevaldson at the Oslo School of Architecture and Design next to the physical and digital prototyping. GIGA-mapping is a great tool to map and relate all the mix-media and transdisciplinary data in a visual way that is necessary for designers. At that time, there was not very suitable software for this mapping, so traditional graphics work in Illustrator/InDesign is used. Recently, our students started to use mapping software yEd Graph Editor (yWorks – Diagraming Company, 2016) that seems to be promising and even having some generative potentials.

My first mapping was of an observation day in the city of Istanbul. The GIGA-map was mixing media of photography, written reports from experiences of interacting with locals in different places, sound recordings on MP3 players and physical objects/souvenirs connected to the board by wires.

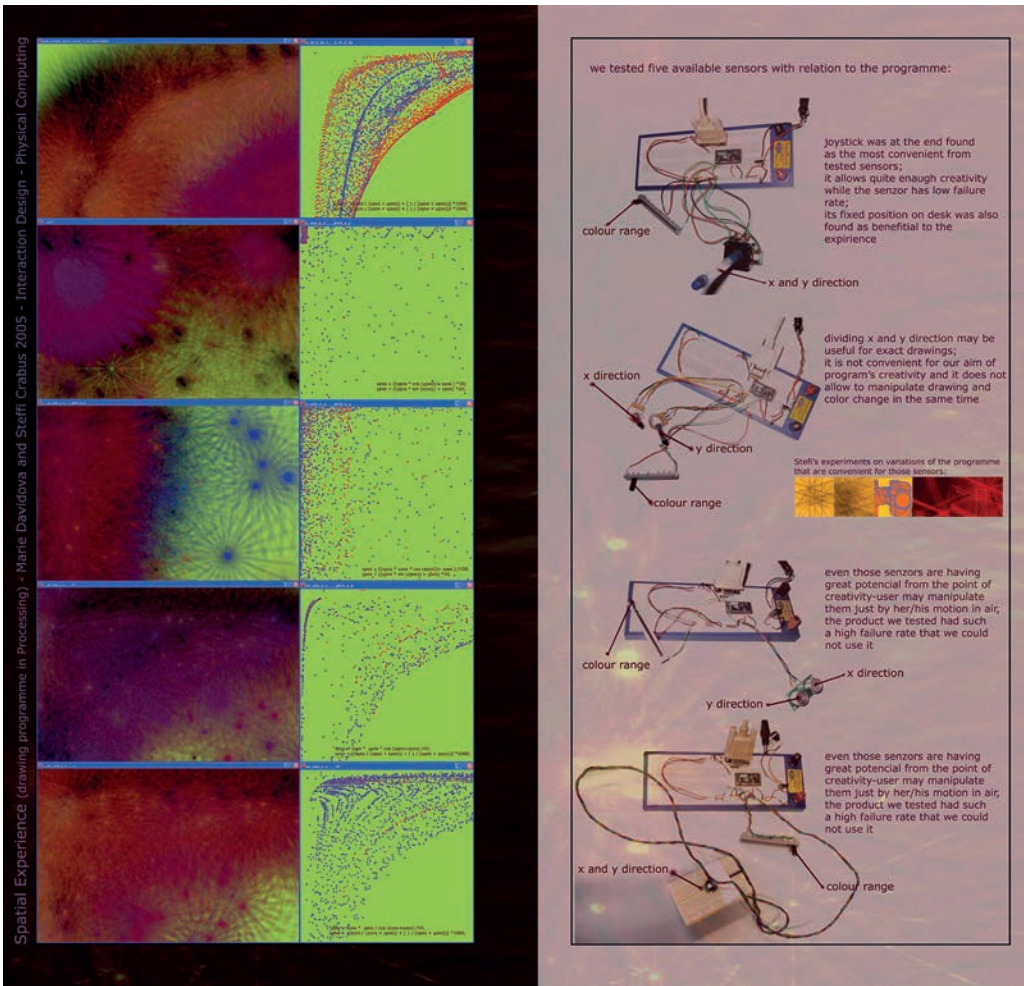


Figure 40: Davidová & Crabus: Spatial Experience. A Drawing Program for Architectural Spaces 2005

In the mapping in the project HOLOSLO: The Penetrating of Latent (see Figure 41 on the next page), I used only a computer, while adding physically the relations by different color-coding with fishermen’s strings (see Figure 42) and attaching sound and radio scanned recordings on MP3 players. The map was constantly used next to the prototypes and related computer generated models, processed analyses and recordings with physical prototypes, mapping the paths of different data sources that were parameters for the proposed design. Some of the features of the environment responsive installations over the city of Oslo would be almost impossible or very difficult to handle in a computer at that time, while easily physically prototyped. The media included sound, radio waves and visual video recording, my synesthetic visualising of recorded sounds and all that wavelet and colour decomposition analysed in MATLAB, its 3D reading in Rhino, several MATLAB wavelet analysis of Oslo city plan, their 3D processing in Rhino 3D and its interpretation through reading by a voronoi plug in for Rhino, combination of Rhino script and physical prototyping/rapid prototyping development of the installation – from the systems performance to joints detailing. The recorded local environmental data informed the physical properties of the installation in order to be responsive to it.

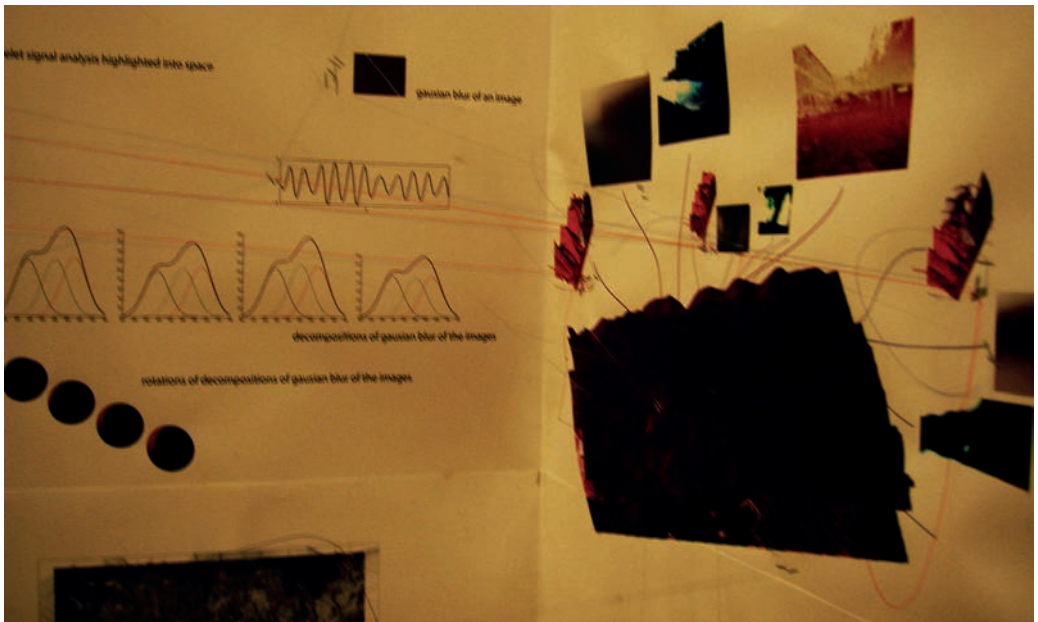


Figure 42: Davidová: Color-coding with fishermen strings in GIGA-map of HOLOSLO: The Penetrating of Latent, diploma thesis at the Oslo School of Architecture and Design. Supervisors: Sevaldson & Kartvedt 2006

The project SpiralTreeHouse (Davidová, 2013c, 2014a, 2016d) is a perfect example when the computing is not enough to handle the task (see Figure 43). No single drawing was made when we started to build it. Only an abstract physical model of the structural system was sketched. The thickness and the angle of the logs were tested in 1:1 scale through the building process. When the structure was built, it was measured on site to computer model the fabric of the removable cocoon in Rhino. At that time, Rhino Nest plugin was not yet advanced in organizing the orientation, therefore the sewing drawings had to be adjusted by hand at the end in order to respect the rain protection of the folds. If we were to model the project before starting, we would have to 3D scan every log because the thickness of the log sets the angle. Then we would have to run structural analysis

Figure 43: Davidová & Závada: SpiralTreeHouse 2010–2013 (photos: Davidová)



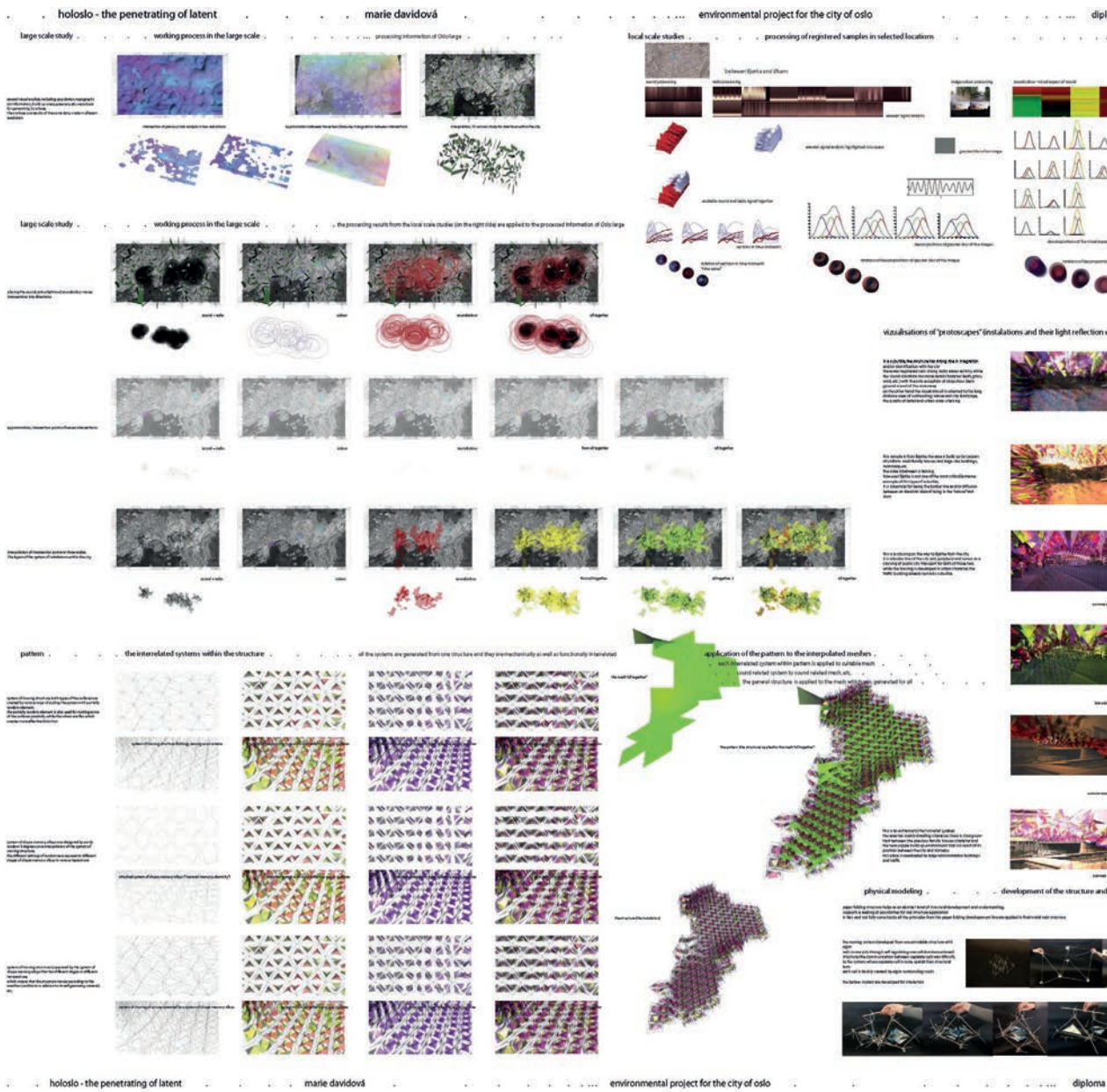


Figure 41: Davidová: HOLOSLO: The Penetrating of Latent, diploma thesis at the Oslo School of Architecture and Design, Supervisors: Sevaldson & Kartvedt 2007

oma summer 2007 supervisors: per kartvedt & birger sevaldson department of architecture - aho

The result of the local scale data processing are applied to the large scale study (on the left side, see below)

the system of moving structure ... the system of moving structure developed by the combination of micro folding and frame structure

effects in different settings ... the structures are applied according to the large scale studies all over the city while having a local settings ... they parasitize on the existing infrastructure, facades of the buildings, etc.

the higher level of interdependency offers both, more possibilities as well as necessary regulation

interaction in more scales

oma summer 2007 supervisors: per kartvedt & birger sevaldson department of architecture - aho



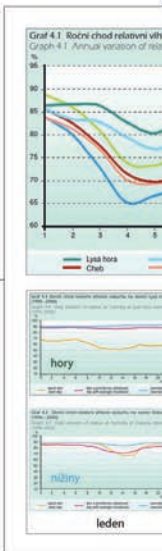
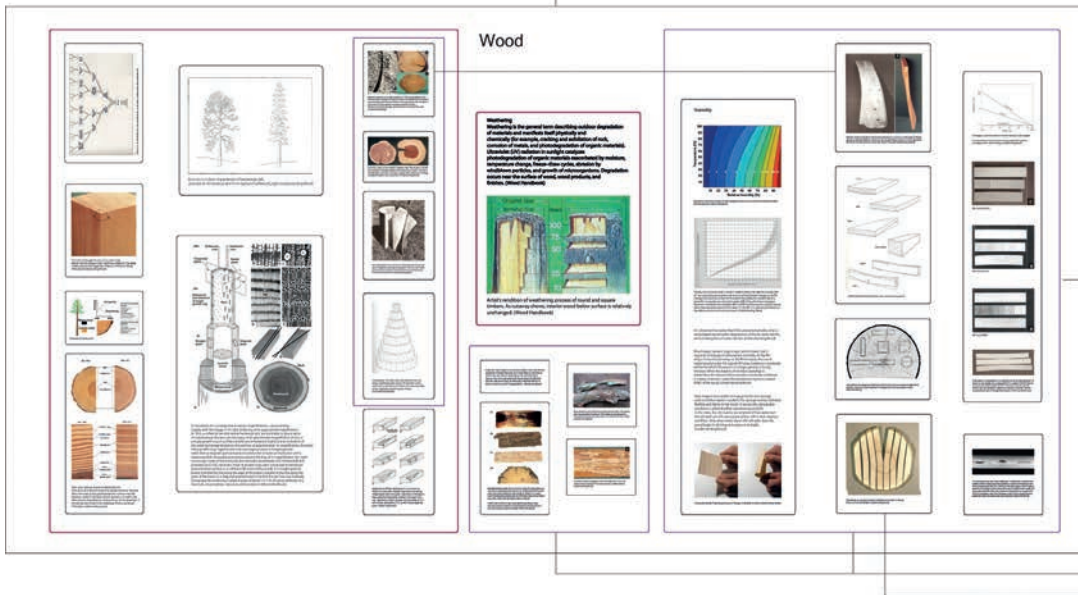
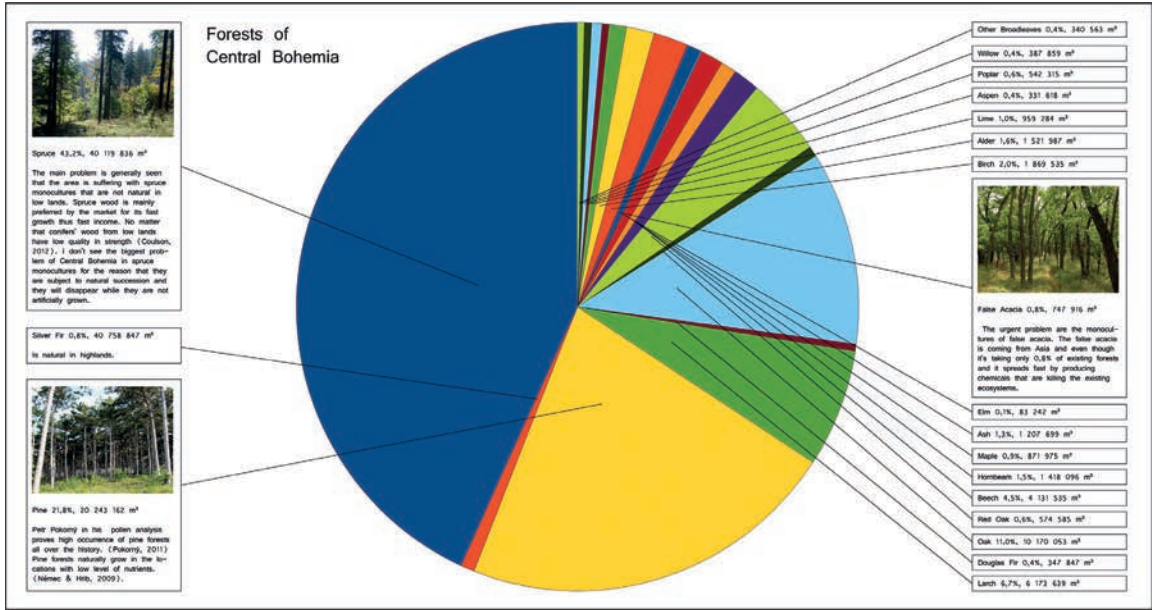


Figure 44: Ray 2: Environment Responsive Screen GIGA-map, Showing Transdisciplinary Relations within the Project, Research by Design GIGA-Map (Davidová 2013 – images from Forest Products Laboratory, 2010; Hoadley, 1980; Menges, 2009; Němec, 2005; Tolasz & Coll., 2007 or photographed by the author, used with the courtesy of USDA Forest Products Laboratory, Taunton Pres, Achim Menges, Grada and Tolasz)

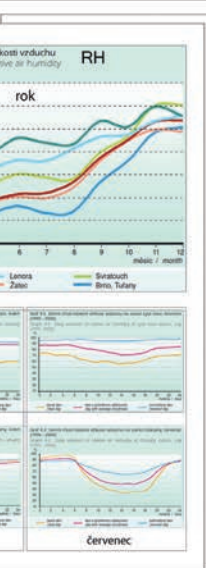


<<< shrinks

does not shrink >>>



Wood Shrinkage



Design Process

1. Fine wood reaction wood
Reaction wood in tangential section warps in tangential direction within the same humidity conditions. More than half of the samples bend the opposite direction. The same occurrence has been observed in regular pine wood in one from ten samples. The tangential later disappeared.

2. Fine lighter wood
Four types of samples were observed as regular green and dry wood: rectangular shape, parallelogram, rhombus and rectangular with notches. There was not so much difference between green and dry wood. The rhombus shape was bending the most, continued with parallelogram and after that rectangle. The rhombus bends into four differences, the rectangle into two. The rectangle with notches was at the beginning not warping at all and later on bent into a side when it stops not in dependency on relative humidity.

3. Fines with algae
A fence covered by algae was observed. The wood with algae has approximately from two to four lower percentage of moisture content than the wood without it. This feature can be used in relation to wood warping.

4. Apocynaceae and Malvaceae
Samples of Apocynaceae and Malvaceae were grown on oak, alder, spruce and pine wood samples. While Apocynaceae is growing on oak wall, Malvaceae clear after certain time. The bark starts with oak wood followed by alder, spruce and pine wood.

Design Process

Environment Focus Concept
The problem needs to address versatility by warping it's shape in the opposite direction. Thanks to that, the problem changes when it's bent and opens when dry warbles. The concept of the opposite flow acceleration in tangential section was further developed into different performative systems proposals.

System Play2
Concept Play2 was developed further for the production from oak. It is based on the fact that the plates from the center of tree trunk warp more than the others. The system is generating 3 cm² hole per 7.8 cm² area of the paneling.

Concept Sponge
The performative facade concept is generating 3 cm² hole per 10 cm² area of the paneling. The panels are interlocking.

Concept Play
The performative facade concept is generating 3 cm² hole per 7.2 cm² area of the paneling. The panels are not interlocking.

The working prototype
The working prototype shows a physical model of the facade system in a natural setting.



Figure 45: LOOP Pavilion GIGA-map as a Result of Transdisciplinary Studio Course; photo and administrator of the map: Pokorný, tutors: Marie Davidová, Šimon Prokop, Martin Kloda, students: Alena Novotná, Anna Hrušová, Antonín Hůla, Barbora Slavičková, Jakub Kopecký, Jiří Fáber, Jiří Pokorný, Petr Tůma, Tereza Jílková, Radim Sýkora, Eliška Antonyová, Tereza Lišková, Filip Janata, Tomáš Kytka, Marie Kortanová, Vojtěch Holeček, Martin Vaníček, Jakub Hlaváček and Petr Havelka 2014



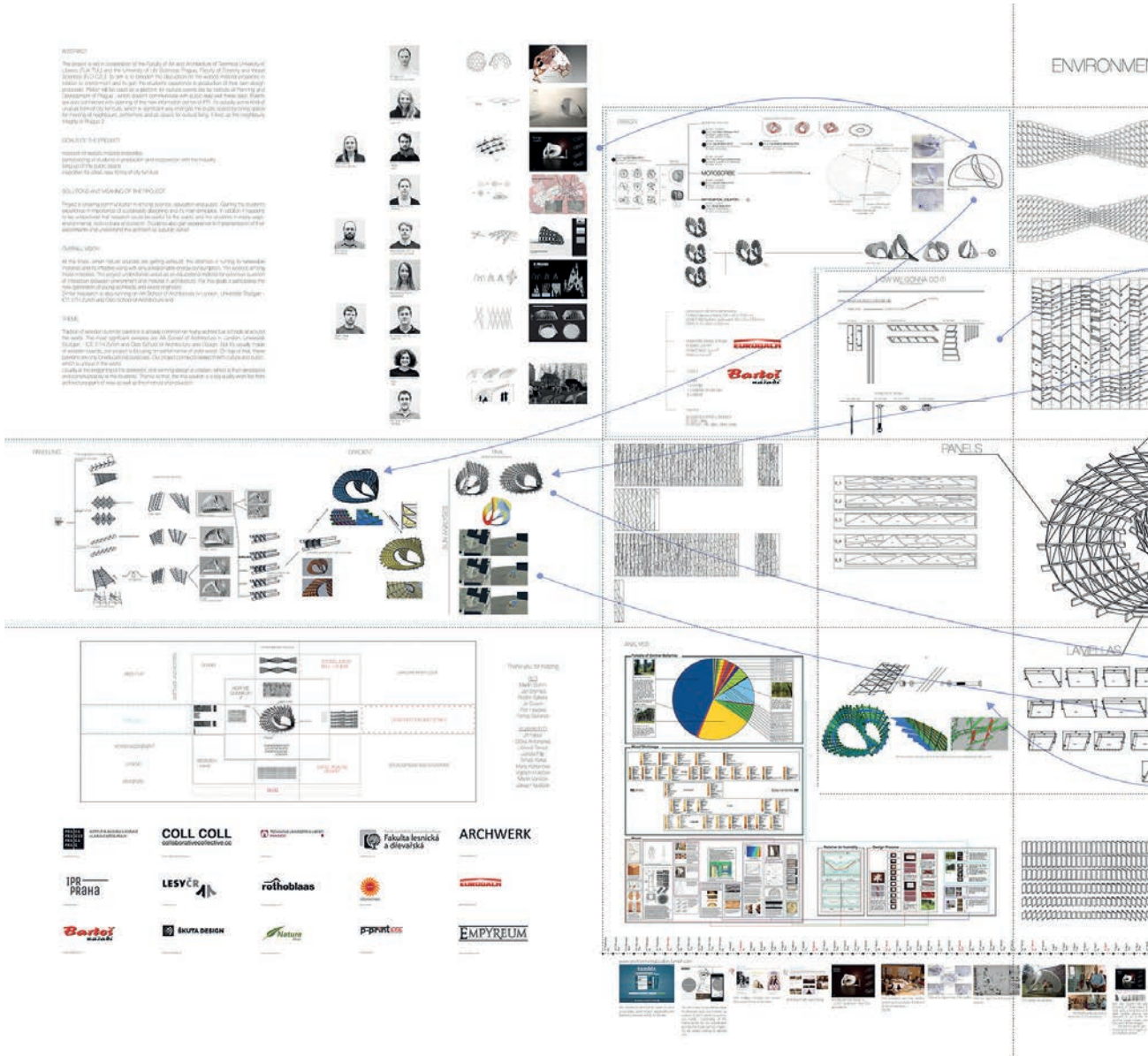
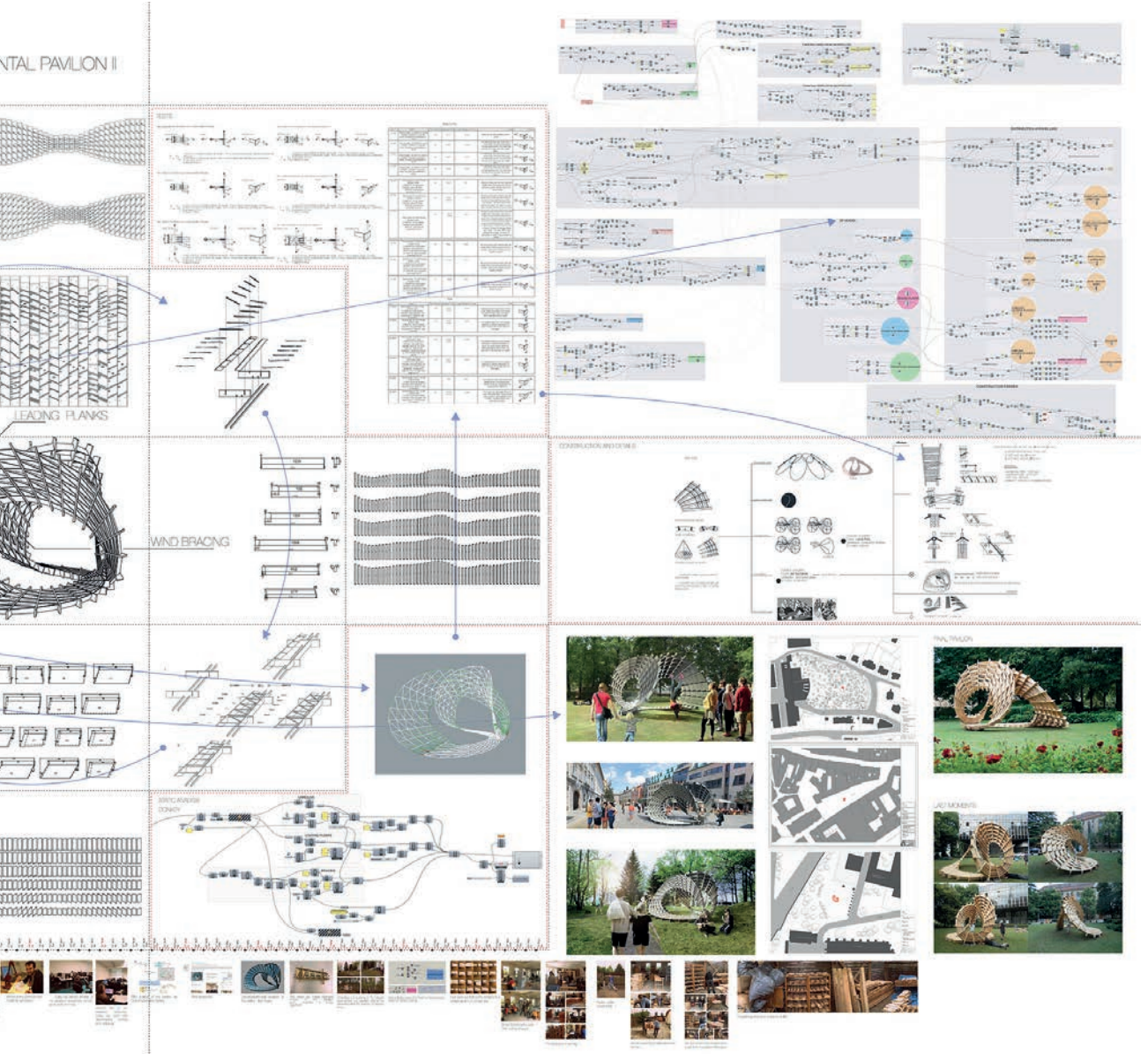


Figure 46: LOOP Pavilion GIGA-map as a Result of Transdisciplinary Studio Course; photo and administrator of the map: Hrušová & Pokorný, tutors: Marie Davidová, Šimon Prokop, Martin Kloda, students: Alena Novotná, Anna Hrušová, Antonín Hůla, Barbora Slavičková, Jakub Kopecný, Jiří Fáber, Jiří Pokorný, Petr Tůma, Tereza Jílková, Radim Sýkora, Eliška Antonyová, Tereza Lišková, Filip Janata, Tomáš Kytka, Marie Kortanová, Vojtěch Holeček, Martin Vaníček, Jakub Hlaváček and Petr Havelka 2014v



that in fact that time didn't take in consideration fibre direction. The cocoon's natural ventilation with the central fire place performs on the basis Indian tee pee. All such properties were analysed physically on different samples and/or directly through building and tacit knowledge was used instead of simulation. The finalisation of the design process has been granted to nature. We grow moss on the platform and plan to support the construction by climbing ivy. For this reason the project's design develops over time in relation to its environment and will be taken from nature where all its material is coming from. These biotic processes would be very hard to simulate as the empiric experience of such complex conditions is lacking. Therefore, the SpiralTreeHouse serves as a prototype for observations.

Within my PhD project, Wood as a Primary Medium to Architectural Performance, supervised by Florián, Sevaldson and Fránek, that covers prototypes of two pavilions (Davidová & Prokop, 2016; Davidová et al., 2013; Davidová, 2013a, 2014b, 2014c; Nam, 2013; Slavíčková, 2014), one responsive screen (Davidová, 2013b, 2014e) and one responsive envelope (Davidová, 2016c), samples observations data were mixed with Grasshopper code. The results from the measuring of the climatic conditions with a digital weather station and its material response with slat with a hole and calliper and electric moisture meter were combining physical, empiric data with a simple geometry-based code for simulation and further concept development. Discussed with environmental coders, environmentally-coded simulation, considering complex environmental data with material responsive system, that is defined by moisture content when it's cut as well as by the position in the tree trunk before cutting, would be very difficult. Different transdisciplinary data, including forestry, meteorology, wood science and craftsmanship, my own samples observations as well as the design process were GIGA-mapped since the time of literature survey until the realised full scale prototype (see Figure 44).

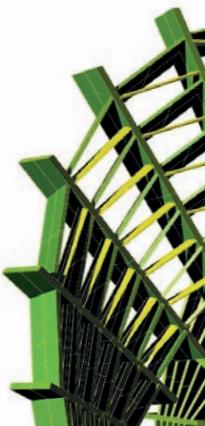
In my research, I am mainly using mapping of images, not vector graphics icons. The reason is twofold, it corresponds better to the media used in my research and at the same time from my experience the image provides more in depth background information, even on subliminal level, that might not be in interest at the moment of mapping but may come to attention later on in the design process. With the notion, 'one image says all', I am avoiding loss of data even on an emotional perspective. Different impasses stayed in the game on the board and were unexpectedly used when concluding particular design issues.

While working in transdisciplinary teams in pavilions projects, handling the data became crucial. Here GIGA-mapping proved its meaning in generation of the design process that has been discussed in a separate paper (Davidová, 2014d). The physical collage of printed computer generated data/images and site photographs connected by threads with pins perfectly covered the cooperation next to prototyping. The GIGA-map was organised as a timeline according to the responsibilities in the team (see Figure 45). My previous GIGA-map from the responsive screen project was used as a starting point as a scientific background for the complex project (see Figure 44).

The media such as 3d scanning, Rhino, Grasshopper for Rhino, its Lady Bug and Donkey plug-ins, physical prototyping and testing of joints, CAD/CAM and digital fabrication, V-ray and Photoshop for visualising the public and public space relations and atmospheres were involved. Simultaneously, the Facebook group discussion and cloud file sharing at Copy was a crucial part of the team's organisation. Several times reorganized, the collage GIGA-map was a generator of collective creativity by addressing the visual relations on discussed topics. Unfortunately the digital analysis tools, as well as the physical partial joints tests proved to fail when it came to 1:1 scale prototype.

Sevaldson suggests switching the media all over:

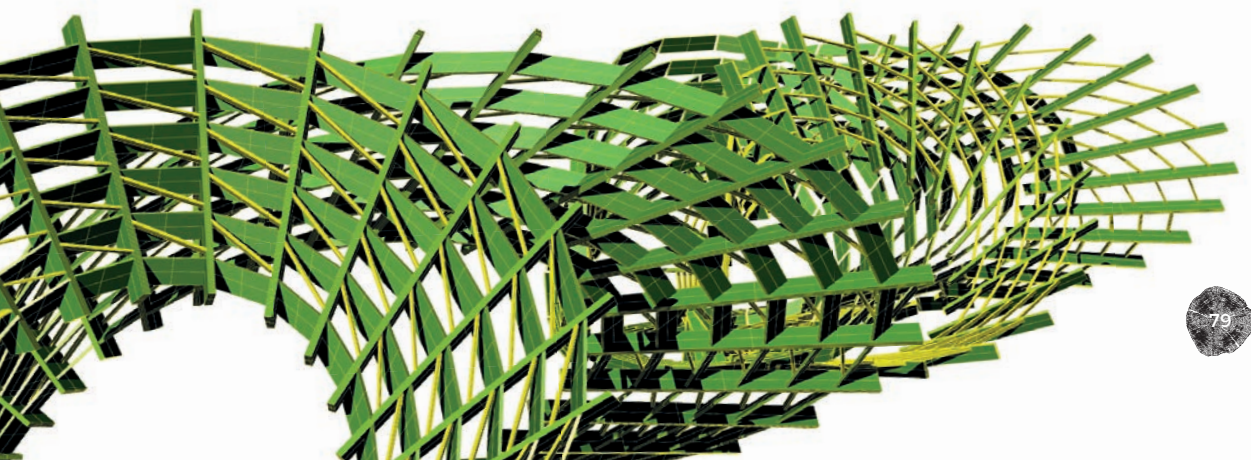
'Start with simple, low-threshold media like big paper rolls and markers but switch to other media later. Redraw the mapping on your computer and plot it out in large formats to continue working manually. Then repeat the process with new iterations.' (Sevaldson, 2012a)



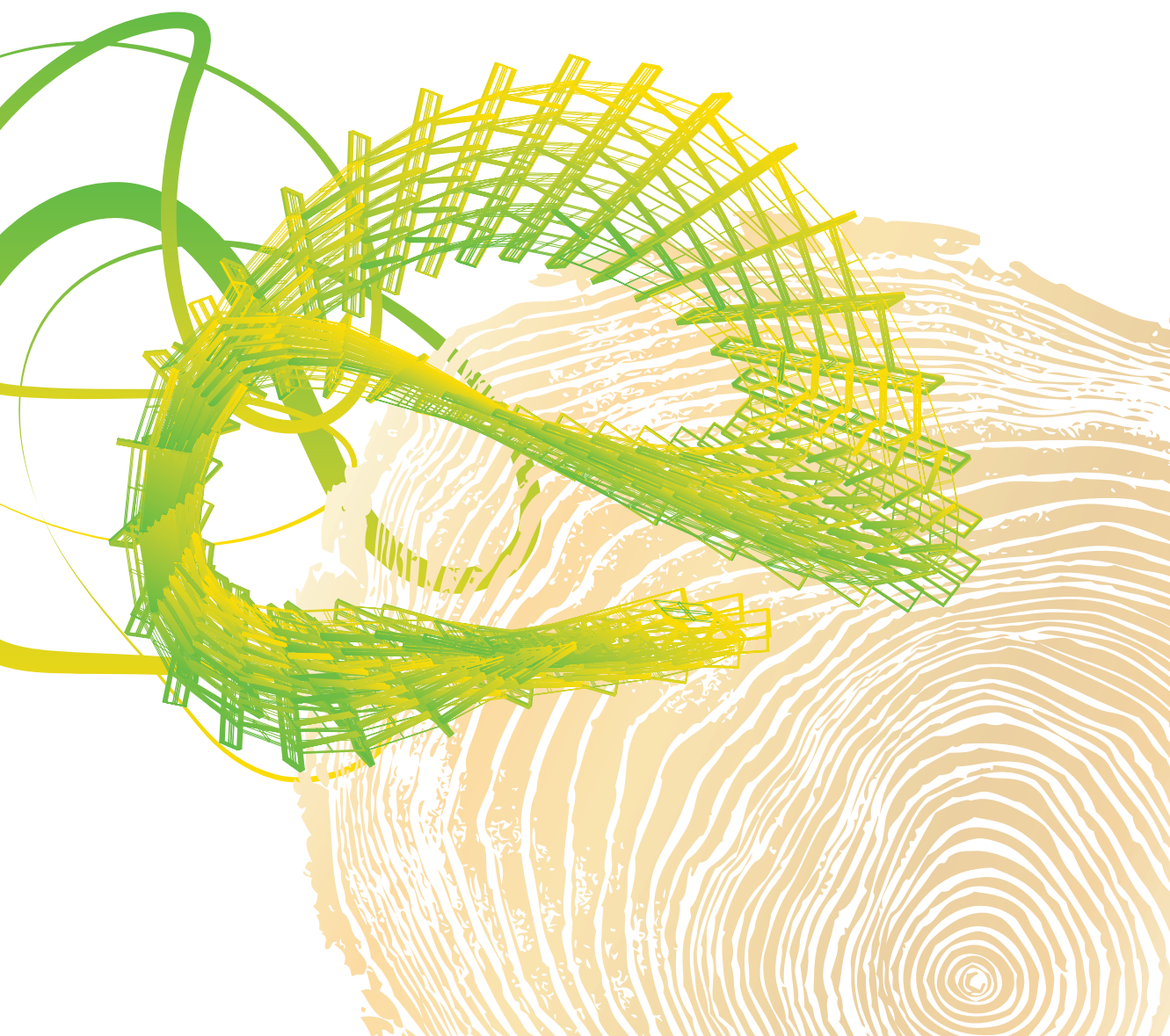
I believe we did a similar thing by reorganizing the existing, thus finding new relations. Finally for presentation purposes, a digital GIGA-map (see Figure 46) was designed ex-post, exhibiting the complexity of the project at the EnviroCity festival (Davidová & Kernová, 2016; Kernová, 2014). As it didn't serve for team cooperation, the timeline was not necessary and the graphics were organised according to different topic areas and their relations, thus saving a lot of white space for the print. For next time, it would be interesting to leave there an interaction space for the festival's visitors. Anyway, we find the exhibiting of the complexity of the design process to the audience next to the full scale prototype very successful. And though not interactive, the GIGA-map engaged the participation at a discussion level when the lecture about the project was performed at the festival in the pavilion.

5.4.4 Conclusions

From my observations, some of the creative artistic processes were definitely lost in new tools development. I.e., it seems we can no longer experiment with software bugs and small amount of pre-sets and predefined codes are repeated. The newly-emerged technical digital tools are often failing on both the performance as well as the designer's cognition. The partial tests in general lack the overall complexity and local data. The digital world is not developed enough to handle complex data of the physical world, and while it can be used for some particular tasks it may be failing in reality. Therefore, mixing the media is still a necessary approach within the creative design process that also operates much better in addressing 1:1 scale physical prototypes. For operating such a great amount of mixed transdisciplinary data, GIGA-mapping seems to be the most suitable tool at the moment. It requires large interactive space with different agents and it is not that important if it's large interactive screen operated by team through any sort of interactive collaborative sketching as proposed in PhD thesis of Nováková (Nováková, 2014) or physical printouts. The new step would be collaborative mix of 3d photography and 3D modelling animated sketching equipped by 3d scanner performed, shared and getting connected in physical space. However, touching and feeling the objects and their performance with their real properties is important for tacit knowledge for all the mentioned issues. A similar point is discussed by Hensel and Sørensen through local live data and AR and VR (Michael U Hensel & Sørensen, 2014). The tool that would be generating full output out of it is far from our imagination because it cannot be quantified. The possible way would be in interacting with brainwaves. To me the future rather seems to lie in a digital world being directly physical and there will be no need of further discussing those borders. The question is which way of open possibilities the route will take, if it is straight biology, or synthetic biology or nanorobotics first. Today a creative design tool of participation often fails by not managing to communicate to the actors that don't have designer's reading skills. From my observation, the participants seem to do well with GIGA-mapping but in fact they are largely getting engaged by addressing physical objects. Therefore, the way would be to search for GIGA-mapping in physical space of performative objects. This is taking forward Allan's discussion from 2001 of what architecture can do opposed to its meaning (Allen, 2011), while joining the media mix with physicality, being the real builder and constructor and most importantly, crossing the disciplines' borders while working on transdisciplinarily through participation, involving the theory. This way, the GIGA-map, prototyping and participation would generate one Rich Design Research Space (Sevaldson, 2008, 2012b).



6/ *The material in relation to environment*



This thesis is a case study in the field of responsive wood within the field of sustainable Performance Oriented Architecture through a Systems Oriented Design approach. Therefore, a deeper look at the material, its origin and relation to environment was crucial. While analysing more closely the forests ecology of Central Bohemia, which is the central location of the research, the conclusions on the sustainable selection of species applies to a much broader region, but definitely should not be taken as a general rule for selecting only one species for whatever purpose and ecology. This selection was also evaluated through species specific wood – environment interaction, zooming into its properties. More complex environment-material interaction data has not been published in this field and therefore much of that had to be observed on the samples and prototypes. In addition, often what was published did not correspond to what was observed on the samples or experiences of engaged disciplines/professions shared through personal conversations. This area definitely requires larger research extension within broad transdisciplinary team. By now, only the data relevant for direct design practice sustainable application in relation to suggested designs are elaborated, as this is the topic of the thesis.

I would argue that each project requires this or even deeper analysis when selecting the material. The disadvantages of LCA were discussed in the State of Art section. For this topic, I think it is more relevant to discuss future speculations. Furthermore, LCA has only a chemistry perspective and not all the consequences might be predicted through such when it comes to its biotic interaction. In my mind, there is not really any suitable simulation of this kind at the moment, though many efforts have been done. For this project, the forestry data was related with material performance in selection through GIGA-map (see methodology section), that took part all the way through design research process.

6.1 ECOLOGY OF FORESTS AND TREES IN CENTRAL BOHEMIA IN RELATION TO MATERIAL

Figure 47: The Percentage of Tree Species in the Forests of Central Bohemia (diagrammed by Davidová 2013; data used from Forest Management Institute Brandýs nad Labem, 2012)

To design a truly sustainable product it is necessary to look at which wood is good to harvest in relation to forestry-material aspects. The importance of an increase of biodiversity in forests is discussed in the European Union's biodiversity strategy for 2020 (EC, 2011). The aim is addressed by Fares and coll., discussing this issue in reference to climatic change, proposing biodiverse forests adaptation, while supporting local suitable species also accepting those from locations of more extreme regions. Fares and coll. are specifically naming pine wood as suitable for harvesting forestry in this context (Fares, Mugnozza, Corona, & Palahí, 2015). This direction of introducing external species to keep biodiversity makes sense just in very sensitive selection. As discussed later, unsuitable invasive species may create serious harm to local biodiversity and turn into extensive monocultures. Also, in some cases of grounds and climatic conditions, monocultures may be natural as a result of more adaptive specie to certain conditions. It would therefore be hard to force biodiversity through a non-adapted species, thus invading local ecologies that may cover different, environment-specific biodiversity.

Since Prague is the central location of my research, I was looking closer at the forests of Central Bohemia (see Figure 47). The long lasting governmental plan of forest management in Central Bohemia is focused on renewing beech and oak forests that are natural to the environment (Němec & Hrib, 2009). The main problem is generally seen in the fact that the area is suffering from artificially grown spruce monocultures (43.2%, 40 119 836 m³ (Forest Management Institute Brandýs nad Labem, 2012)) that are not natural in lowlands that are common in many large areas of Central Bohemia. Spruce wood is mainly preferred by the market for its fast growth resulting in fast income. It was, and often still is, an ignored fact that usually conifers' wood from low

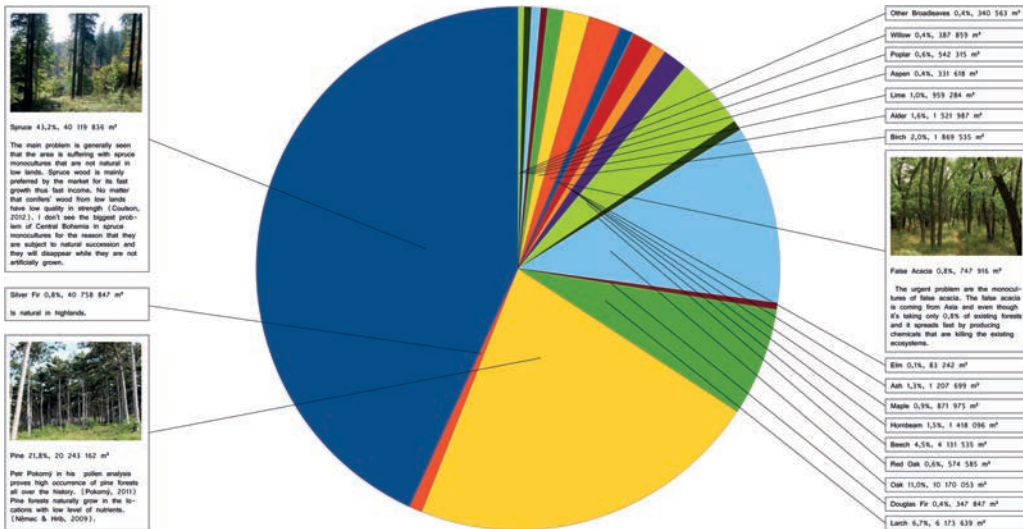


Figure 47: The Percentage of Tree Species in the Forests of Central Bohemia (diagrammed by Davidová 2013; data used from Forest Management Institute Brandýs nad Labem, 2012)

lands have low quality in strength due to fast growth (Coulson, 2012). I don't see the big problem of Central Bohemia with spruce monocultures for the reason that they are subject to natural succession, since events according to Bellasen and Luysaert are insignificant over decades and at the global scale, though having large socio-economic and ecological impacts regionally (Bellassen & Luysaert, 2014). And in this case, the local ecological impact would be positive. Spruce monocultures will slowly disappear while they are not artificially-grown, as the rejection of their promotion in their unnatural locations is covered in the long lasting plan of governmental forest management in the Czech Republic (Němec & Hrib, 2009).

The urgent problem is widely experienced in the monocultures of false acacia. The false acacia is coming from North America and even though it is taking only 0.8% (747 916 m³) (Forest Management Institute Brandýs nad Labem, 2012) of existing forests, it spreads fast by producing chemicals that are killing the existing natural ecosystem. The false acacia was grown in the past for honey production. According to the Forest Management Institute Brandýs nad Labem, most of the trees are about 70 years old (Forest Management Institute Brandýs nad Labem, 2012). This means that they are ready to be harvested and if the roots are removed, it will no longer propagate.

By observing the behaviour of the samples of false acacia, the material performed unexpectedly. Some samples cut in the same circumstances were swelling and some were shrinking. Based on personal conversations in 2012 with wood scientist Aleš Zeidler from FLD CZU and axeman Josef Kudrna, this was caused by the reason that the samples were made of reaction wood. Having a closer look at the false acacia monocultures in Central Bohemia, it was discovered that many of these trees are most likely to be reaction wood for the reason that they invade mostly on inaccessible slopes where they are not so much attacked by human forestry activity. This property leads to the conclusion that they are not suitable for my design purpose for the reason that the reaction wood is behaving unexpectedly. Němec says that the wood of false acacia has no use in the industry for its curly growth (Němec, 2005). However, this fact can be questioned for different purposes and also the unprogrammable behaviour may find its use. In Czechia, only one company sells false acacia wood that is in fact popular for outdoor urban furniture and playgrounds for its durability. However, this wood is not local but imported from Hungary.

Surprisingly, pine monocultures are not considered in the governmental plan, though Petr Pokorný in his pollen analysis proves the high occurrence of pine forests in Central Bohemia throughout history (Pokorný, 2011). Pine forests naturally grow in the locations with low levels of nutrients even in low lands (Němec & Hrib, 2009). Coulson explains that the softwoods from warmer climates have lower density due to the wider spaced rings (Coulson, 2012). However, Saranpää states that in softwoods with abrupt transition from early wood to late wood the growth rate has little influence on density (Saranpää, 2013). This is the case of the Czech pinewood species. As a result, the faster growth of pines in low lands should not affect the wood's properties in such extend. In addition, Schweingruber explains that trees growing on the sites with low level of nutrients don't grow fast (Schweingruber, 2007). Therefore also in reference to ongoing climatic change in our region, following the fact that pines are one of the most adaptable tree species, they seem to be, among others, suitable to grow and harvest. The pine wood properties are known to be soft and with good qualities suitable for the building industry, largely criticized and avoided for its movement. The last quality is the subject prompting the analysis in this research.

6.2 WOOD'S MATERIAL PROPERTIES IN RELATION TO MOISTURE CONTENT

6.2.1 Overall Perspective

According to Hoadley, wood always remains hygroscopic (Hoadley, 1980). This means that it is absorbing or releasing water in relation to relative humidity and temperature.

Based on this fact the wood shrinks, swells or moves and warps. Since the wood always remains hygroscopic, it can be expected that it also always remains warping. However, it is important to note the hysteresis effect that entails that the wood is less hygroscopic after the first desorption from the green wood, when the initial resorption is the lowest (Skaar, 2011).

Wood shrinks and swells or moves in relation to relative humidity and temperature based on the species and the grain orientation (see Figure 48). The greater shrinkage is associated with greater density (Glass & Zelinka, 2010). Dinwoodie explains that wood is anisotropic in its water relationships. It is due to the vertical arrangement of cells in timber and to the particular orientation of the microfibrils in the middle layer of the secondary cell wall between tangential and longitudinal shrinkage. And due to a) restricting effect of the rays on radial plain, b) increased thickness of the middle lamella on the tangential plane in comparison with the radial plane, c) difference in degree of lignification between the radial and tangential cell walls, d) small difference in microfibrillar angle between the two walls, and e) the alteration of early wood and late wood in the radial plane, which, due to the greater shrinkage of latewood, induces the weaker early wood to shrink more tangentially than if it would be isolated, between the tangential and radial sections (Dinwoodie, 2000). From green wood to air dried, the pine shrinkage is 6,8%, 3,8% and 0,201%, and swelling is 5,72% 3,04% and 0,076%, in tangential, radial and longitudinal section, respectively (Němec, 2005). Reaction and juvenile wood may shrink even 2% in the longitudinal section from green wood to oven dry (Glass & Zelinka, 2010). These facts are a cause of but are not equal to wood's hygroscopicity – movement after the wood is dried. The design research elaborates on different stages of moisture content, transiting from greenwood to air dried wood for manipulating the prototypes' performance. For this reason, the drying shrinkage also had to be considered.

Diwoodie specifies three cases of moisture flow in timber, which are: a) free liquid water in cell cavities giving rise to bulk flow above the fibre saturation point, b) bound water within the cell walls which moves by diffusion



Figure 48: Davidová 2012: Map of Shrinking and Warping of Different Local Wood Species (data and most of the images from: Němec, 2005 used with the courtesy of Grada)

below the fibre saturation point, c) water vapour which moves by diffusion in the lumens both above and below the fibre saturation point. Generally, the pines are much more permeable than the spruces, firs or Douglas fir (Dinwoodie, 2000).

The effect of change in moisture content, and thus of movement in wood that differs in different sections, is warping. There are four cases of warping: a) The most common warping occurs in the tangential section as a cup, which is caused by higher shrinkage on the left surface, b) a bow, which is not that common, occurs for the reason that the grain that is closer to pith shrinks more in the longitudinal direction, c) a crook, which is caused by reaction wood, d) a twist, that is caused by the spiral grain (Knight, 1961). In this research only cup warping is applied and elaborated.

Hoadley demonstrates that the wood cut in the tangential section from the centre of the tree warps more than the boards cut from its border (Hoadley, 1980) (see Figure 49). This fact was proved by my prototypes of Ray 2 and 3 which are using such conditions for generating a water resistant system (Davidová, 2013b) (see Figure 11 and Figure 16).

The research was often criticised for low durability of untreated wood and it was stated by many across the profession that the untreated wood will fully disintegrate upon being exposed to direct environmental conditions at this thickness within three years. Therefore, preservations through different stains were discussed and sampled in cooperation with Pavel Kašpar from Acolor, s.r.o. According to Dinwoodie water-repellent preservative stain or exterior wood stain, that is a natural finish based on resin solutions of low viscosity, lets the water vapour pass through, while it is protected from water ingress and photochemical attack. Compared with a paint or varnish it allows the wood to dampen and dry at a much faster rate. This paint is not transparent. Also, water born exterior paints have a high level of permeability. Those are based on acrylic or alkyd-acrylic emulsions and protect it from the passage of liquid water (Dinwoodie, 2000). After considering several options and looking at different permeable treatments, in the end, my research lead to protection through salt water souse used in Norwegian traditional architecture that seems to be the most natural and least harmful to the environment. According to Jon Bojer Godal from Nordmøre Museum, Norway, such treated panelling can last 200 years or longer. For more information on this see subchapter Ray 3: The Performative Envelope. Of what was discussed with Pavel Kašpar from Acolor, s.r.o., it seems that this treatment has no concurrence also when it



Figure 49: The severity of cupping in a board is related to its position in the log
(photo: R. Bruce Hoadley from: Hoadley, 1980; with the courtesy of Taunton press)

comes to durability, as the chemical stains have to be renewed every twenty years.

It is important to state that as of now the three-year-old untreated prototype Ray 2 hasn't experienced any environmental harm, but has gained beautiful patina.

6.2.2 Wood Warping Observations

My research focused on the tangential section, which warps into the cup. There is not much literature elaborating environment-wood in tangential section interaction in detail and also the little which was found was questioned by my observations. I was registering samples of false acacia and pine wood, cut in the tangential section into a shape of a square, a trapezoid and a rhombus of thicknesses of 0.3, 0.5 and 1 cm in the same

environmental conditions (see Figure 51). In all the cases, the rhombus shape performed approximately twice as much as a square and the trapezoid was in between in reference to the thicknesses (see Figure 50). Due to the material waste, the rhombus shape was replaced by two triangles later during the design process. Of course, the thinner the sample is, the more it warps and reacts faster to environmental changes.

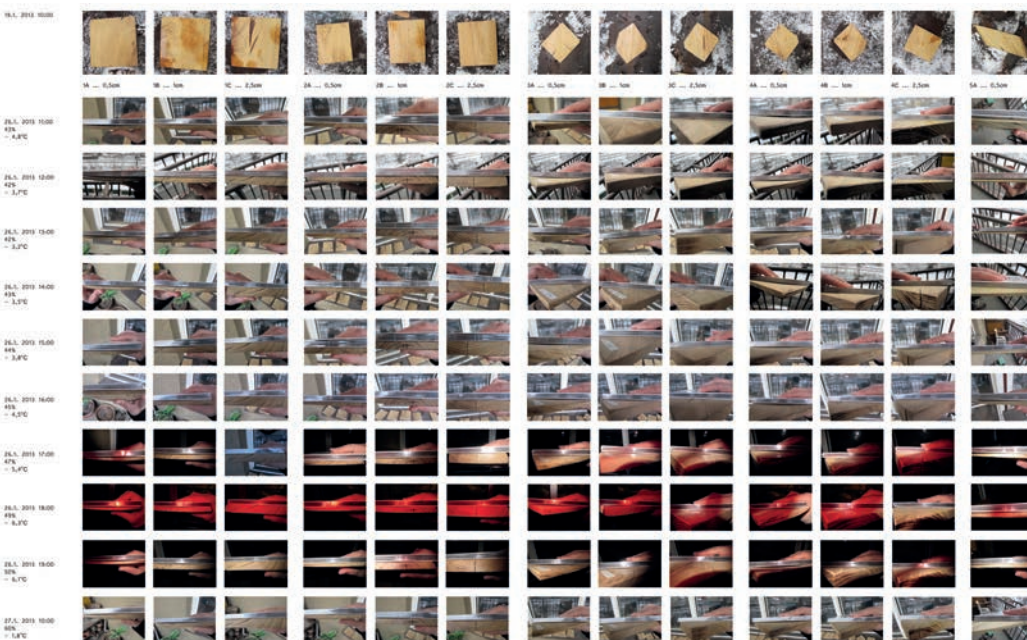


Figure 50: Warping of 0.5 cm Thick Pine Samples in 10% RH and 21°C (Davidová 2013)

In the false acacia case, the wood was warping in both directions (left and right side) on different samples in the same environmental conditions. The samples were cut from one tree at the same time, with the same moisture content, temperature and relative humidity. The ratio was one to one. Discussed with the wood scientists, carpenters and one axeman, it was found out, that it is probably for the reason that the samples were cut from the reaction wood.

According to Barnett and Jeronimidis, gymnosperms and angiosperms have generally adopted different strategies for coping with the mechanics of active change of curvature and bending stresses. On gymnosperms, the reaction wood is formed on the lower side of the stem, which is under compression – so called compression wood. It can eventually restore the stem to vertical alignment. On the lower side of branches of gymnosperms compression wood is also formed. With angiosperms the situation is the opposite, the reaction wood is formed on the upper part of the stem which is in tension – so called tension wood. The branches of these trees also

Figure 51: Samples with Different Thicknesses and Shapes of False Acacia Measured from One Morning to an Other (Davidová 2012)



develop tension wood on its upper side for maintaining their angle of growth (Barnet & Jeronimidis, 2003). Compressive values are also found in young soft woods with a normal strain pattern, shifting to usual tensile values in the adult stage. Also, the growth eccentricity is much more common in softwoods while it has lower risk of cracking (Thibaut & Gril, 2003). A high amount of compression wood can also be found in juvenile wood of fast grown trees (Bendtsen, 1978). However, Thomas states that compression wood in juvenile wood has little influence on its properties (Thomas, 1984). As discussed earlier, the reaction wood is caused by the environment. So, though it might be more common on softwood than on hard wood, if we compare the locations where pine woods and false acacias woods grow, the result should be opposite. This fact is supported by samples observations, though it cannot be used as an argument as not a large enough extension of samples was observed. If Schweingruber is correct, pine woods in Central Bohemia don't grow fast, therefore they grow in the locations with low nutrients (Schweingruber, 2007) and therefore, there should not be higher occurrence of compression wood even in its juvenile wood.

The same occurrence as with the tension wood of false acacia was observed on the straight pine wood with 10% of the samples but this effect disappeared after a while. The explanation is that after the cutting of the tree some stresses remain in the fibre but they narrow down with the cut over time (personal conversation, Zeidler from FLD CZU 2013). The same behaviour was observed in detail on 275 triangular samples of the pareSITE pavilion and more generally on other prototypes.

The research then continued on narrow pine wood. The samples of green wood (over 30%MC) and dry wood (10%MC) were compared. At the beginning, the samples performed the same but after a certain time the samples from the green wood were warping much more, even in the humid weather.

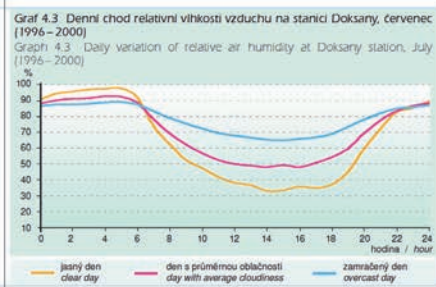
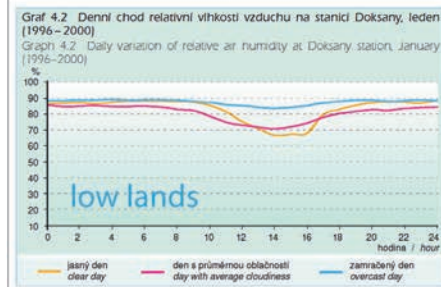
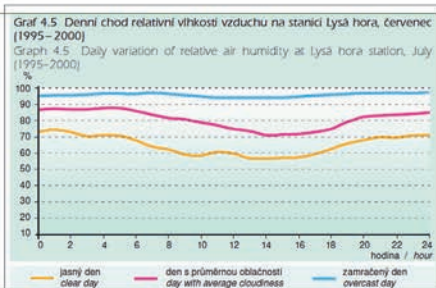
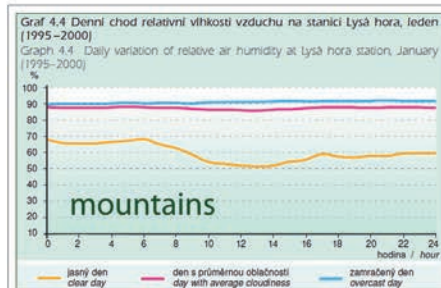
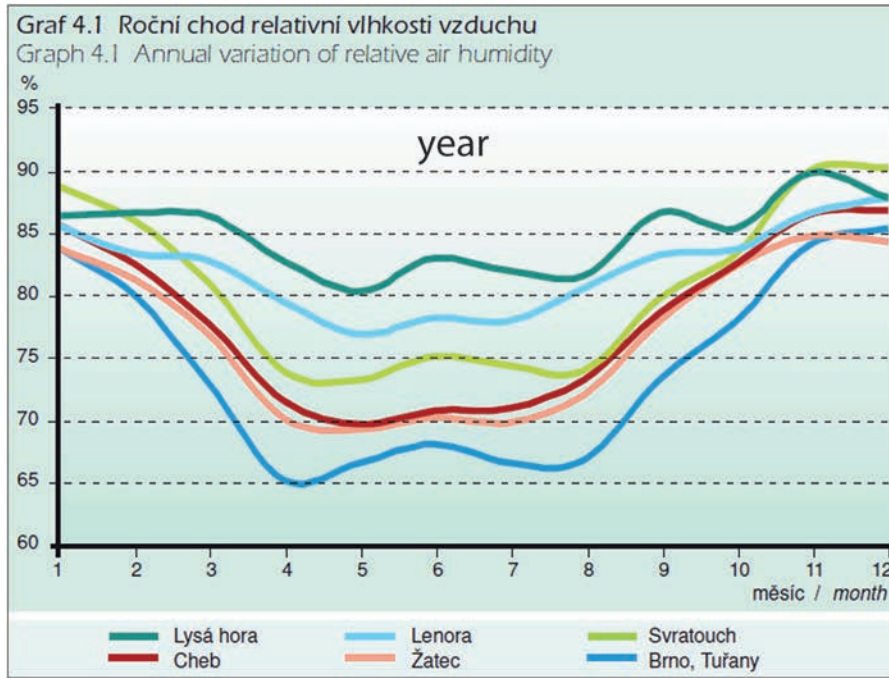
To program the warping of tangential cut solid wood panels, samples in different moisture contents were cut every two weeks from a drying trunk of 18%, 20% and 22% as moisture content was observed in natural climatic conditions. This relation was proved and specific moisture content when cutting was assigned to panelling of prototype Ray 3. This is elaborated closer in subchapter Ray 3: The Performative Envelope.

When oscillating between use of 0.5 and 0.8 cm thick panels and samples, 0.8 thickness was assigned to a durable solution with enough performance and was applied on both prototypes of Ray project. No panel ever broke on 0.8 cm thick while observed for three year on the Ray 2 prototype which reacts fast enough within the mostly slow changes of weather conditions in Czechia while we experienced a minor amount of cracking on 0.5 cm thick panels of pareSITE pavilion after one year. However, it was two panels out of 275 caused by unsuitable joinery that was used. For joinery experiments and the solution see section Ray 3: The Performative Envelope in projects chapter.

6.2.3 Factors of Moisture Content

Wood's moisture content (MC) depends on relative humidity (RH) and temperature (t) (see Figure 53). Relative humidity is defined by Fathy as water-vapour content of air at a given temperature that can be expressed as the ratio of the portion of the total atmospheric pressure contributed by water vapour to the portion necessary to cause saturation at that specified air temperature (Fathy, 1986).

According to the Climate Atlas of Czechia, the average relative humidity in the Czech Republic culminates the most in low lands in the summer seasons, where it reaches the lowest points in the afternoon while in the winter in the mountains it stays high and almost doesn't change at all. The highest relative humidity is during the nights while the lowest occurs in the afternoon in low lands during the summer (Tolasz & Coll., 2007) (see Figure 52). Therefore, designs have to be specific to their locations, while also considering micro climatic conditions. As the pavilions' prototypes were moving to different environments – city heat islands and the outskirts of Prague, asphalt, stone and grass on the ground surfaces – different performances were observed.



January

July

Figure 52: Relative Humidity Graphs (Tolasz & Coll., 2007 – used with the courtesy of Tolasz)

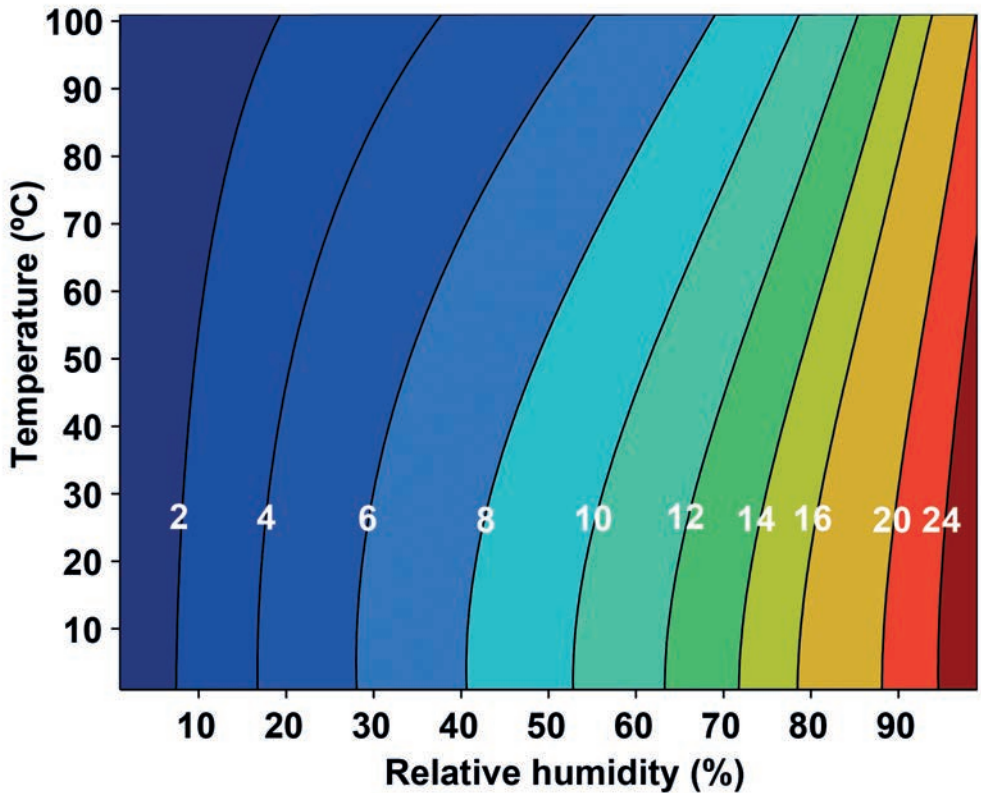


Figure 53: Equilibrium moisture content of wood (labeled contours) as a function of relative humidity and Temperature (Glass & Zelinka, 2010 – used with the courtesy of USDA Forest Products Laboratory)

Another factor is the temperature. Dinwoodie's diagram shows that wood with 5% MC is obtained from the green wood in 16% RH and 15°C as well as in 50% RH and 100°C (Dinwoodie, 2000). Therefore the world orientation also plays its role. It was measured on the pareSITE pavilion (see Figure 14) that the main effect on warping had the direct sun radiation. It is caused by the shrinkage of the upper surface. While the 0.5 cm plates, originally cut from the green wood, in 40% relative humidity and 21°C bent inside (right side of the tangential section) by 1 cm with 14% MC in the shadow at the North orientation, on the South it was warping outside (left side of the tangential section) by 3 cm with 7% MC under the direct sunshine. This shows that the situation is more complex and other factors besides the relative humidity have to be considered.

The speculation that different organisms affect the wood moisture content was observed and proved on algae. It was measured that the algae surface on one particular wooden fence lowers the moisture content of wood by from 2 to 4% in the equal climatic conditions (see Figure 54). Two types of local algae, *Apatococcus* and *Klebsormidium*, were artificially grown on ash, false acacia and pine wood for six months. While there was success with the *Apatococcus* on all the samples, *Klebsormidium* failed to grow. Generally, the algae were growing the best on the ash samples, and on the false acacia the pine wood the worst (see Figure 55). This is for the reason of the chemical content of each wood species, as pine wood is the most acidic. However, the Ray 2 prototype is inhabited by algae and even lichen after three years of exposure to biotic and climatic conditions in

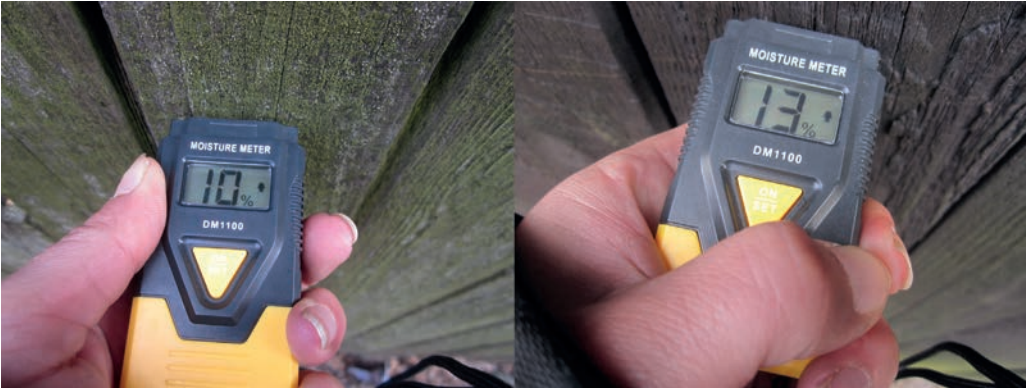
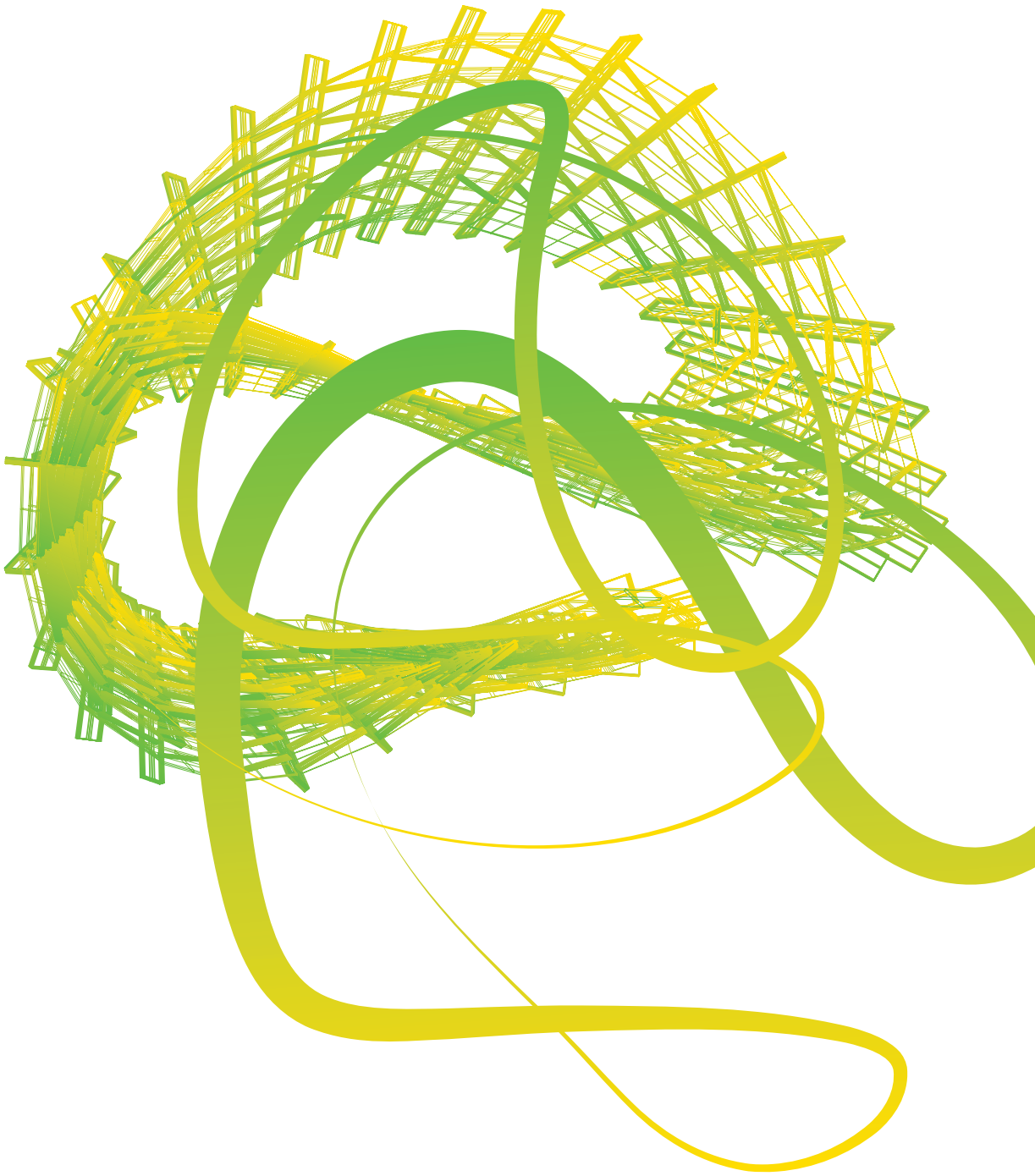


Figure 54: Fence with and without Algae Measured with Moisture Meter. Nové Město nad Metují (Davidová 2013)

the courtyard next to the forest rocky slope in Štěchovice near Prague (see Figure 11). This feature was not used in the end, as the wood warped also in high relative humidity and it was further regulated by specific moisture content when cut. However, I consider this to possess crucial potential for future exploration in Performance Oriented Design. Wider ranges of material programming will have to be tested and explored. By now, the research is avoiding such through salt water souse on Ray 3 prototype (see Figure 16) to keep control but the speculations on future applications are open.



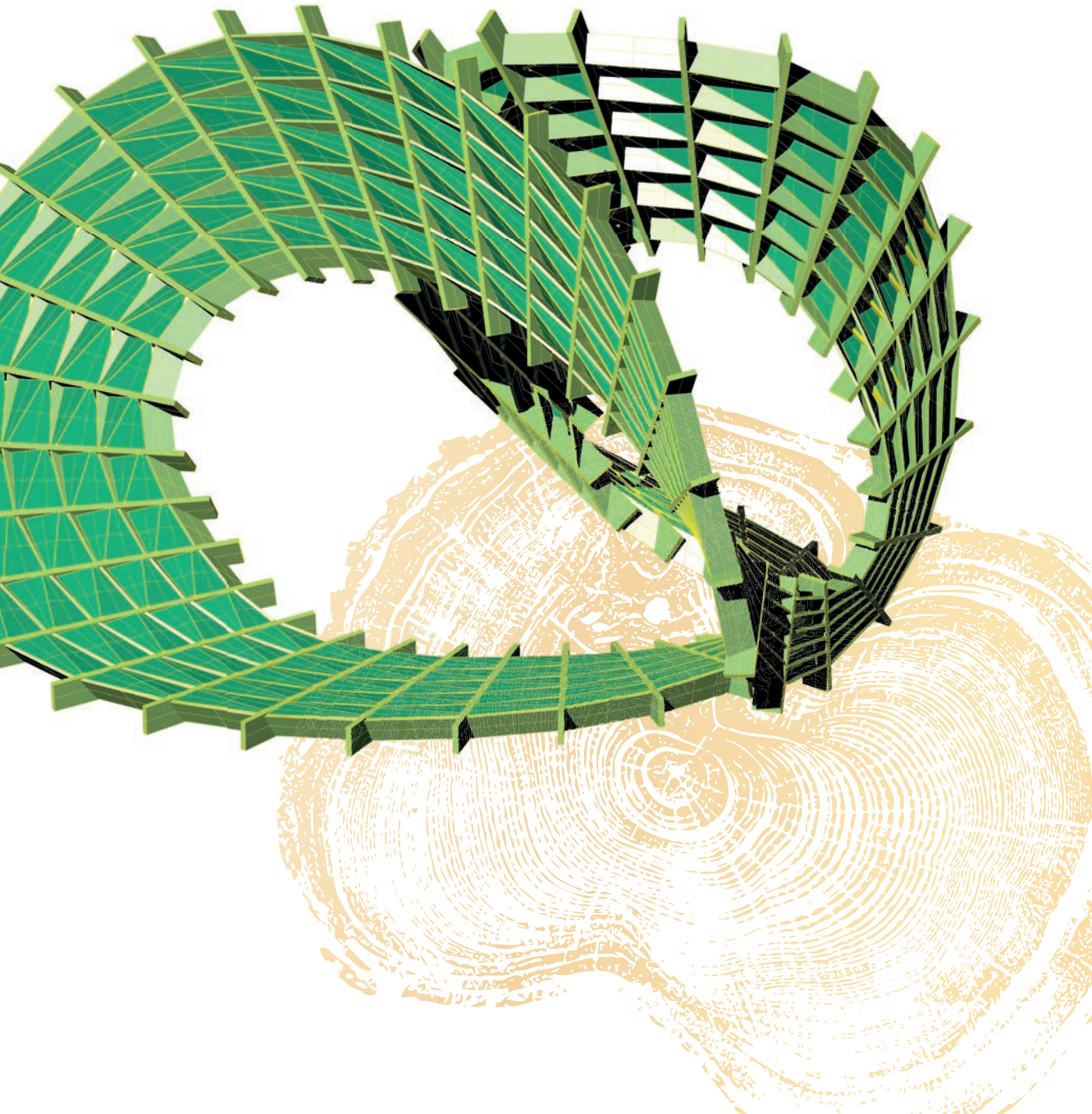
Figure 55: Samples of Artificial Growth of Apatococcus and Klebsormidium (from up to down) on Ash, False Acacia and Pine Wood from Left to Right, Respectively (Davidová 2013)



Marie Davidová

WOOD AS A PRIMARY MEDIUM TO ARCHITECTURAL PERFORMANCE

7/ *Projects*



This chapter explains all prototypes' projects and their development performed throughout the research. Previously, several concepts of the wood relating to relative humidity and temperature were drafted in a creative, non-critical mode. Afterwards, they were undertaken through criticism and developed or put aside.

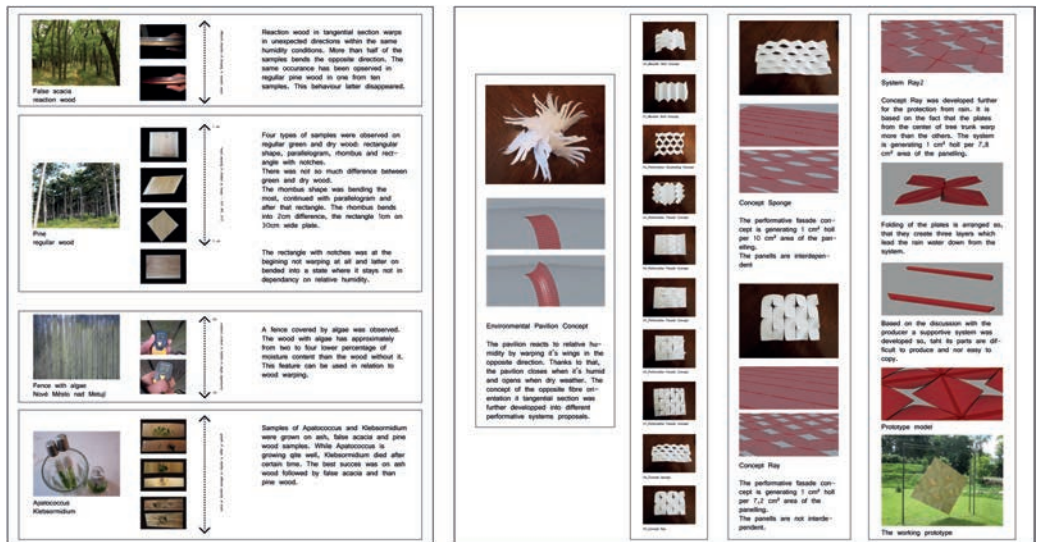


Figure 56: System Development (Davidová 2013)

The system development started with the concept of the summer pavilion that closes in wet weather and opens in dry conditions. Through gradation of the the plate's thicknesses the structure would reach the goal. It was a naïve concept which didn't consider structural or social performance. However, it led into the concept of combining the left and the right side of the plates in the tangential section which was further developed in the concepts of performative screens Ray and LOOP pavilion. Some concepts were meant for sun shading and some for the dry air circulation in between the different discrete spaces. From the several sketches, two were chosen for further consideration and simulated in Grasshopper for Rhino 5 (Davidson, 2016) with the data measured from the samples observations (see Figure 56).

The system Sponge (see Figure 57) has its advantage in the resistance to sudden rain. Its disadvantage is the interdependency of each plate, as the wood does not shrink exactly the same. Another problem is that the system shrinks in general. With 30 cm plates, the system shrinks by cca. 3 cm with seven panels. For the height, the system extends 28 cm with eight panels of 20 cm height with 3 cm overlapping. This could be developed into a nondependent system, but the durability would be questioned anyway as the plates would move one on another. It was simulated that the concept generates 1 cm² airing gap per 10 cm² of the surface in 10%RH and 21°C (see Figure 58).

Another concept, Ray (see Figure 59 and Figure 60), was not resistant to the sudden rain, while its performance was much better. According to the simulation for 10%RH and 21°C, it generates 1 cm² airing gap per 7.2 cm² of the surface area because of the use of the triangles that warp more than the rectangles. The system had overlapping from the lower parts of the boards and not from the sides. Getting back to the GIGA-map, the system was further developed into prototype Ray 2 that deals with the material properties of wood. Directly with the capacity of different warping based on the position of the tangential cut within the tree trunk, thus allowing overlapping by layering.

Following development of the concept, Ray was proposed in two variations of prototypes (see Figure 65 and Figure 67). By going through material and design research, this study has been supported by two prototypes of pavilions (see Figure 73 and Figure 82), testing the concept in a higher amount of samples, in orientation to all Earth axes, testing design proposals in larger complexity while considering all environmental, physical and biotic aspects. Thus, the pavilions became projects of themselves, having their own agenda while also benefiting from Ray project.

Figure 57: Concept Sponge (Davidová, 2013)

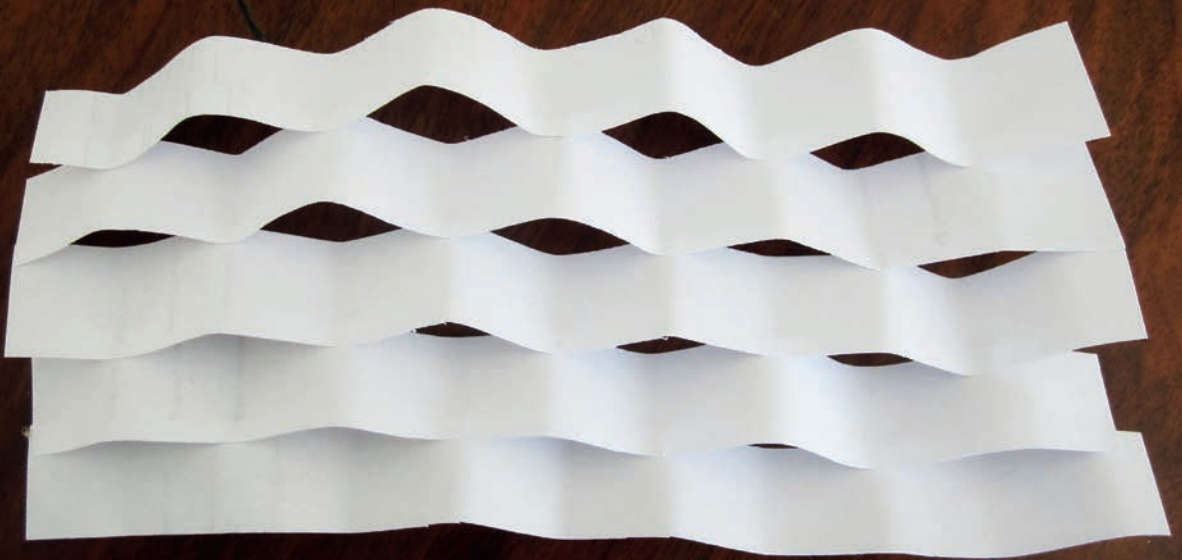
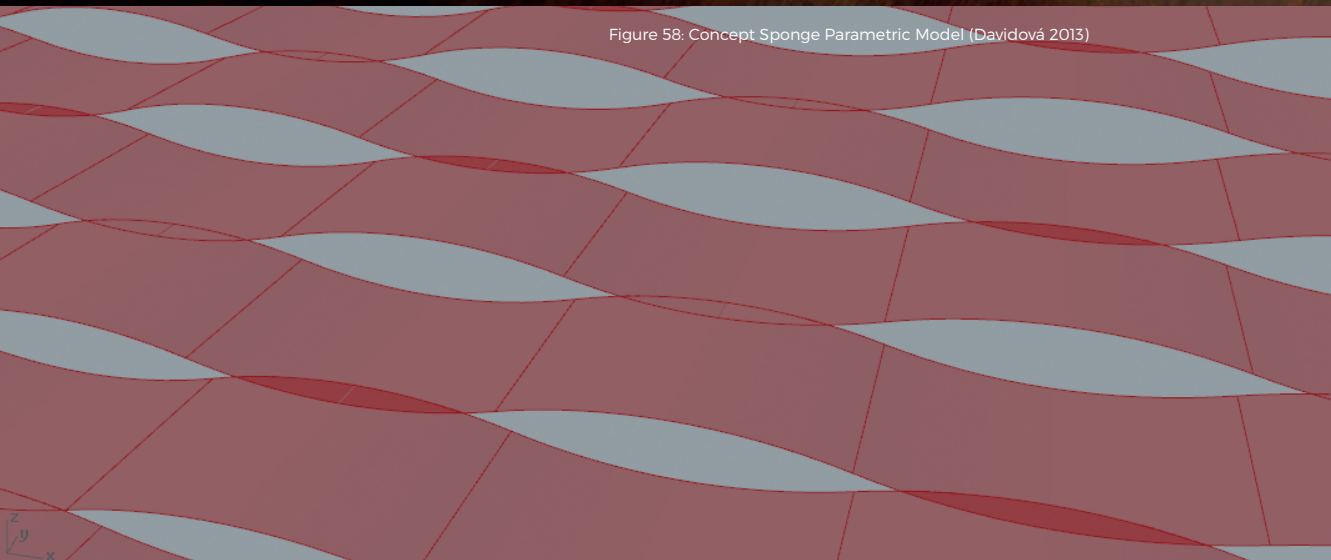


Figure 58: Concept Sponge Parametric Model (Davidová 2013)



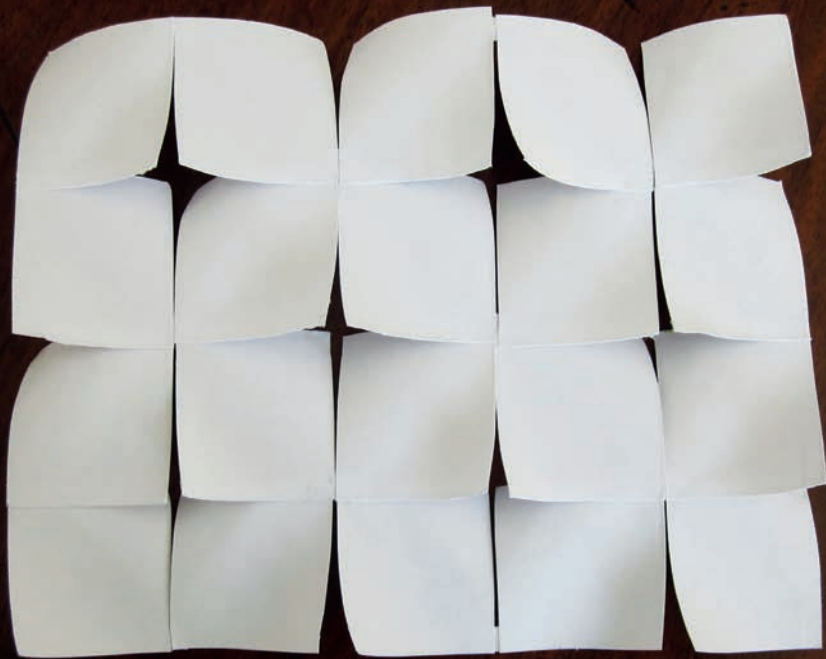


Figure 59: Concept Ray (Davidová, 2013)

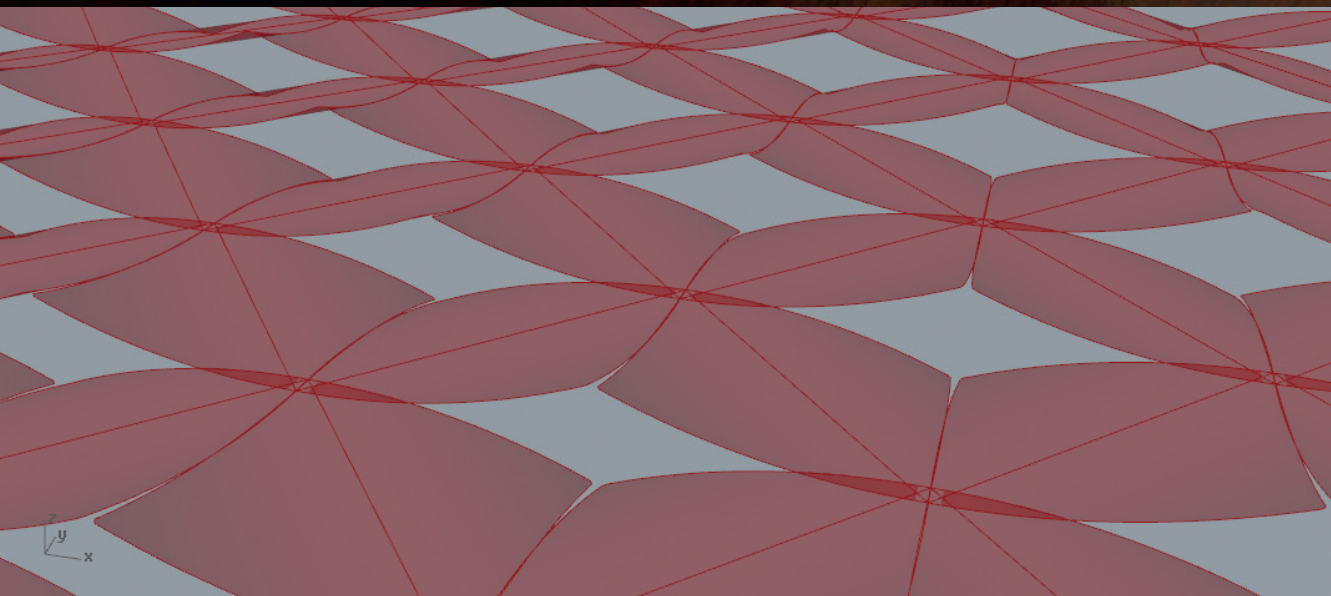


Figure 60: Concept Ray 1 Parametric Model (Davidová, 2013)

All these prototypes were, are and/or will be observed in relation to climatic conditions, moisture content and warping. Much of the performance has been also mapped through human perception and interaction (please, see the methodology chapter). Thus, they promise to be a step forward in bettering the different discreteness of spaces radiant from outdoor to indoor climates within the times of its increasing extremes due to the climatic change.

7.1 RAY

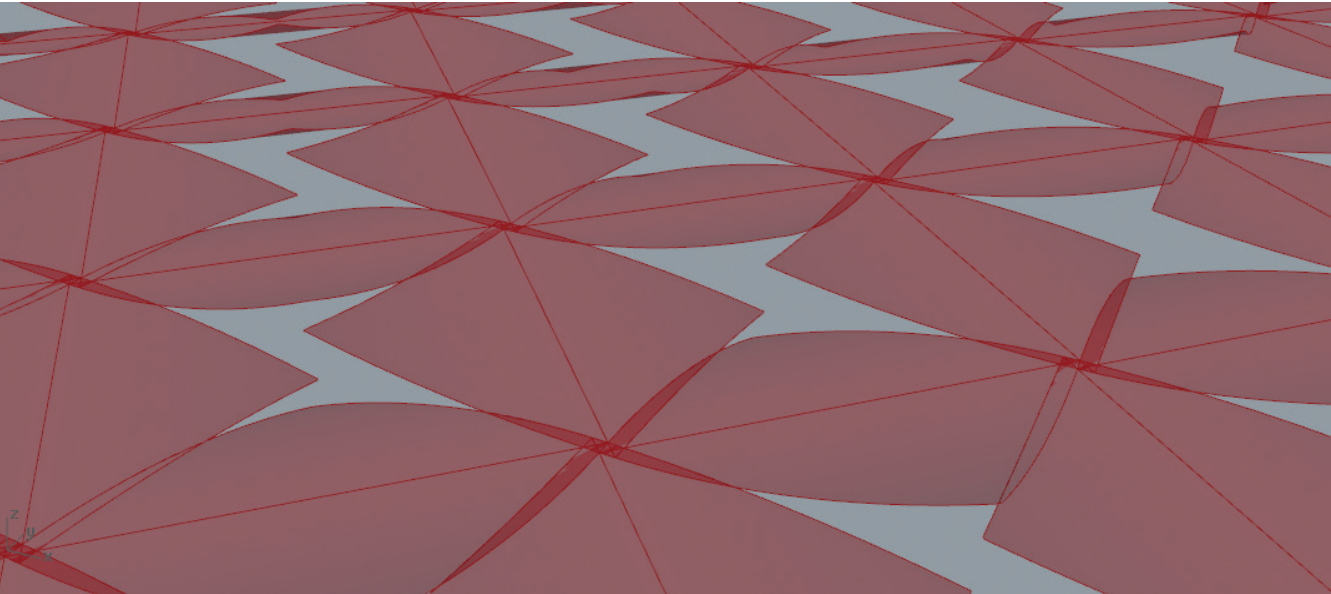
7.1.1 Ray 2: The Performative Screen

This prototype was elaborated in two papers: 'Ray 2 The Material Performance of a Solid Wood Base Screen' (Davidová, 2013b) and 'Wood's Material Performance: Ray 2' (Davidová, 2014e). Though widely cited in the thesis, non were suitable as a separate section for this sub-chapter. This section explains the performance and development finalised with prototype Ray 2. Being the first prototype of the Ray project, as the first Ray was only digitaly simulated, it demonstrated many failures in simple complex thinking that led to further research, samples observations and the Ray 3 prototype. As it seems to be the first current prototype of this performance made of solid wood cut in the tangential section and no literature or knowledge is available for its historical references, these failures are not that surprising and they served very well as a research tool for defining the parameters of the project.

Ray 2 (see Figure 65) is a wooden environmental responsive screen system that reacts to changes in relative humidity and temperature. Based on the material properties of wood, cut in the tangential section, the system opens in dry/hot weather thus airing the environment. Whilst in the humid/cold conditions it closes, not allowing the moisture into the structure.

Ray 2 was developed from the concept of Ray (see Figure 59) with the fact that it resists sudden rain. Based on the properties of tangential cuts from different positions of the tree trunk, the plates are combined in diagonal directions. In 10%RH and 21°C, the concept generates 1 cm² airing gap per 7.8 cm² of the surface area which is good enough for planned performance. This fact was first simulated in Grasshopper for Rhino 5 based on measured samples (see Figure 61) and afterwards measured on the prototype (see Figure 66).

Figure 61: Concept Ray 2 Parametric Model (Davidová, 2013)

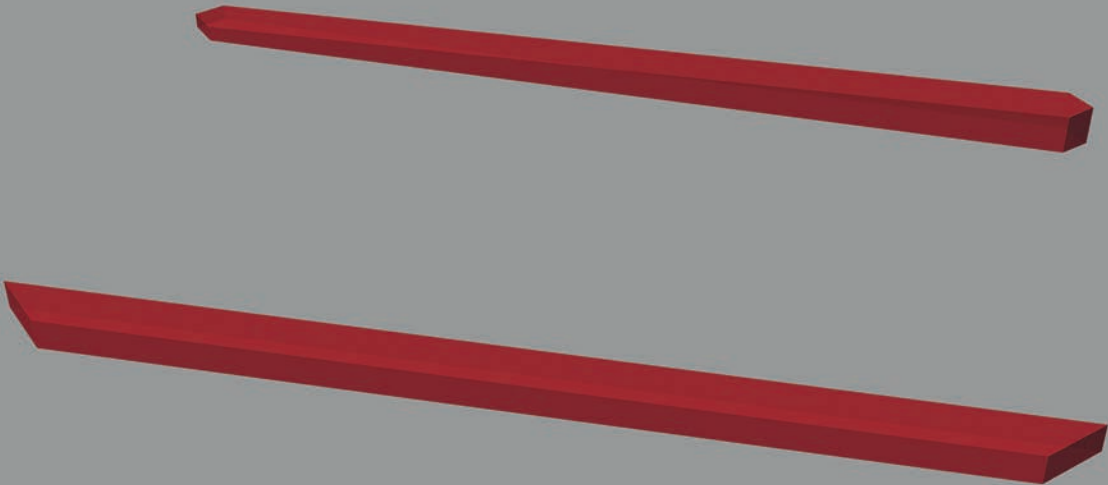


The system Ray 2 is based on two triangles fit together into a rectangular shape while each of them have a different orientation of the tangential section. The upper one warps outwards and the lower one inwards, generating a large gap within the system for airing (see Figure 61). Within the grid, based on two diagonals, one direction is based on the rectangles coming out from the centre of the tree trunk and the other direction from the border pieces. The direction of the boards that warp more (the one from the centre of the tree trunk) is in one plane. In the other direction, the board is fit under the layer of the first direction on the top while fixed on the top of the first direction on its bottom (see Figure 62). This ensures that the boards overlap within the whole system (see Figure 64) and therefore offer protection from the sudden rain when the system does not react immediately.

Figure 62: System Ray 2 Layering (Davidová, 2013)



Figure 63: System Ray 2 Base of the Plates (Davidová, 2013)



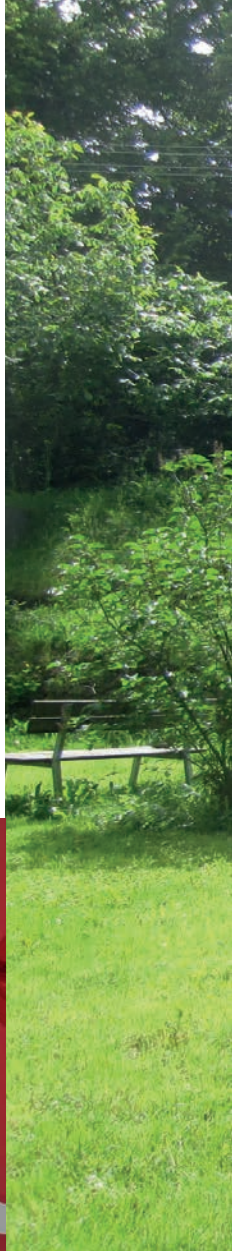
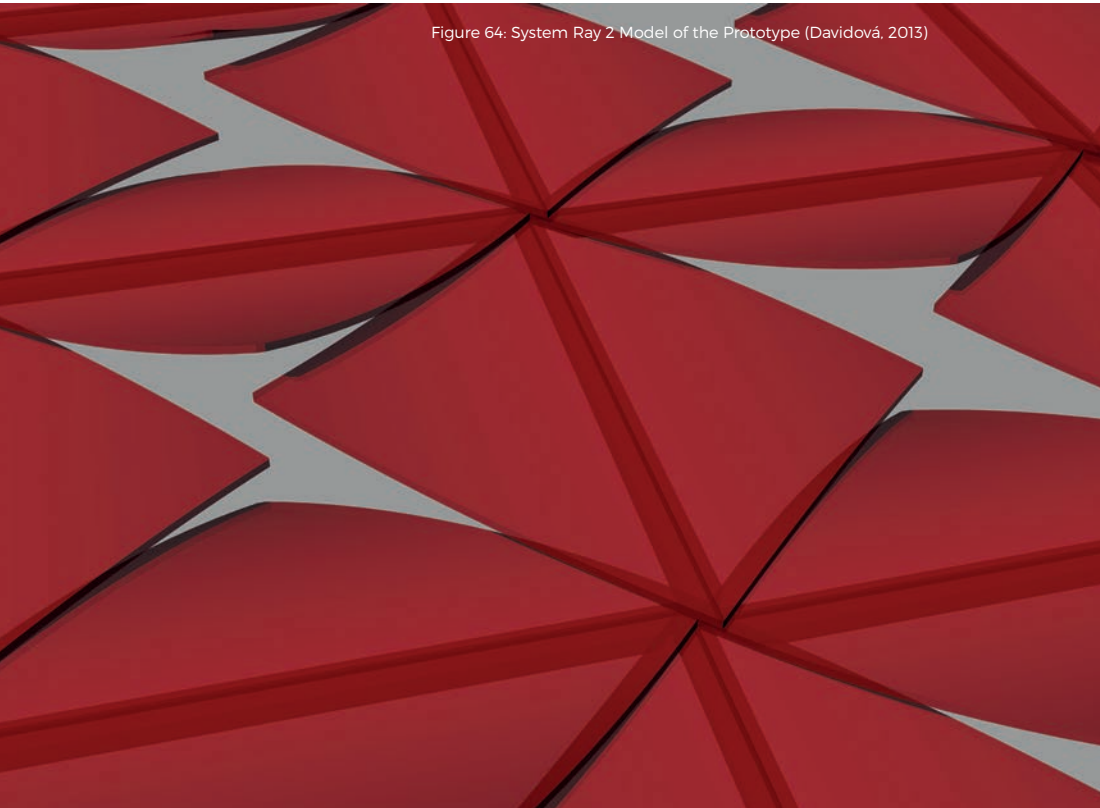
From the discussion with the producer, it was concluded that the design should cover some specifications of the production that are not easy to copy. The bases of the plates were developed under the certain angle that fit the structure into plane (see Figure 63). It was also agreed on using 0.8 cm thickness instead of first planed 0.5 cm and filleting the edges for durability reasons.

After this discussion with the carpenters, the prototype was produced and it was agreed that the product will be offered as a roofing and facade system on the market and other uses will be explored.

Conclusion

The prototype was further measured. It was discovered that 2 cm overlapping is not sufficient for heavy rains and the system needs to be further tuned. The gaps at 85% relative humidity are not yet fully closed. Samples with different moisture content were therefore measured for their performance that lead into the next prototype. The used joinery that was not fully considered in this prototype was not really resistant, sustainable and in relation to the durability of the panelling. We experienced problems during low-cost transportation on cart on local Czech roads when not securing the prototype. This fact, and also the eager for durable sustainable solution, leads to the further research discussed on the application in prototype Ray 3 (see Figure 67).

Figure 64: System Ray 2 Model of the Prototype (Davidová, 2013)



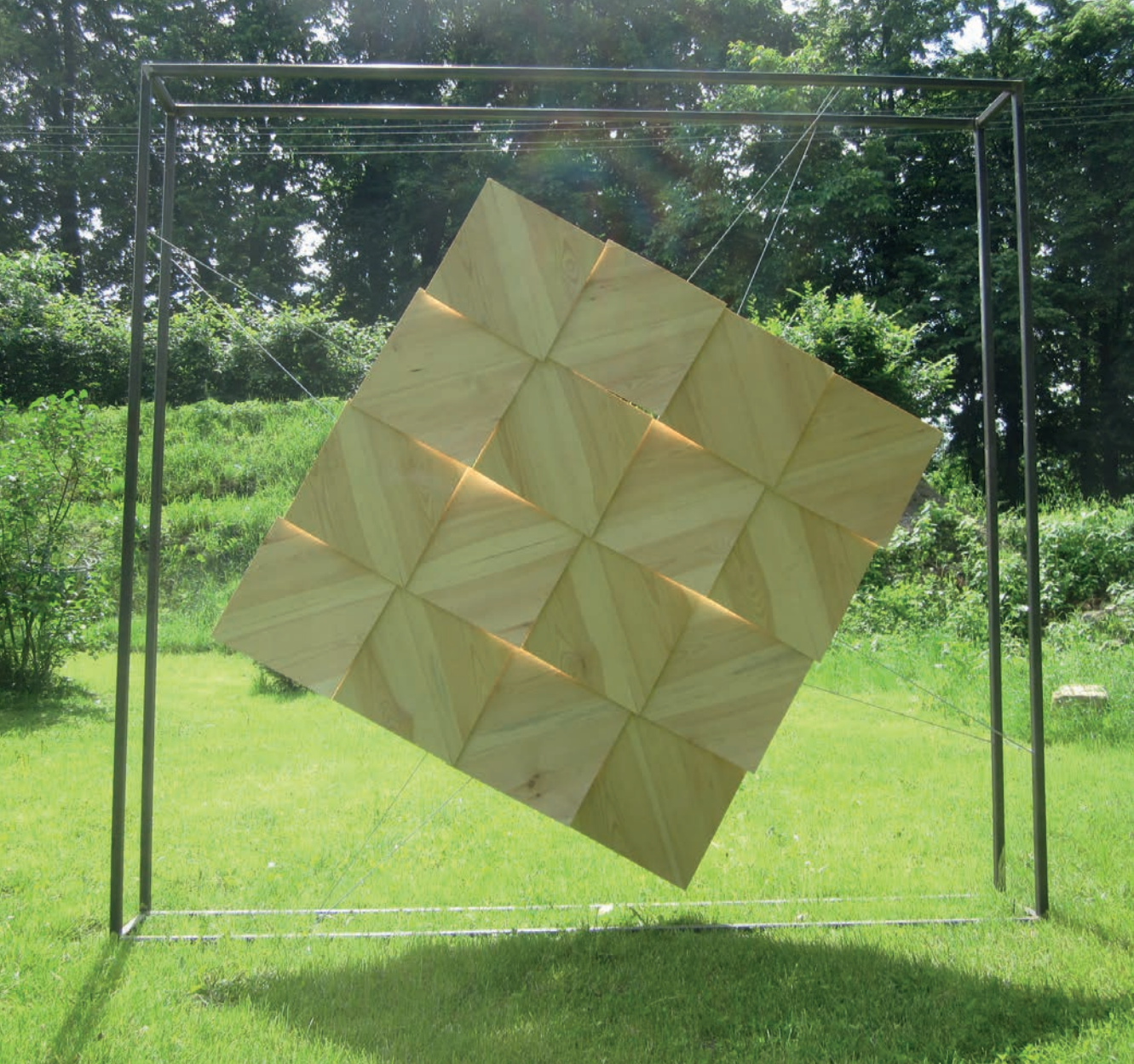
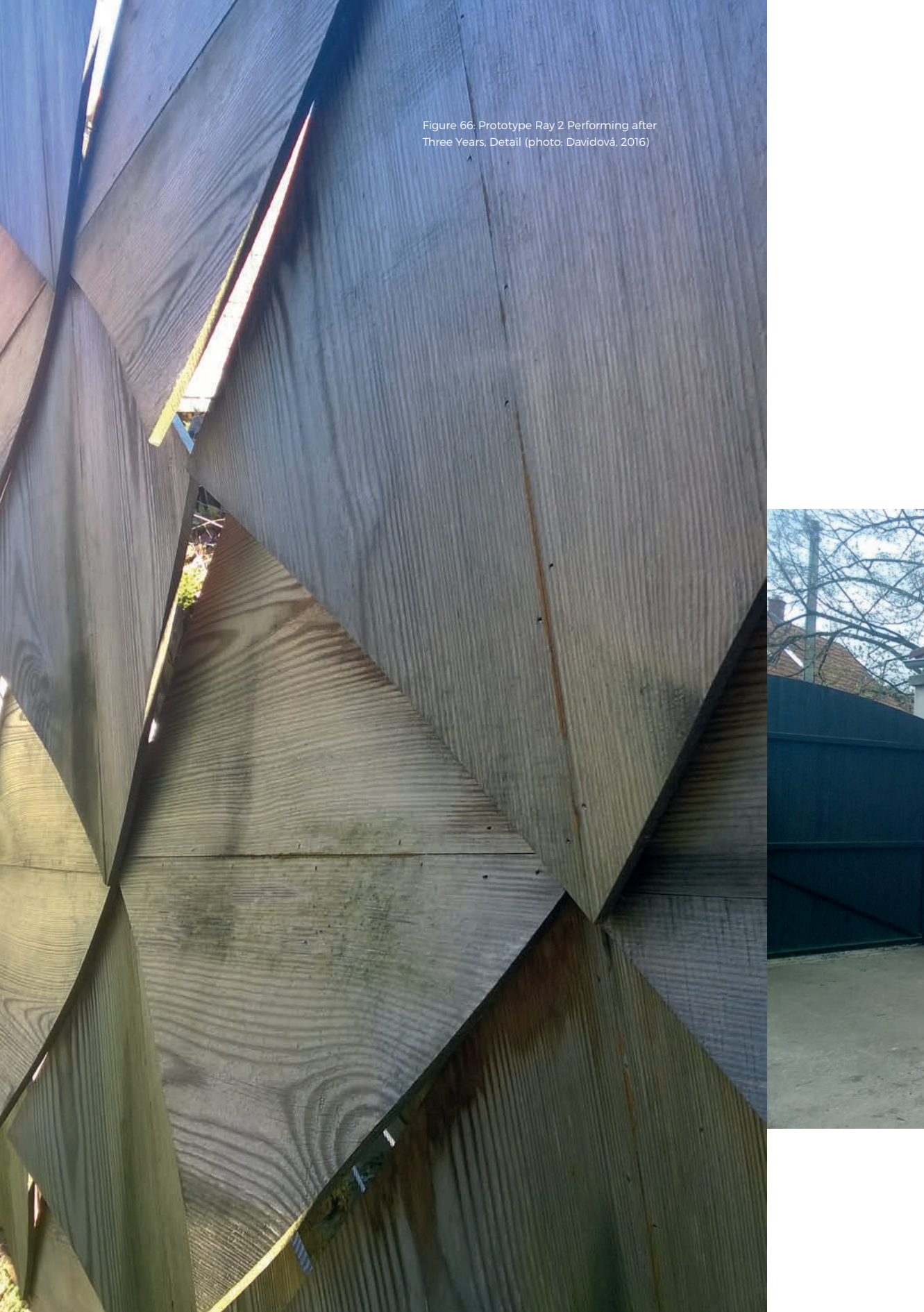


Figure 65: System Ray 2 Prototype (photo: Davidová 2013)

As mentioned in the material chapter, the triangles that were initially warping in the opposite direction behaved smoothly after the first summer. The prototype didn't really experience any environmental harm during the years it was exposed to it in outdoor conditions. It gained beautiful patina and has been inhabited by algae and lichen that don't have any decaying effect.

This project was kindly supported by Defio, s.r.o.

Figure 66: Prototype Ray 2 Performing after Three Years, Detail (photo: Davidová, 2016)



7.1.2 Ray 3: The Performative Envelope

(Davidová, 2016c)

This paper is currently in press at the DCA 2016 conference proceedings. It develops the solutions for programmability, durability, and potentials of thermal comfort and the joinery question brought about through the Ray 2 prototype while discussing the possibilities and intentions of the application as well as its borders set by today's market. Though the application example is shown on the Collaborative Collective's project that is localised to Norway, not Czechia, the discussion is targeted to the systemic approach of layering spaces within the onion principle, in this case in correspondence of specific environment needs that are highly relevant to this application, rather than the discussion of the site-specific environment-material interaction. The 'På Vei' project, designed with my colleague Křištof Hanzlík in my practice Collaborative Collective with other external collaborators in 2011, fostered a great part of my/our motivation to undertake this PhD research project. The prototype is new and will have to be observed over several years. As mentioned in several parts of the thesis, the full scale prototypes often showed different performance or design problems than the observed samples or simulations. In addition, other unexpected difficulties can appear over time.



Figure 67: System Ray 3 - Prototype
(photo: Davidová 2016)

7.1.2.1 Abstract

Ray 3 (see Figure 67) is a fully functional envelope that reacts to relative humidity and temperature of air. Based on the material properties of pine wood, it is allowing dry air into semi-interior, while closing in humid weather. This is due to the tangential section of the panelling that warps based on the different fibre density on the left and right side of the plate in low relative humidity percentage and high temperature. The envelope is meant for non-discrete architectural spaces, the spaces between exterior and interior.

This design is a continuation of proposal Ray 2 (Figure 66), The Performative Screen. Compare to the previous prototype of Ray 2, Ray 3 is a fully solving the performance, durability and is equipped with solved joinery and thermal, humidity permeable solution.

Recent samples observations are leading to currently produced prototype that will close its panels at 75% relative humidity level, will be treated by salt water against biological decay and fastened by plugs attached at lower moisture content to the construction frame. The glass bubbles based thermal comfort solution, performing on reflection, originated from NASA technologies was selected instead of any kind of thermal insulation.

This partly trans-, partly inter-disciplinary project, next to the architects involving carpenters, forest and wood engineers, wood preservation architectural and ships historians, environmental engineers, insulation material engineers as well as climatologists or even marketing engineers, suggests future applications for built environment and reflects upon the past. However, the conclusion has to be taken that material based building industrial practice is far behind contemporary trends in different disciplines.

Figure 68: System Ray 2 – Prototype Detail (photo: Davidová 2013)



7.1.2.2 Introduction

Wood belongs to so called ‘self-x materials’ described by Speck, Knippers and Speck as:

‘...materials that show – typically in addition to their main mechanical or protective functions – intrinsic properties that enable them to react to external or internal stimuli or disturbances. Examples include: self-organisation, self-adaptation, self-healing and self-cleaning. Self-x materials are suitable for many technical applications and are currently becoming of increasing interest in materials and biomimetics research.’ (Speck, Knippers, & Speck, 2015)

Its self-organisational capacities of warping related to humidity and temperature has been used in traditional Norwegian panelling over generations on solid wood in tangential section (Larsen & Marstein, 2000) and are explored today through Research by Design at academic institutions. The first published prototype of recent research realized by Asif Amir Khan at AA School of Architecture under the leadership of Michael Hensel and Achim Menges in 2005 was mentioned in Morpho-Ecologies publication in 2006 (M Hensel & Menges, 2006). That time, it was a screen made out of laminated veneers. Since that time, the research under Michael Hensel at the Research Centre of Architecture and Tectonics at the Oslo School of Architecture and Design developed into experiments with ply-wood, also enabling a double-curvature (Haugen, 2010; Michael U Hensel, 2011a; Michael Hensel, 2013) and the research lead by Achim Menges at the Institute of Computational Design at the University of Stuttgart leads towards creation of synthetic material of similar properties and exploration of solid wood, cut in tangential section (Menges & Reichert, 2015) as proposed by the author for the durability reasons (Davidová et al., 2013). The ply-wood solution is durable but the results of LCA comparison of solid wood and plywood for Czech environment, performed for prototype of screen Ray 2 by Vladimír Kočí and the author suggest, that use of solid wood is more sustainable, when it comes to given product in given location (Davidová & Kočí, 2016). Prototype Ray 3 (in fabrication) is following prototype Ray 2, explained by the author as follows:

‘Ray 2 is wooden environment responsive screen system that reacts to changes in relative humidity. Based on the material properties of wood, cut in the tangential section, the system opens in dry weather thus airing the construction. Whilst in the humid conditions it closes, not allowing the moisture into the structure.’ (Davidová, 2014e)

Cut from green wood, Ray 2 prototype closes when already wet not in latter proposed 75%RH. When fully wet, the panels warp the opposite direction, while overlapping is not enough. The coming prototype uses the data from samples and the previous prototype observations. Programed for certain relative humidities combined with temperatures, it should also solve wood’s durability issue and temperature permeability of 0.8 cm thick panels.

Proposed for generating non-discrete architectural spaces, the envelope is designed to exchange the environmental conditions between exterior and interior when suitable. As shown on the example of the application on ‘På Vei’ project, designed by Collaborative Collective as competition entry for Sogn and Fjordane Muzeum and Depository in Norway, it has its meaning in Hensel’s and Turko’s proposal:

‘...we propose grounds and envelopes as potentially correlated spatial devices that can give rise to approaches towards non-discrete architectures for the purpose of a spatially and performatively enriched build environment. As this shift is predicated on grounds and envelopes as a way of staging spatial organization and transitions, it involves careful consideration of sectional articulation and organization of such architectures, including the way in which these are embedded within their specific local settings.’(M Hensel & Turko, 2015)

A bit different approach is suggested by Reichert, Menges and Correa, putting their interest in *‘...opening roofs for semi-interior spaces, such as sports stadiums, and adaptive facades for fully enclosed buildings.’* (Reichert, Menges, & Correa, 2015)

7.1.2.3 The Panelling

7.1.2.3.1 The Wooden Layer

Wood in tangential section generates so called cup when warping (Knight, 1961). The project Ray is using this property to close the system in high humidity and open it in dry weather. The previous prototype of Ray 2 is closing at too high relative humidity level based on the fact that it was made from green wood. Plates, in the exact dimensions of the panelling, cut from one trunk in the period of March and April 2015 per two weeks have been observed to find out in which moisture content the wood should be cut so that it's narrow at 75% RH. It has been previously observed by the author, that the greener the wood is, the more instable it reacts (Davidová, 2013b). The samples were measured from June to November 2015. While in June, it seemed that the plates cut in 18% moisture content (MC) were the most appropriate, latter it got stabilised on the samples cut in 22%MC that seem to be narrow from around 70%RH up and from around 10°C lower.

The samples were treated with salt water, as according to Jon Bojer Godal such wood can last for more than 200 years in dramatic environmental conditions of Nordmøre in Norway as sugar and amylose had been washed out (Godal, personal correspondence 2015), and tested for its hygroscopicity performance. In Mari Sand Austigard's report from Mycoteam as for Røros Kommune, the samples of pine wood samples were sank in salt water for four month (Mycoteam As & Austigard, 2014). As my pine samples were 0.8 cm thick, one week period was tested. The samples seem to sustain their hygroscopic properties such as warping and moisture content.

The wood properties has been widely consulted at the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences and with Jon Bojer Godal from Nordmøre Museum, Norway.

7.1.2.3.2 The Joinery

The joinery is inspired by Erwin Thoma's Holz 100. Holz 100 is panel such as CLT but joined by oak plugs dried to 0% moisture content when fastening instead of polyurethane glue (Thoma, 2006). Pine wood plugs were dried in microwave oven and tested in natural environmental conditions on panelling samples by the carpenters from Defio, s.r.o. producing the prototype (see Figure 69). Different radiuses in circular or oval shapes of plugs were tested in relation to different moisture content of the samples. At the end, the 0.8 cm in diameter, circular shape was selected, as there never appeared cracks on 0.8 cm thick panels' samples.

7.1.2.3.3 The Thermal Comfort

The 'insulation' AZ ThermaCoat (see Figure 70), based on the micro glass bubbles M3 from NASA technologies, was selected due to its thinness, sustainability and revolutionary concept. Generating great thermal comfort by having warm surface, the inner temperature doesn't need to be so high. In a way, it is not really thermal insulation as the concept works not only on low thermal penetration of the hollow glass bubbles (from 0.05 to 0.26 W/mK at 0°C) that cover 90% of its ingredients, but most importantly, on their reflection of electro-magnetic heat radiation. The paint is vapour permeable and should keep elastic enough for warping of the 0.8 cm pine wood board, therefore perfectly suitable for the task. It is applied in about from 0.5 to 1.0 mm thin layer that does not evaporate any chemicals, is harmless to health even when recycled and fully washable. The company AZ Tech, s.r.o. will apply their product directly on the prototype with their technology and will cooperate on the development of the product, solving its possible failures.

Figure 69: Test of Plugs in Natural Environmental Conditions (photo: Bouma 2015)

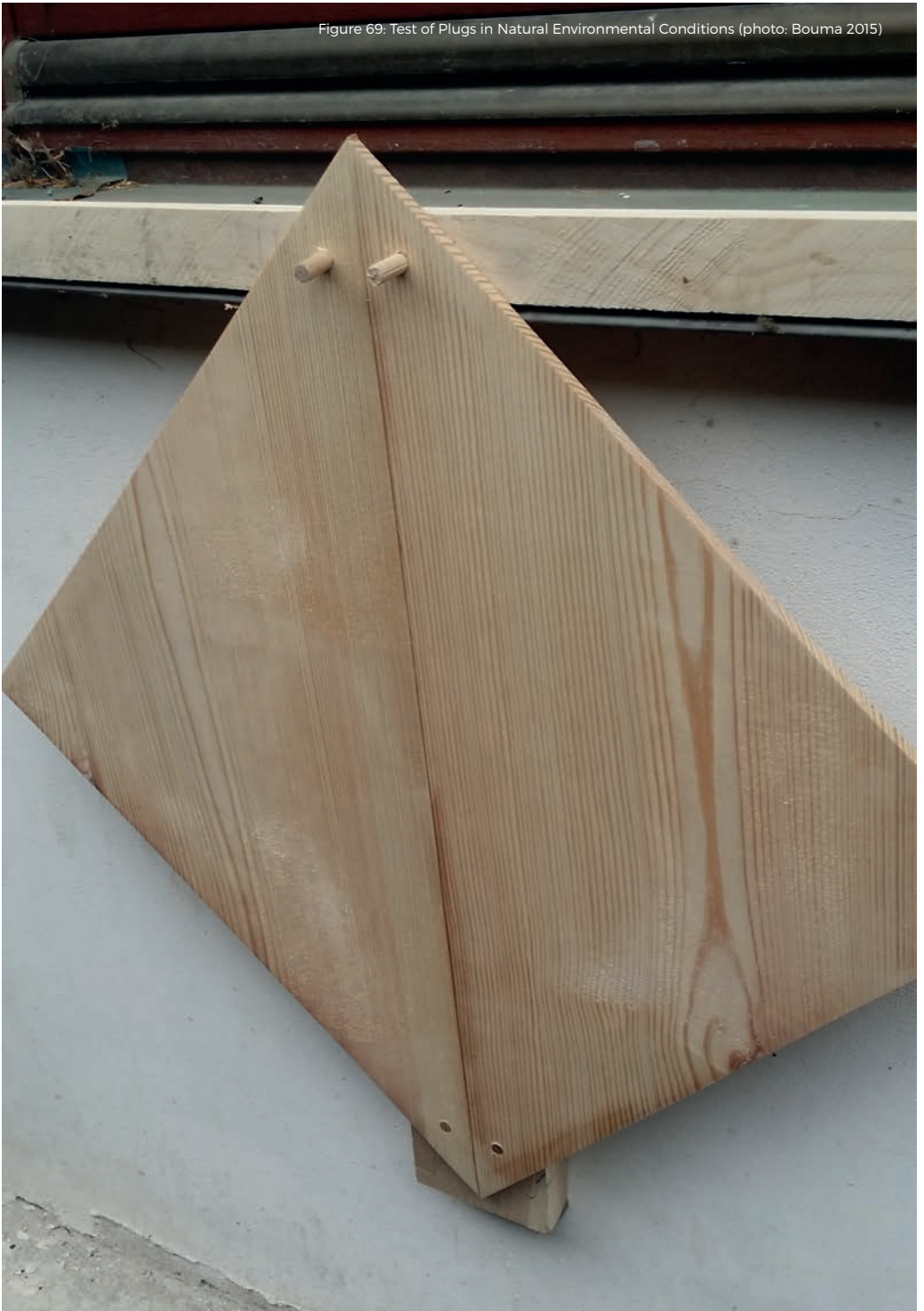




Figure 70: Test of AZ ThermaCoat Paint (photo: Davidová 2015)

7.1.2.4 Vision for Possible Application

Non-discrete spaces, the spaces between the exterior and interior, are common in vernacular architecture also in colder climates (M Hensel & Turko, 2015; Michael Hensel, 2013). For the author, the ‘Onion System’ is in particular attention. The Onion System covers unclimatised, more or less ventilated, space between exterior and climatised interior, divided from the exterior by semi-permeable envelope. It could be such as veranda or winter-garden or working semi-interior space, as shown on the pictures from Norway (see Figure 71). The upper example of Lillehammer farm seems to be equipped by open ventilation, compare to the lower image of city house in Tønsberg that has windows.

Similar proposal could be applied for example to competition proposal for museum of vernacular culture by Collaborative Collective (Collaborative Collective, 2012) ‘På Vei’ (see Figure 72). As the gallery artifacts were very sensitive to relative humidity and temperature, we proposed an onion system between the exterior, the unclimatised gallery space that receives warmth from the climatized neighbouring offices with facilities for researchers and administration in the ground of the sloping valley between two hills, lightened by fans. The gallery, and in accordance to it, also the attached spaces, is designed as path walk from ramps crossing the steep landscape between two mountains. The proposed envelope Ray 3 would do the best for the unclimatised gallery space that has to keep stable humidity and lower temperatures for the wooden artifacts. While the screen evaporates the moisture absorbed at night, when the relative humidity is high; in the time of too dry weather, it doesn’t allow exterior high humidity into the semi-interior space. This space receives heat energy from



Figure 71: The Unclimatized Spaces, so called Onion System, in Norwegian Traditional Architecture (photo: Davidová 2015)

climatized rooms attached to the mountain or green roof on the other side, which secures temperatures above zero (or not too high during summer), when thermal comfort for visitors is generated by the semi-interior side of the envelope.

Such conditions might be also well suitable for residential buildings, introducing a different approach to 'thermal loss' and different temperatures for different purposes in the house as in examples from Norwegian traditional architecture.

The concept was proposed to marketing specialists from InovaCentrum, CTU in Prague, where was the research conducted at that time, for support and cooperation on the research with the creation of author's start up. The marketing engineers, coming from different discipline, seemed to be open to the topic. Unfortunately today

building market in the Czech Republic is not open to long terms visions and the proposal was rejected by civil engineering reviewers who concluded it as a façade system that just brings disadvantages compare to existing ones and is more difficult for production.

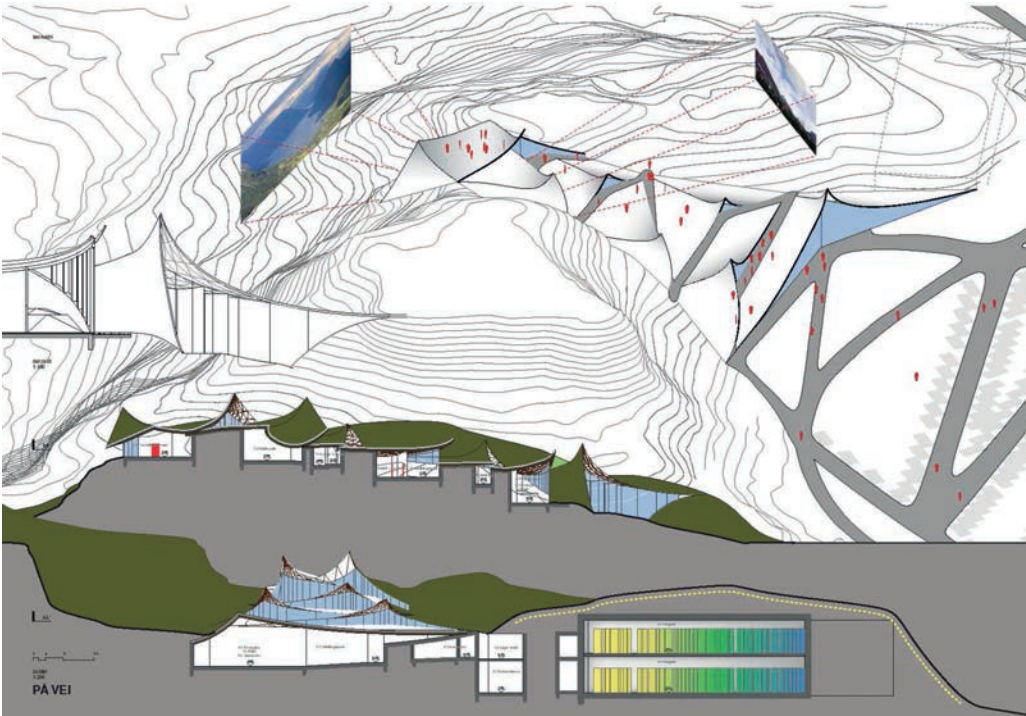
7.1.2.5 Conclusions

Ray 3 (see Figure 67) is taking the concept of Ray 2 (see Figure 66) further by replacing the façade and roofing system by fully functional envelope for non-discrete architectural spaces, while both of the products will be offered on the market.

The new prototype (in production) will have a programmed performance when it comes to warping, durability and thermal comfort through the wood cut in 22%MC that will be treated by salty water and connected to frame by wooden joinery in 0%MC of circular shape 0.8 cm in diameter (see Figure 69) and painted by environmental-friendly product with reflection of electro-magnetic heat radiation (see Figure 70). Thus the project keeps its sustainability of the material and its future recycling.

The cooperation among the disciplines of architecture, carpentry, forest and wood engineering, wood preservation architectural and ships history, environmental engineering, insulation material engineering, climatology as well as marketing engineering was fruitful for the project that could not happen otherwise. The project was only facing the wall when it came to the engineers neither from research, nor from fabrication industry, but private practice related to academy as no fast income in accordance to building laws was seen. At

Figure 72: Pã Vei, from up to down: axonometry, detail and sections
(competition entry by Collaborative Collective 2011)



the parts, where the cooperation is transdisciplinary, the co-working becomes more enthusiastic as each of the profession searches for the use of the research. However, not all the professions can be involved at such level, as some of the disciplines are represented based on consultancy of, for the experts, trivial information that is creatively used by other field of research. It was surprising to meet such interest from production side of the fabricators.

The speculations of future applications, as well as the historical references, sound promising but the approach of building laws and industry will have to change in order to accept such concepts. The square meters of built up area are considered valuable only when fully climatized. It is an unfortunate fact that even the non-discrete spaces of historical buildings are getting thermally insulated by thick layers of either toxic, or at least unsustainable materials, when renovated, disabling any exchange of the exterior with the interior. Such tendencies are even financially supported by the government of the Czech Republic. This leads to the conclusion that the practice of our profession is far behind contemporary trends of interaction through the boundary condition such as Internet of Things in Service Design. Furthermore, the presented research is just using primary resources, based on the bio-morphology through material's self-organisational capacities. More popularisation has to be done in the topic.

7.1.2.6 Acknowledgement

This research would never happened without the kind support of Lesy České Republiky (the Forests of the Czech Republic), Defio, s.r.o., AZ TECH, s.r.o. and Collaborative Collective, o.s.

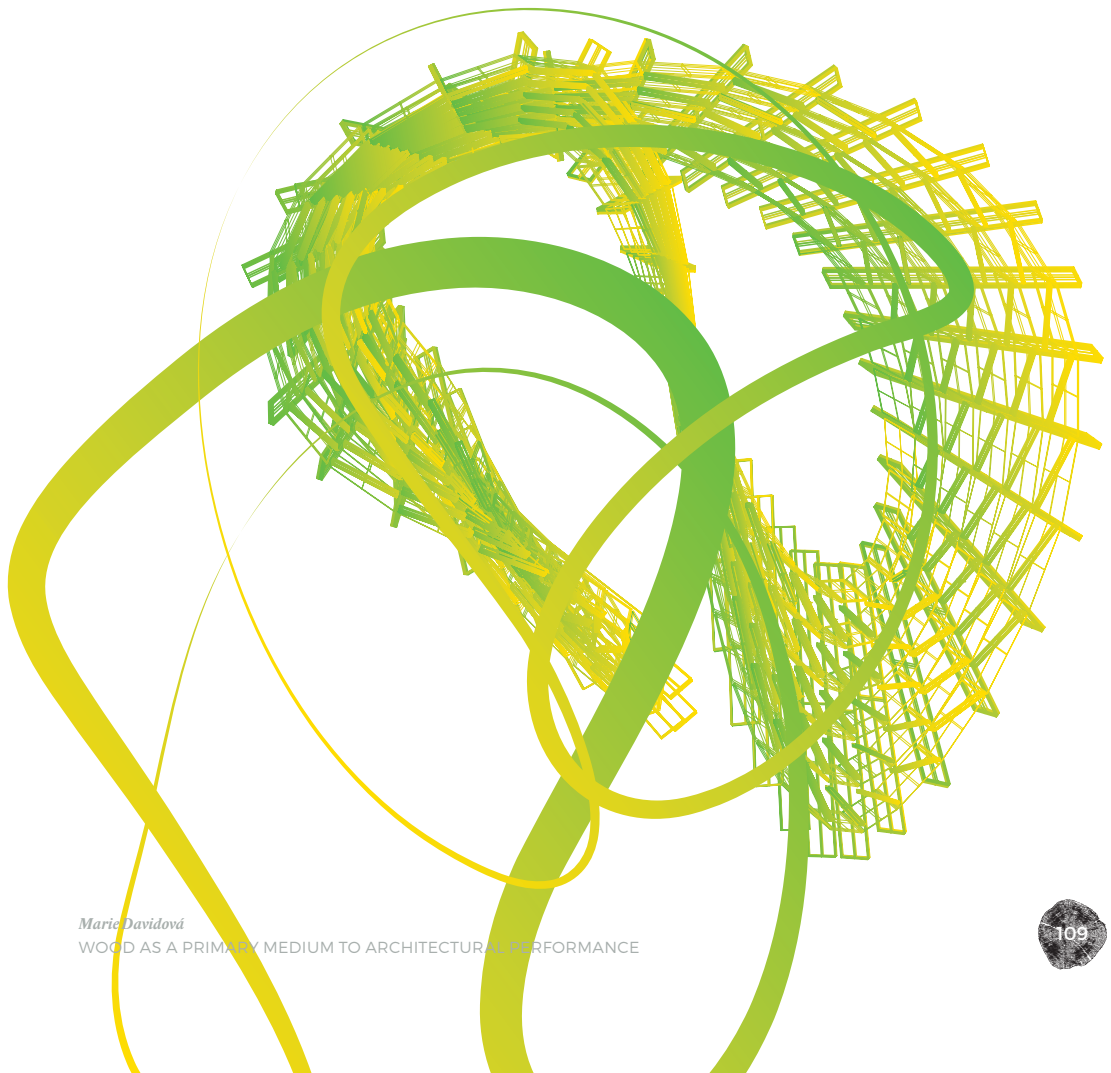




Figure 73: pareSITE (photo: Wágnerová 2013)

7.2 ENVIRONMENTAL SUMMER PAVILIONS

The Environmental Summer Pavilions project takes in consideration a larger view on responsive wood performative capacities through engaging different kinds of public spaces in its overall complex environmental conditions. This required large trans-disciplinary and trans-institutional teams and searches for methods suitable to the project and available technologies through trial-error approach. Many failures have been encountered that lead to new definitions of the parameters involved. The project generally suffered from short time schedules and low budgets when it comes to comparison to similar projects in the field. However, I believe it brought new topics to the discussion anyway and served well as a research tool for variety of performance.

7.2.1 pareSITE: The Environmental Summer Pavilion I

(Davidová et al., 2013)

This project was explained in paper: Material Performance of Solid Wood: Paresite, The Environmental Summer Pavilion, co-authored with Šichman and Gsandtner, published in Fusion – Proceedings of the 32nd eCAADe Conference – Volume 2. It is discussing the first experience of 1:1 scale transdisciplinary prototyping studio, resulting in built solid wood responsive pavilion that was parametrically designed in the team in combination with prototyping in very short time frame. It serves as a prototype of wood warping, twisting of solid wood in certain moisture content and social interaction. The pavilion served as a stage and meeting point of reSITE festival in the centre of Prague and afterwards as urban design furniture of Czech University of Life Sciences in Prague campus, where the students who took a part in the course also took a part in its social interaction observations. These observations are unfortunately not discussed in this paper, published earlier than they were performed. However they proved that the pavilion was widely interacted by kids, lovers and party people from the academy as well as from the neighbourhood. No part of the material or joinery was broken or stolen by this interaction which is in contradiction to the situation when the pavilion was dismantled and stored outside without covering any performance. This paper discusses mainly its material performance, digital design and structural design and fabrication of the prototype.

7.2.1.1 Abstract

The Paresite – The Environmental Summer Pavilion designed for reSITE festival, is a möbius shaped structure, built from torsed pine wood planks in triangular grid with half cm thin pine wood triangular sheets that provide shadow and evaporate moisture in dry weather. The sheets, cut in a tangential section, interact with humidity by warping themselves, allowing air circulation for the evaporation in arid conditions. The design was accomplished in Grasshopper for Rhino in combination with Rhino and afterwards digitally fabricated.

This interdisciplinary project involved students from the Architectural Institute in Prague (ARCHIP) and the students of the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences Prague (FLD CZU). The goal was to design and build a pavilion from a solid pine wood in order to analyse its material properties and reactions to the environment and to accommodate functions for reSITE festival. The design was prepared within half term studio course and completed in June 2013 on Karlovo Square in Prague (see Figure 73) where it hosted 1600 visitors during festival weekend.

7.2.1.2 Research Questions

- * The main area of our occupation lies in the material performance of solid wood: Wood – Humidity – Temperature Interaction (section ‘Material Performance’).
- * A second topic is the question of how to create parametric model of the design and produce CNC fabrication data, leading up to the question: Can parametric design cover all the design tasks? Section ‘Design Process in Grasshopper for Rhino 5’.
- * To finish, we ask ourselves over the structural possibilities of CNC fabricated design (see section ‘Structural Design’).

Figure 74: Torsed Structure with Responsive Skin (photo: Zapletal 2013)



7.2.1.3 Material Performance

The tradition of building wooden summer pavilions has been established in many architectural schools. The most striking examples have been created at the AA School of Architecture in London and at the Institute for Computational Design – University of Stuttgart. Usually, they are built from ply-wood. On the contrary, the project is aimed at experimenting with the material performance of solid wood. The strength in the torsion of the planks and the humidity – wood interaction has been explored.

The form of pavilion does not allow subdivision into planar surfaces, but anisotropic properties of the material support torsion. Several prototypes of the triangles with different plank thicknesses and moisture content were sampled. The angles of cuts hold the boards' torsion together in the joint. Because of its ability to bend, it was agreed to use green wood for the structure.

The Environmental Summer Pavilion is based on the concept of wooden oriental screens so called 'mashrabiya's' (see Figure 13). Mashrabiya's absorb moisture during the night when the relative humidity of air is very high and release moisture whilst providing shadow during the arid conditions of sunny summer days. The performance of 'mashrabiya's' has been explored by Michael Hensel. Hensel writes:

'Mashrabiya's are multi-functional elements that control light penetration, airflow, privacy and views, while operating on a synergetic relation between ornamental pattern and material distribution' (Michael U Hensel, 2011a)

Figure 75: Responsive Skin (photo: Zapletal 2013)



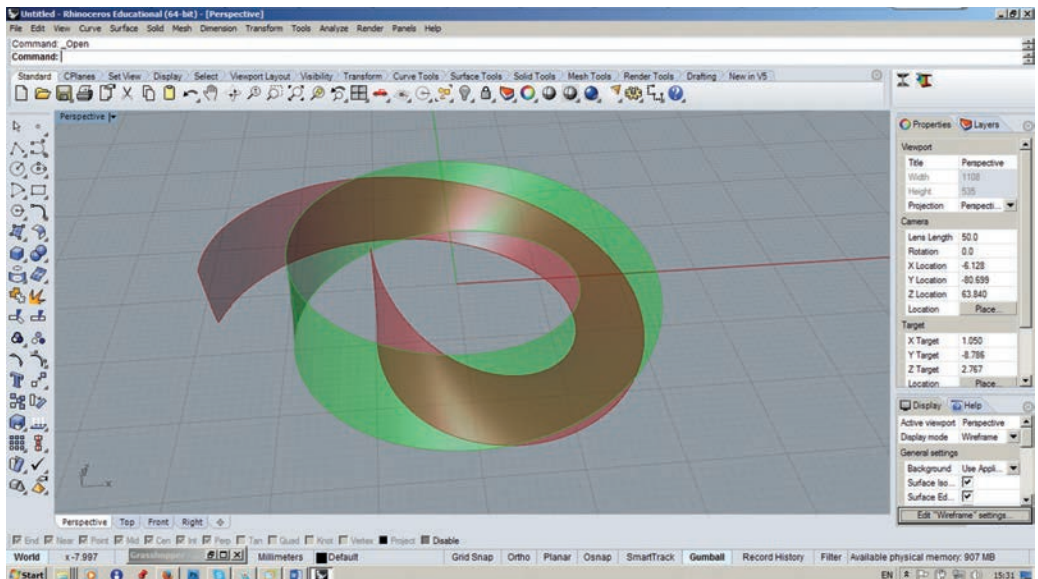
Wood – humidity interaction systems (see Figure 74) have their origin in traditional Norwegian panelling (see Figure 3) and further on they were explored by Asif Amir Khan at the AA School of Architecture with a veneer based screen (see Figure 5). The research on performative wood is held by Michael Hensel at the Oslo School of Architecture and Design and by Steffen Reichert and Achim Menges at ICD University of Stuttgart. Most of the contemporary research has been done on laminated veneers to reach the highest performance of the material. Such structures have the best performance, but since the pavilion served for a festival in public space, they would have been too fragile. In case of this pavilion, the air circulation was supported by warped triangles cut in tangential section. Warping in tangential section generates so called ‘cup’ across the fibre (Knight, 1961). It has been observed that most warping occurs on the plates in rhombus shape. Considering material waste, this figure in the project was replaced by two triangles (see Figure 75).

7.2.1.4 Design Process in Grasshopper for Rhino 5

The studio course Environmental Summer Pavilion was focused on generative concepts and algorithmic mechanisms for creating performance-based and interactive design systems. It was open to architects, designers and anyone interested in learning generative and algorithmic design techniques based on graphical algorithm editor – Grasshopper. The students learned from the basics to advanced coding and implemented several Grasshopper plug-ins to the design process. LunchBox plug-in from the author Nathan Miller was used to design Environmental Summer Pavilion. The plug-in contained algorithmic geometry, panelling tools, structure and powerful utilities. It became the main tool to finish and create better workflow for the final definition.

For the initial surface it was decided to use a möbius surface with its logic of closed and vertiginous continuity. After the best spatial concept and the area solution was found, the final surface of two layers was developed. The first layer contained static structure presented by triangular tiling creating torsional hexagon loops over the

Figure 76: Möbius Stripe Offset (Davidová 2014)



surface. The second layer was again a triangular tilling that was cracking each triangle of the first layer of the initial surface. The after effect of cracking was used to obtain a star perforation generating under diverse angle positions different views through the Pavilion.

Due to the geometry of möbius stripe, the structure was not easy to generate. The initial surface was generated in Lung Box than edited in Rhino 5 afterwards offset in Grasshopper (see Figure 76). The ends of the surfaces had to be connected in Rhino 5 manually and the structure was loft between those two offset surfaces, through the panelling tools from Lunch Box.

Afterwards the main problem was, that the planks in the structure were torsed. That time Grasshopper couldn't unroll into plains. The planks were unrolled and constructed back into objects manually in Rhino 5 while the component, written by Tudor Cosmatu for unrolling in planes was found on Grasshopper3d forum (Cosmatu, 2011). For the reason, that the structure could not be generated other way than offset (möbius geometry) the model of the pavilion was imprecise, not respecting the width dimensions of the planks. But it worked well for the generation of the fabrication data that were adjusted in Rhino 5 manually.

7.2.1.5 Structural Design

Triangular grid was chosen for the construction of möbius shape because of its ability to mimic curvatures and stability features. Grid was offset inward thus defining shapes of planks which are generally perpendicular to the surface of möbius stripe. The shapes of planks were not planar, and they could not be generated as such while

Figure 77: Production of Triangles (photo: Davidová 2013)





Figure 78: Ribs (photo: Davidová 2013)

keeping general perpendicularity to the surface. Hypothetically, to achieve planarity, all of the joints axes would have to intersect in one point. In case of möbius stripe, parts where joint axes would be parallel with the surface would occur, making planks parallel too, and therefore weakening rigidity of whole structure.

The experiment had therefore to deal with twisted planks which introduced new set of forces into the structure. Due to rather unpredictable and complex nature of these forces, decision was made to encapsulate these into triangular particles, preventing unwanted accumulation and interactions.

Planks were cut by Hundegger Speed-Cut 3 cnc saw, and put together to form triangular particles. Each particle consisting of three twisted pine 20 x 150 mm planks was connected by 0.6 mm metal sheet overlay on whole length of connecting edge tightened by screws (see Figure 77). These particles were afterwards connected with each other by 4 M8 bolts and large washers, hiding the metal overlay (see Figure 78).

System presented good manufacturing options as particles or differently sized clusters could be prefabricated indoors and easily assembled on site later. However, certain level of imprecision due to twisted geometry of planks was to be expected. Bolt connections allowed for a later distribution of imprecision throughout surrounding structure, making it less disturbing. Each plank and joint (accept rim parts) was doubled, providing additional strength necessary for the use of green solid wood. Structure, once assembled, was covered by smaller 5 mm thick pine wood triangles creating moisture-reactive skin. These triangles were made using HOMAG Venture 06S 3-axis milling machine, Washers, hiding the metal overlay.



Figure 79: Responsive Skin (photo: Zapletal 2013)



Figure 80: Structural Stability Test (photo: Novák 2013)

7.2.1.6 Conclusion

Thanks to the material performance of untreated solid wood, the pavilion generated pleasant environment for its visitors in hot days of the festival. The skin reacted to the humidity changes as was observed on the samples. During the night the sheets were bent inwards while warped outwards in the day time. The relative humidity along the pavilion was higher compared to the other places covered with asphalt. This effect in its full performance takes time till the initial stresses from the tree trunk disappears. Therefore the structure has to be ready at least one month before the expected performance.

Torque forces locked in triangles preloaded them and added rigidity, proving advantages of solid wood. Underlying structure proved to be rigid enough to sustain 200 kg weight on the highest not directly supported point (see Figure 80). Such load bearing capability was necessary for the public exposure of the pavilion (vandalism, children climbing, etc....).

However we experienced some problems in very shallow joints after the winter season. This also could be for the reason of using green wood at initial stage. (Dinwoodie, 2000)

Figure 81: pareSITE (photo: Wágnerová 2013)



The structure itself was dynamic and it found its stable state which a bit differs from the digital model. Furthermore, the project itself is disturbing the concept of digital fabrication by the impossibility of generating precise Grasshopper model. This fact leads to the conclusion that the parametric modelling still have limits for designing experimental structures.

The combination of physical, parametric and digital modelling tools might be necessary in the design and fabrication drawings process. The use of solid untreated wood allowed for significant budget savings, making the price of all material, CNC cutting/milling and transport less than 5000 euros, and for creating structure with no built in chemical agents.

The pavilion serves as a prototype for further development of industrial solutions for performative screens.

The project was accomplished with the kind support of Skanska, Eurodach, Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences Prague, Lesy České republiky, reSITE, ARCHIP, Collaborative Collective and Oximoron. We also like to thank all the students who took place in this, namely: Yuliya Pozynich, Jason Nam, Alena Repina, Daria Chertkova, Yana Vaselinko, Mikkel Wennesland, Dan Merta, Daniela Kleiman, Liv Storla, David Lukas, Christopher Hansen, William Glass, Jiří Šmejkal, Milan Podlena, Josef Svoboda, Tomáš Pavelka, Miroslav Runštuk, Ladislav Rubáš, Radim Sýkora, Anna Srpová, Ivana Kubicová, Gabriela Smoliková, Karel Ptáček, Jan Matiš, Tomáš Mišoň, Lukáš Růžička, Jan Hyk, Marian Loubal, Jan Dostál, František Juhász and Jakub Vykoukal (Davidová et al., 2013).

7.2.2 Loop: The Environmental Summer Pavilion II

(Davidová & Prokop, 2016)

The Loop pavilion was introduced by the author and Prokop in the article: 'Advances in Material Performance of Solid Wood: Loop, the Environmental Summer Pavilion II' and is currently in press at the DCA 2016 conference proceedings. It is further developing the above concept merely in reference to design though which it is increasing performance. This new prototype takes in consideration the spatial organisation of panelling in combination of the left and right side of the plates as previously used in project Ray. In this context, expansion and shrinkage also had to be considered. It shows that the use of different partial-design media, such as specific simulation plug-ins and samples and prototypes, may not perform in the same manner as the full complexity of overall full-scale prototype in relation to its outdoor environment. The GIGA-mapping tool for the transdisciplinary studio and the performance towards human behaviour, interaction and perception are closer elaborated in the methodology section. This paper mainly covers its material/design performance, parametric design and fabrication and structural design of the prototype.

7.2.2.1 Abstract

Loop is a solid wood pavilion that adsorbs the moisture during night and evaporate it during hot summer days. Its panelling is warping in the sun and low relative humidity, thus supporting the circulation of humid air in its environment.

Loop is a contribution to the Research by Design on Responsive Wood started by Michael Hensel and Achim Menges at the AA School of Architecture in 2005 and is a second prototype of the first author's Environmental Summer Pavilions project that developed the previous one, pareSITE Pavilion, further. By spatial organisation of its panelling and the shape of the overall structure, we reached much higher performance. The design was accomplished in Grasshopper for Rhino 5 and digitally fabricated.

The project is a result of a transdisciplinary, one semester lasting, studio course at the Faculty of Art and Architecture at the Technical University of Liberec and the Faculty of Forestry and Wood Sciences at the Czech

University of Life Sciences in Prague lead by Marie Davidová, Šimon Prokop and Martin Kloda. Architect, environmental design and wood engineering students were involved in the project as transdisciplinarity is crucial in the field of Performance Oriented Design in general.

The pavilion served as a stage for EnviroCity festival in Prague during the summer 2014.

Figure 82: New Meets Old, Loop Pavilion (photo: Okamura 2014)



7.2.2.2 Research Questions

- * The main area of our occupation lies in the material performance of solid wood: Wood – Humidity – Temperature Interaction. Can design push the performance further? (see section ‘Material Performance’).
- * A second topic is the question of parametric possibilities of the design and production of CNC fabrication data: Section ‘Grasshopper for Rhino 5 and Fabrication’).
- * To finish, we ask ourselves over the structural possibilities of parametric design from wood (see section ‘Structural Design’).

7.2.2.3 Material Performance

The studio course took an advantage of the first author’s Research by Design in Responsive Wood that aims to be applied in building industry. The research covers facades and screens for non-discrete spaces that breathe and operate the indoor and outdoor environment. The data from samples and prototypes observations were shared among overall team. Loop is a second prototype in Environmental Summer Pavilions project, following the pavilion pareSITE (see Figure 73).

‘The Paresite – The Environmental Summer Pavilion designed for reSITE festival, is a möbius shaped structure, built from torsesd pine wood planks in triangular grid with half cm thin pine wood triangular sheets that provide shadow and evaporate moisture in dry weather. The sheets, cut in a tangential section, interact with humidity by warping themselves, allowing air circulation for the evaporation in arid conditions.’ (Davidová et al., 2013)

Concluding the project of the pareSITE pavilion, we asked the question, if the specific design may heighten its performance. Both of the pavilions are inspired by the concept of oriental screens, so called ‘mashrabīyas’ (see Figure 13). Among other properties mashrabīyas absorb moisture at night, when the relative humidity of air is high and evaporate it during the hot summer days. This performance was studied by Michael Hensel:

‘...these (mashrabīyas) consists of wooden lattice work and are characterised by a range of integrated purposes or functions: they regulate in a finely nuanced manner the passage of light, airflow, temperature and humidity of the air current, as well as visual penetration from the inside and the outside.’ (Michael Hensel, 2013)

According to Fathy:

‘Water will evaporate from a wet surface if it is exposed to air with a dew point lower than the surface temperature. The rate at which water evaporates from the surface depends on the relative humidity of the neighbouring air, the surface temperature, and the velocity of air movement. Thus, for a wet surface at a given temperature, a reduction in relative humidity or an increase in air velocity both increase evaporation.’ (Fathy, 1986)

PareSITE pavilion was reaching better performance of this concept by warping of its panelling from plates, cut in tangential section in triangular shape (see Figure 79). The concept of wood warping has been originally used in traditional Norwegian panelling (Larsen & Marstein, 2000) and has been further on explored by many authors in this century. The first recent century prototype (see Figure 5) was published by Hensel and Menges in Morpho-Ecology publication with a comment:

‘Study by Asif Amir Khan commenced from an analysis of pine cones and the way they open and close in relation to changes in the relative humidity level, which informed the design of full scale prototype of a screen that deploys the selforganisational capacity of thin timber sheets under changing humidity conditions.’ (M Hensel & Menges, 2006)

Compare to Norwegian origin based on tangential section of the trunk, the current research, except the one of the author, is using either laminated timber sheets or plywood. The LCA comparison, made for similar prototype in Czech conditions, by Vladimír Kočí from the University of Chemistry and Technology Prague, Dept. of Environmental Chemistry with the first author clearly talks for the use of solid wood for its environmental sustainability (Davidová & Kočí, 2016).

From the samples observations, the triangular shape warps twice as much as the rectangular one (Davidová, 2013b). In the Loop pavilion we tested the spatial organisation of the panelling and combination of left and right side of the plates (see Figure 83) which resulted in propeller when warping. The sheets were also shortened by solar analysis to equalize the wood shrinkage and expansion. However, extreme conditions were not considered. The expansion data were also not taken from the samples of identical material used for the pavilion as this was impossible to arrange with the material supplier due to the industrial processes of the production as well as the evaporation of sap from former green wood material.

The looping shape of the overall structure was speculated to support the performance next to the spatial organisation of panelling.

Within this task, the architectural students took the main part in the design of performance and the wood engineering students in the discussion on wood properties, structure, fabrication and building.

Figure 83: Panelling (photo: Davidová 2014)



7.2.2.4 Design Process in Grasshopper for Rhino 5 and Fabrication

The pavilion was designed and built by all the team, including students and tutors. Its concept was a result of competition among the students, where the students were asked to deliver a concept sketch model and a concept research diagram. The winning concept sketch model, designed by Antonín Hůla was based on double curved folding of paper. Once the design was selected, all the members picked their responsibilities in the project, such as panelling, structure, shape, analysis, blog, the GIGA-map, photo documentation and so on.

After the introductory Grasshopper workshop a group of students started with modelling the whole pavilion. All the students were new to Grasshopper, but some of the architectural and environmental design students were familiar with Rhinoceros 5. Further design research was dedicated to finding the exact curves which the physical model exhibited after curved folding. However thanks to the parametric approach in modelling other students could work parallel on the structure as well as the panelling even though the exact shape wasn't yet

Figure 84: Antonín Hůla with Micro Scribe (photo: Pokorný 2014)

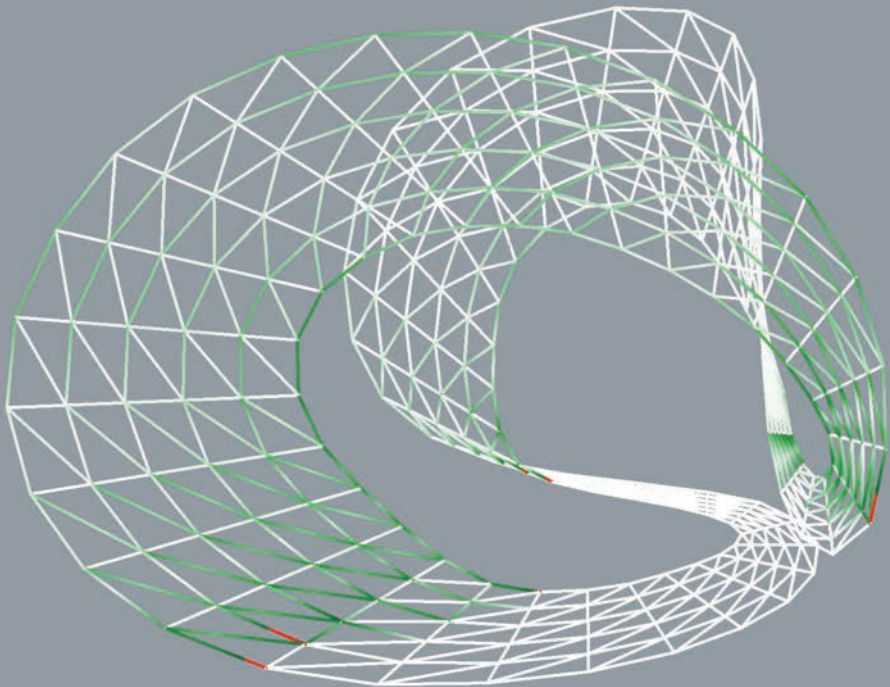


found. Finally a precise paper model was scanned by Micro Scribe (see Figure 84) to Rhinoceros 5 and further on parameterized and developed in Grasshopper for Rhinoceros 5. Due to the parallel work of different students on some areas of the design, some difficulties appeared mostly in data structuring. This was partially caused by the nature of scripting in grasshopper where visual control slightly overbalances other more thorough ways, speaking particularly about beginners.

Numerous versions of the structure and panelling were tested and discussed in the team and consulted with structural engineer. The code was shared by online file sharing and discussed in Facebook group next to the regular meetings over a physical GIGA-map. The concept of GIGA-mapping was introduced by Birger Sevaldson for mapping the complexity of the overall design from the study to the design outcomes. The decisions to be taken in design were printed out and pinned to the board so all relevant specialists could comment on it. By plotting time on the x axis of the GIGA-map deadlines and time organisation was apparent at all times.

For structural analysis the team used plugin called Donkey developed by Lukáš Kurilla (see Figure 85). It utilises Final Elements Method (FEM) to evaluate efficiency of usage of each profile. Outcomes from this analysis guided the decisions about number of elements in the structure and also provided important insights regarding stability and seating of the pavilion. Even the author of Donkey doesn't aim to replace detailed structural assessment methods (Svoboda, Novák, Kurilla, & Zeman, 2014) rather to provide architects and designers with a simple tool to be able to understand structural behaviour in early stages of design.

Figure 85: FEM Analysis in Donkey (Prokop 2014)



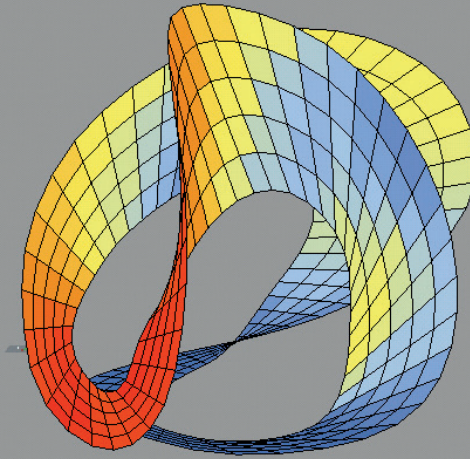


Figure 86: Lady Bug Analysis (Prokop 2014)

A plugin called Ladybug developed by Mostapha Sadeghipour Roudsari was used to predict exact positions of the sun and then the solar gain analysis. Again the analysis has to be done early in the design process to harness its true potential (Mostapha Sadeghipour Roudsari & Adrian Smith + Gordon Gill Architecture, Chicago, 2013). Each individual panelling plate was resized accordingly to its maximum possible solar gain (see Figure 86).

During construction the team faced several difficulties. One of which was maintaining order in the 1082 different pieces of the pavilion. The problems appeared already in the design phase. Because the script was created in a collaborative way by up to four people some irregularities emerged in data organising. Also the production numbering of elements at the 5-axis CNC sawmill was very different from the numbering the team used. After delivery of cut pieces manual measuring had to be done on a fraction of pieces to maintain order.

During the fabrication the team faced a challenge of putting two main skew wooden planks of every rib of the pavilion together in precise angle. A pair of unique 'rulers' with fitting slits had to be fabricated prior to the assembly of each rib. The fact that the CNC machine was to be operated exclusively by an antique Windows XP based PC with no maintenance over a few years was significantly user unfriendly.

7.2.2.5 Structural Design

The structure had rather complex fashion when it comes to forces. After the FEM analyses was processed (see Figure 85), several different prototypes of joints were tested at FLD CZU by Universal Testing Machine 50kN with software TIRA by Ing. Vlastimil Borůvka, Ph.D. at the Faculty of Forestry and Wood Sciences at the Czech University of Life Science in Prague to find the most suitable solution (see Figure 87). The results from FEM analysis and joints prototypes' tests were coming out well. However, we experienced problems in reality. In one of the most stressed planks appeared cracking and most stressed joints were losing.

We were performing weekly the pavilion's structural behaviour checks with structural engineer and placed steel belts over each joint. The problems seemed different than in the FEM simulation. Compare to WIP Version 2015.11.5.0 of Scan and Solve plug in for Rhino released in 2015, FEM analysis by its nature does not consider neither fibre orientation nor joints.

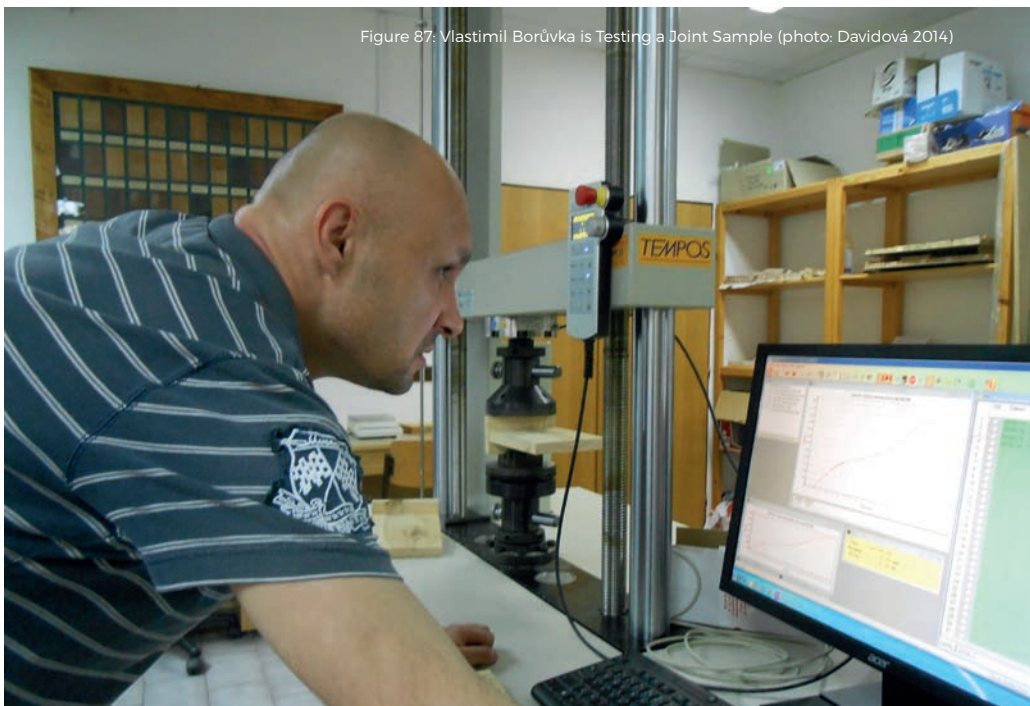


Figure 87: Vlastimil Borůvka is Testing a Joint Sample (photo: Davidová 2014)



Figure 88: Physical Structural Test (photo: Davidová 2014)

As a first test, we built the single structure in front of the workshop before bringing it to the festival site. At that point, we didn't realize any problem. The cracks appeared after two weeks on the site which is also tricky wood's structural behaviour that was experienced by the students as well as by the tutors in practice.

7.2.2.6 Conclusions

The design can support wood's material performance. The circulation of humid air was way much higher than at the previous prototype of pareSITE pavilion (see Figure 81). This fact was clearly perceived by all the visitors of the festival who had experience with both of the pavilions. However, better attention has to be given to wood extension. In extreme storms, some of the panels extended more than expected, which resulted in their cracking due to its spatial organisation. Better combination of sampling for extreme conditions and solar analysis has to be achieved.

FEM analysis for solid wood is not yet that advanced which is most likely for its anisotropic nature as we experienced structural difficulties. The recently released WIP plug in Scan and Solve for Rhino that considers fibre orientation might lead to the solution. The physical structural test proved the importance of the fact, that wood's structural stability is time based. The pavilion's observations in time was a great learning tool for all the participants among the disciplines where everyone took her/his part to certain profession.

The transdisciplinary cooperation among the architect, environmental design and engineering students worked very well even though the schools were in different cities. All the files were shared and discussed online which enabled us to develop the design any place – any time.

Though the roles were not divided at the beginning, the architecture and environmental design students were more advanced in the design tasks while wood engineering students in structural design, joinery and the work in the workshop. This way we used all the talent of the students. It is a satisfying fact, that the students who chose responsibility which involved Grasshopper scripting became fully capable of using the tool to an intermediate level. The same happened with the site analysing, panelling design development, structure, detailing and joinery, fabrication data or, experienced by all fabricating and prototyping, GIGA – mapping and Systems Oriented Design in general and the most targeted topic of the course, the Material Performance was adopted by whole team.

7.2.2.7 List of the Participating Students

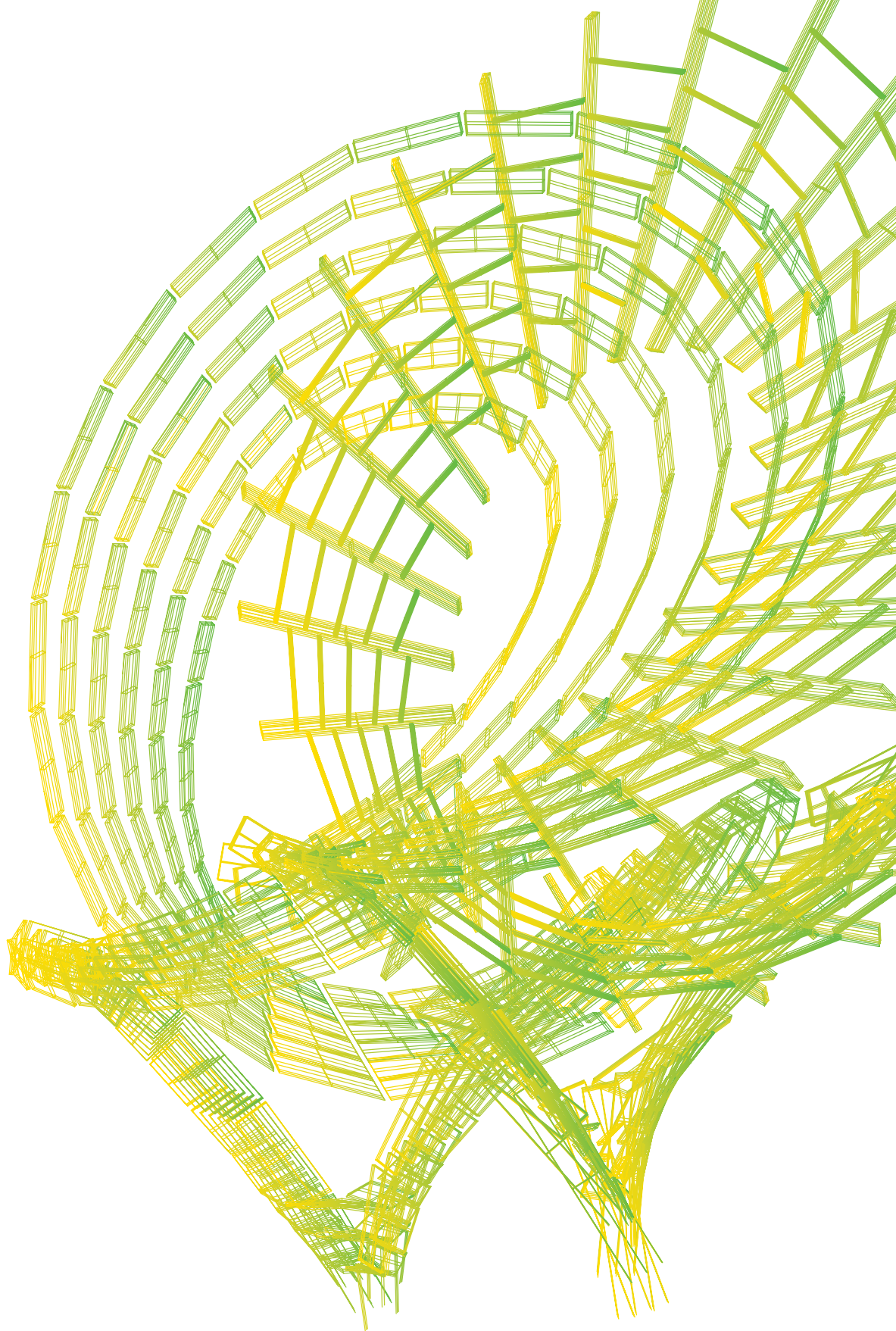
Alena Novotná, Anna Hrušová, Antonín Hůla, Barbora Slavičková, Jakub Kopecký, Jiří Fáber, Jiří Pokorný, Petr Tůma, Tereza Jílková, Radim Sýkora, Eliška Antonyová, Tereza Lišková, Filip Janata, Tomáš Kytka, Marie Kortanová, Vojtěch Holeček, Martin Vaníček, Jakub Hlaváček and Petr Havelka

7.2.2.8 Studio Course Leaders

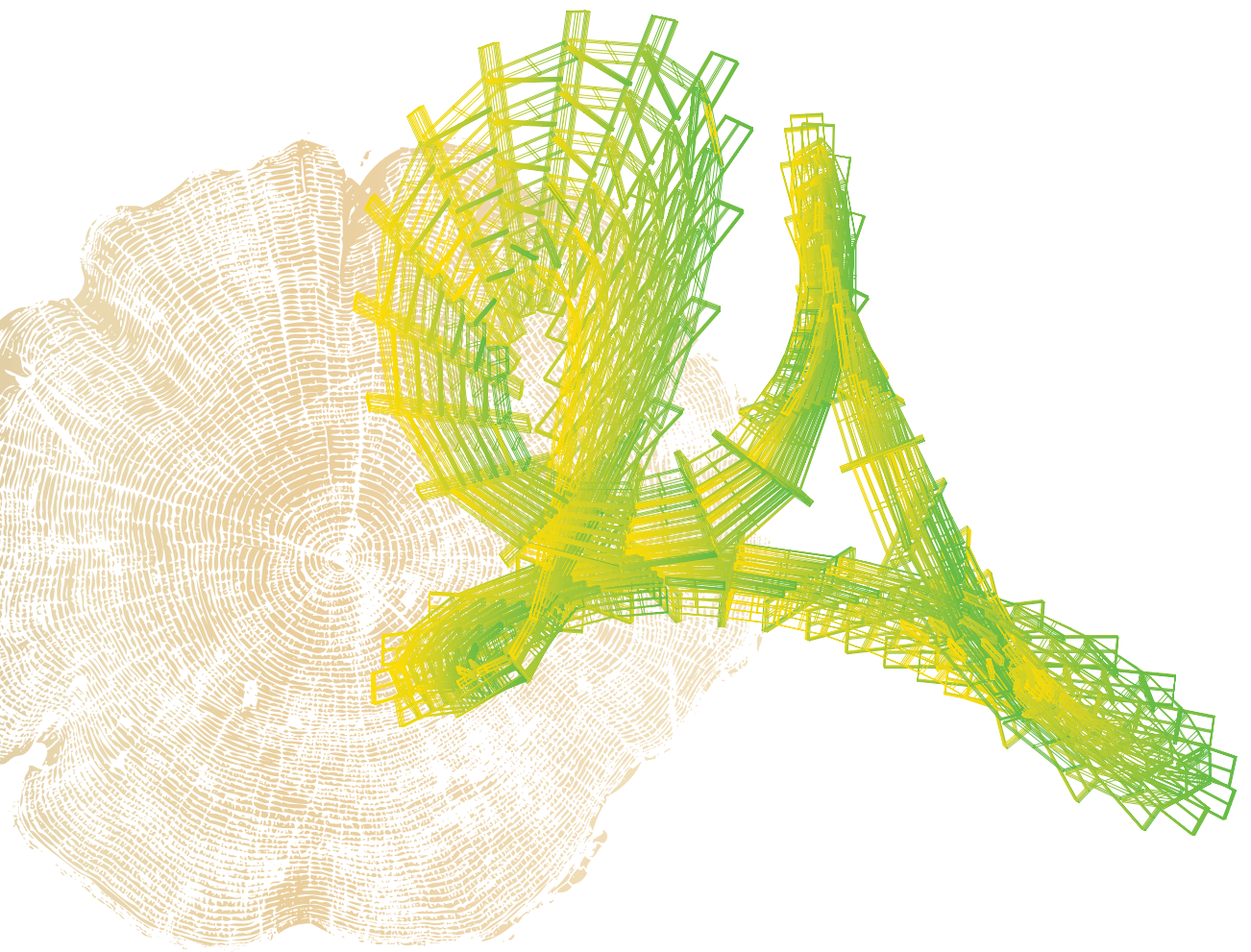
Marie Davidová, Šimon Prokop, Martin Kloda

This project would never happen without a kind support of the Faculty of Forestry and Wood Sciences and the Czech University of Life Sciences in Prague, the Faculty of Art and Architecture at the Technical University of Liberec, Stora Enso, Rothoblaas, Nářadí Bartoš, Eurodach, Lesy ČR, Natura Decor, Easy Moving, and Collaborative Collective.

For further information, please, follow our blog at: <http://environmentalpavilion.tumblr.com/>



8/ *Summary and Conclusions of the Thesis*



I have concluded this thesis in my Relating Systems Thinking to Design 5 paper submission: ‘Socio-Environmental Relations of Non-Discrete Spaces and Architectures: Systemic Approach to Performative Wood’. This paper places the research into overall reflection concerning examples of my projects in the Performance Oriented Design field in relation to its boundary conditions and performed biotic and physical interaction utilised in GIGA-map, a case study example mapping relations in architectural typology in reference to world axis, human behaviour and use options, placement and macro and micro climatic conditions of the exchange of exterior, semi-interior and interior in non-discrete spaces in Norwegian traditional architecture, so called ‘svalgangs’ and through this analysis, the project’s application in the context of the contemporary living environment in Czechia.

8.1 ABSTRACT

The paper puts into the context of practical applications my case study research of responsive wood located in Czechia, being inspired by Norwegian and oriental traditional architecture. Approaching the field from a socio-environmental perspective, the article relates human, social and biotic behaviour with climatic and geographical data, addressing interactions in the performance of architectures and its additional issues in urban design. The opportunistic activities, use or habitation of spaces and objects, meets its performance through environment – material and/or design interactions. The paper claims that, at least in observed climatic locations, semi-interior, or so called non-discrete architecture addressed by Hensel and others, are the grounds for and generators of individualistic and social activities in public and public-private spaces, securing environmental comfort. In this time of increased weather extremes coming with climatic change in certain locations, noise, light pollution, etc., the topic is gaining greater relevance. Inspired by Library of Systemic Relations for GIGA-mapping introduced by Sevaldson (Sevaldson, 2016c), the relationing of such in GIGA-maps required its own coding or update and/or combination of the existing proposed library. The maps are expressing different ranges and intensities of behaviour or performance in relation to placement or designs that are represented by informational layers of images. Relating gradients within (Allen, 2011; Banham, 2009; Michael Hensel & Menges, 2009; Hight, 2009) and among the fields, thus generating a matrix of interlinked information where zooming, sequencing or feedback looping appears. This way somewhat develops the core ideas of Allen from 1997 on matrixes and fields (Allen, 2009). The three thematic GIGA-maps are in fact developed ZIP-analyses (Sevaldson, 2016d) of each other, zooming a problem of the theme’s topic. The semi-interior or non-discrete spaces as a climatic, sound, etc. and biotic – including social gradient-are complex interlinkings of outside and inside environments and have implications for activities and forms of life. Therefore, a systemic approach is needed to fully understand it.

8.2 INTRODUCTION

‘Architecture is a material practice. Materials make up our built environment, and their interaction with the dynamics of the environment they are embedded within results in the specific conditions we live in.

Moreover, culture and the way materiality and materials are understood and instrumentalised mutually condition one another.’ (Michael Hensel et al., 2008)

I have expressed my understanding of environment in relation to interaction in space and time in exploratory paper for NORDES in 2009 as an exemplification of the difficulty of imagining space which is, for instance, traditionally defined by three dimensions x, y, z, but there is no light there making possible to see anything (and

perhaps there is also nothing to see either), there is no heat you could feel, nothing to hear, no smell, etc. Pointing out that it is as difficult to imagine that this space is happening in time. Arguing that, from the architectural view, the word environment could be defined as space which is enriched by interaction and that we could say that the space as such does not exist in time and that the space-time dimension is defined by interaction, concluding that the space-time with interactors then forms the environment. This is supported by the fact that to design in relation with light, sound, wind, weather or stars position, politics, etc. has been common throughout architectural history whether in symbolic, metaphysical, pragmatic, phenomenological or other manner, which leads to the fact that these factors are important dimensions of the environment (Davidová, 2009).

This seems to be supported by Oliver, who emphasize that the concept of space is not universal and, i.e.:

'In the Navajo world view, all is in motion and all is changing within an overriding concept of order and harmony. Space is related to movement,...' (Oliver, 2006)

Though considering himself a modernist, Frampton called for an environmentalist direction in architecture's future development several decades ago in the early eighties (Keneth Frampton, 2011), discussing the poetical approach of the relationship between humans and nature in an interview with Mitášová in 2010 (Kenneth Frampton & Mitášová, 2012). In my mind, humanity, such as everything we know, is fully part of nature, and therefore I would better discuss the relationship of the individual and its environment – living or non-living- which involves their evolving interactions. Reconsidering regionalism, Heat stays:

'For example, some practitioners study the built environment through a culture concept, whereby regional landscapes become sources for exploring the manner in which human populations around the globe create, adapt, and transform their environments in response to personal beliefs, human interactions, situational opportunities and constraints, traditional and evolving technologies, and forces of the natural environment.' (Heat, 2009)

This seemed to be exemplified in the following study of Norwegian semi-interior spaces 'svalgangs' (see Figure 91), where different alterations of openness and closeness appear even on one building, reflecting climatic and site orientations and locations as well as opportunities of use and social interactions. Furthermore, in some cases their aesthetics, often decorated by carvings, securing special climatic conditions through environmental exchange has an almost spiritual character, while other parts are unfoldable for more down-to-earth activities such as material loading.

Jan Gehl categorised three types of human activities that in my opinion also must cause various layers of interactions in outdoor areas: 1) necessary, 2) optional and 3) 'resultant' social activities, arguing that the two last appear way more frequently in good quality of physical environment. (Gehl, 2011) 'Good quality of physical environment' or I would better say suitable environmental conditions, are in large degree operated by weather or other physical aspects such as sound and light. Therefore, in most of the climatic locations semi-interior, so called non-discrete architectures defined by Hensel (Michael Hensel, 2013), take place. Discussing the spatial transitions from exterior to interior, Hensel is for instance mentioning canopies, screenwalls and full enclosures. (Hensel, 2015)

Vegas and coll. expresses their performance from socio-cultural perspective as such:

'... – but in-between spaces that generate relationships, places for sociocultural exchange. Just as it occurs in nature, where life does not flourish as much in a homogeneous habitat as on the borderline between two different habitats, they are architectural sites with a great wealth of cultural and social activity, which often foster life and promote personal, familial, social and other relationships.' (Vegas, Mileto, Songel, & Noguera, 2014)

Such spaces operate on public – public-private – private transition levels, often increasing self-confidence of anxious individuals to interact with the outside world. The analysed projects that have been presented involved observations and interviews with the participants of various age, gender and disciplines/professions, while enacting and interacting with the designs. Working in the experimental field, the children's play and

socialization observation, complained to be seriously under-researched by Oliver (Oliver, 2006), played a crucial role next to the artistic enactment and embodiment of the performative objects or architectures.

The modern history and theory of well-tempered environment in relation to social context was discussed by Hight, concluding with a call for conversion of ecology and environmental issues from technical problems with engineering solutions into engines for innovating and opening the discipline (Hight, 2009), which has been the aim of this research from start to completion.

Within the Czech region, these questions were not fully addressed by local practices. To my knowledge, the only exception is my own practice Collaborative Collective (Collaborative Collective, 2012) and ORA – Original Regional Architecture office (Zmeková, Hora, & Veisser, 2016), both mainly integrating social and/or cultural with physical environmental performance.

8.3 DESIGN'S BOUNDARY CONDITIONS IN RELATION TO ENVIRONMENTAL INTERACTIONS

Searching to understand the dialogue of a design and its environment, I GIGA-mapped the interactions of some examples of my designs, organized in range from fully open to almost closed.

GIGA-mapping has been proposed by Sevaldson as a tool in Systems Oriented Design and expressed as follows:

‘For each design case the phenomena at hand is deeply researched, starting with a very rapid learning process with a very steep learning curve. This process starts with visualisation: large maps are used for systematizing and interrelating the knowledge, preconceptions or speculations we already have of the subject. This needs to be done to an extent that produces several hundreds of items on the maps.’ (Sevaldson, 2013c)

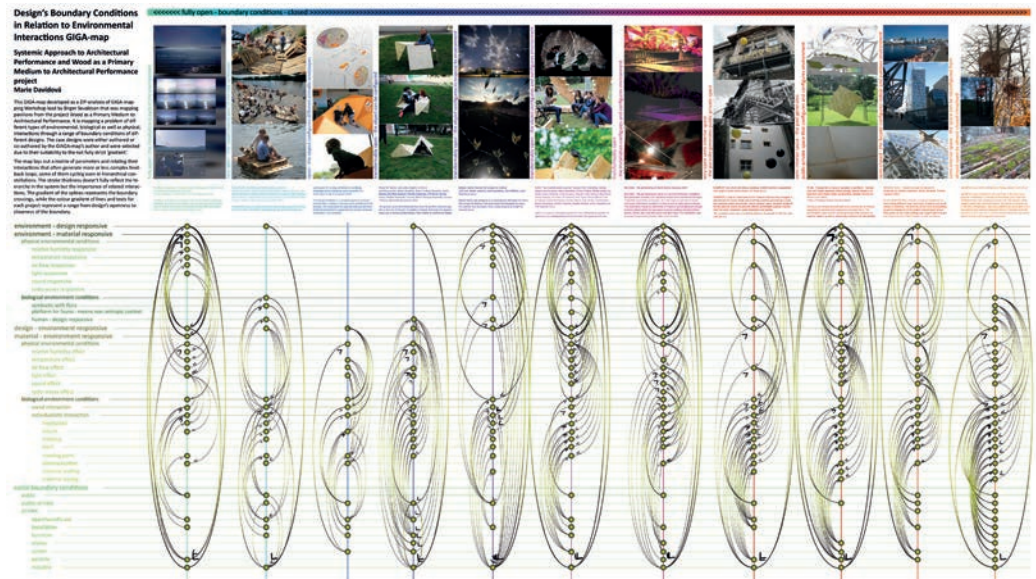


Figure 89: Davidová: GIGA-Map of Design's Boundary Conditions in Relation to Both, Physical and Biotic. Including Social, Environmental Interactions. Mapping the Spaces Organized from Fully Open to Almost Closed (please, zoom in at my blog post: Davidová, 2016a)

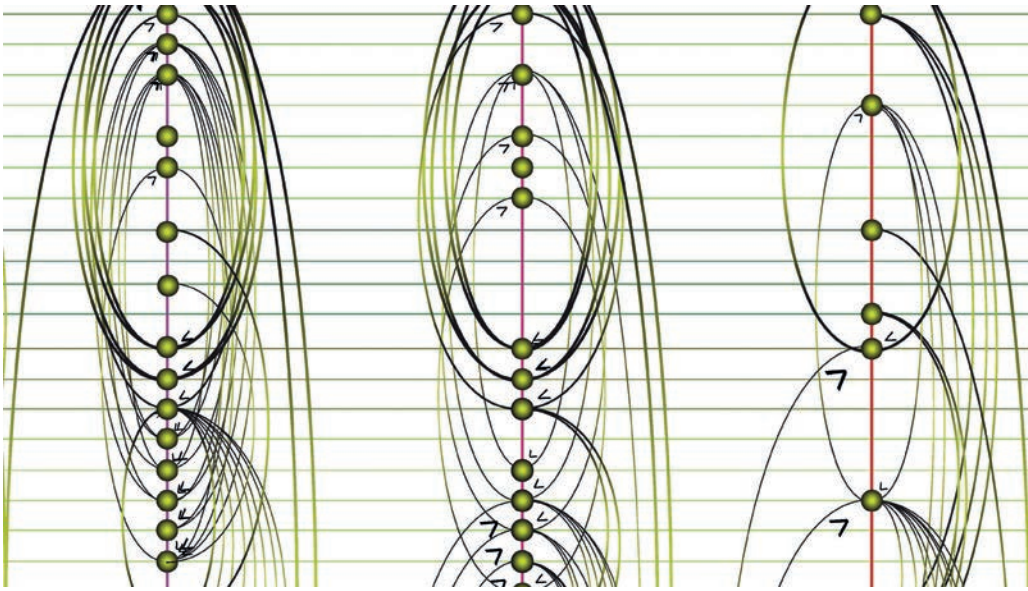


Figure 90: Davidová: Detail of GIGA-Map of Design's Boundary Conditions showing different levels and hierarchies in feedback looping among interactions of different parameters through the boundaries.

In all these, in certain degrees performative projects, the local environmental conditions meet human sensory through poetics discussed by Frampton (Kenneth Frampton & Mitášová, 2012). It is interesting to note that the designs with larger non-human act responsiveness seem to be engaging humans to interact through generating ideal settings for opportunistic use without their involvement. Furthermore, it seems that the parasitic semi-interior spaces, enabling openly programmed environmental exchange, are motivating different individual and social activities to generate a pleasant environment in larger diversity of conditions.

The following GIGA-Map of Design's Boundary Conditions (see Figure 89) developed as a ZIP-analysis, which is defined by Sevaldson as a simple method for developing GIGA-maps through finding and zooming in potential areas for interventions and innovations (Sevaldson, 2016d), of GIGA-map of a workshop lead by Birger Sevaldson at the Faculty of Art and Architecture at the Technical University of Liberec that was mapping pavilions from the project Wood as a Primary Medium to Architectural Performance. It is mapping a problem of different types of environmental, biological as well as physical, interactions through a range of boundary conditions of different designs. The case designs were either authored or co-authored by me and were selected due to their suitability to the not fully strict 'gradient'.

The map lays out a matrix of parameters and relates their interactions that often generate more or less complex feedback loops, some of them cycling even in hierarchical constellations. The stroke thickness doesn't fully reflect the hierarchy in the system but the importance of related interactions. The gradient of the splines represents the boundary crossings, while the colour gradient of lines and texts for each project represent a range from design's openness to closeness of the boundary. The detail (see Figure 90) shows feedback looping documenting, i.e., sound, visual or climatic aspects through and by specific media effect on different biotic, i.e., human, behaviour and/or perception and returns to the effect of the later on the former.

8.3.1 Svalgangs

The unclimatized spaces between the interior and the exterior, generating the onion principal of the building, securing to different extents visual, sound and climatic penetration through its boundary conditions have its place in almost all traditional architectures, functioning as its energy exchange with the surrounding environment. Nice examples from around the world are, for instance, discussed in the article *In-between spaces, borderline places* by Vegas and Coll. in the publication entitled *Heritage for Tomorrow: Vernacular Knowledge for Sustainable Architecture* (Vegas et al., 2014) This publication, next to, i.e., Sustainable Environment Association (Michael U. Hensel, 2011b) and many others argue for studying and learning from traditional examples as they are source of knowledge of architectural environmental interaction developed through generations. ‘Svalgangs’ (see Figure 91), the semi-interior spaces in Norwegian traditional architecture, that are give various opportunities of use and serve as public-private and indoor-outdoor interface, developed in high potentials of articulation with different or even gradual degrees of permeability in relation to socio-environmental conditions were analysed and speculated through GIGA-mapping (see Figure 92).

The GIGA-map is relates such spaces in the context of their original climatic location, opportunities for use or inhabitation, options of penetration of overall environment and spatial dimensions, its distribution enveloping the interior spaces and measurements of micro climatic exchange and moisture content of the material within the onion principle. Similarly, microclimatic research of ‘exchange of different strata’ was proposed by Hensel already in 2010, mentioning it as pending for advances (Michael Hensel, 2010a). The overall mapping requires both soft and hard data as discussed by Sevaldson:

‘In design we most often are looking at composed perspectives. This means that we are navigating complexities that are crossing technological, biological and social realms. We deal with both deterministic and unpredictable systems, framed and tamed ones as well as wild and wicked ones. This implies that we might find ourselves at both soft and hard ends of the systems approaches.’ (Sevaldson, 2015)

The GIGA-map is zooming into various scales, relating data and their development through colour coding gradients, their intensity through dashed lines and weights, themes through curvature degrees and arrows suggesting the process of the performance. Generating a matrix of ‘micro systemic relations’ (Sevaldson, 2016c) while placing in sequences spatial evolutions ranging from open to closed spaces, while paying attention to options of penetration density and its aesthetics character, in relation to regional site location, orientation, macro and micro climatic, social constellations and opportunities of use, the map serves as an analysis for proposing new architectural spaces and atmospheres.

The map relates data, such as if the boundary can retransform or how the exchange is secured, for instance through carving, if it generates space for which periodicity of leisure, work, etc., how such is distributed along the interior space and what the climatic and wood moisture content data is of the interior, semi-interior and exterior. The researched buildings are from Norsk Folkemuseum Oslo, Maihaugen Open Air Museum, Lillehammer and Glomdalsmuseet, Elverum. However, their original locations are known and were mapped and linked with their macro climatic data, as such must have had crucial effect on their design and redesigns. A lot of ‘svalgang’ spaces were added to the original building later on, often after a century of its use (Berg et al., 2011; Hauglid, Hosar, Krekling, Mathisen, & Songli, 2005; Sveen, n.d.). The interiors were not heated and the data were measured after a period of very cold temperature within one afternoon in February 2016 in Oslo Folkemuseet. Therefore, the interiors are mainly the coldest but variations are obvious, though the data cannot be precise for the reason that the climate was changing also with the progress of that particular afternoon of measurements. The moisture content was not measured on the original wood of the buildings, as the preservation does not allow it, but on the wooden object in particular spaces or wooden elements that replaced the old ones through reparation. There is not much literature regarding æ ‘svalgangs’. For the consultations and enabling the measurements, I would like to thank to Terje Planke from Norsk Folkemuseet, Oslo.



Figure 91: Svalgang of Hjeltarstua from 1763, recently placed in the Maihaugen Open Air Museum in Lillehammer (photo: Davidová 2016) shows the opportunity of indoor-outdoor environment including the range from social to climatic interaction while working actively.

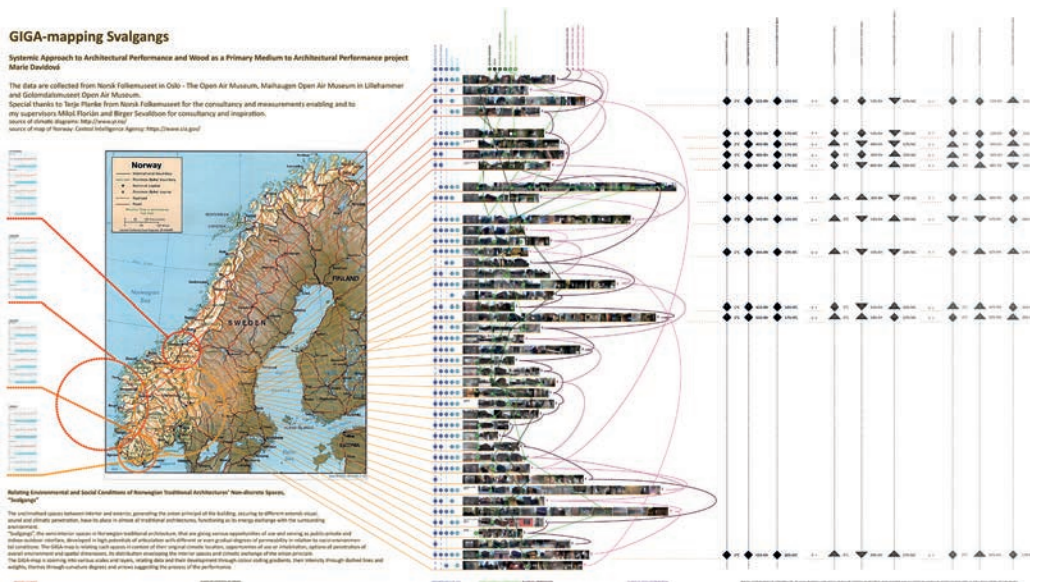


Figure 92: Davidová: GIGA-mapping Svalgangs (please, zoom in on my blog post: Davidová, 2016a, the map of Norway is a public source from: Central Intelligence Agency: <https://www.cia.gov/> the macro climatic diagrams are used with the courtesy of yr.no reached at yr, 2016)

8.3.2 Wood as a Primary Medium to Architectural Performance Project

Following the ‘bottom up’ approach, the project Wood as a Primary Medium to Architectural Performance started on the side of material science, craftsmanship, forestry and meteorology while having speculative imaginations of its applications, thus slightly combining it with a ‘top down’ approach. Through one part, the Environmental Summer Pavilions projects, pareSITE (Nam, 2013) (see Figure 14) and LOOP (Slavičková, 2014) (see Figure 15), originally planned mainly as a more complex study for the environment responsive envelope Ray project, it immediately reached a social dimension. As opposed to Katarína Boháčová’s doctoral thesis classifications (Boháčová, 2012), the pavilions joined both purposes, design-research experimentation as well as public social activities generator and prototype. Its relations have been mapped (see Figure 93) at Birger Sevaldson’s GIGA-mapping workshop (Davidová, 2016b) at the Faculty of Art and Architecture at the Technical University of Liberec (FUA TUL, 2016), that developed more complex understanding/questions also in relation to its multileveled opportunities of use and social aspects.

The above GIGA-map with several ZIP analyses’ takes into consideration the overall process, introducing feedback loops. The color-coded threads and markers were employed in mapping with a highlighter for zoom points.

The pavilions served as more complex material-environment interaction prototypes for the development of the performative envelop Ray project while following their own biotic – human and social responsive agenda. Generating a pleasant climatic environment for both its festivals’ (Barry, 2016; Davidová & Kernová, 2016; Kernová, 2014) events as well as for individual opportunistic use, the pavilions provided data for interrelated interactions of actors and their physical environment (Davidová & Sevaldson, 2016 – in press). Freely inspired by the performance of oriental screens, so called ‘mashrabiyas’ (Fathy, 1986; Michael U. Hensel, 2015b; Michael

U Hensel, 2010b, 2011a; Michael Hensel, 2013), the pavilions generate humid air circulation evaporated out of its material on dry, hot summer days lately typical for the city of Prague. Such performance for the outdoor interaction is also taken into consideration by Ray project.

The envelopes Ray 2 and 3 (Davidová, 2013b, 2014e, 2016c) (see Figure 94 and Figure 95), proposed as, in a way parasitic, screens for semi-interior spaces of the so-called onion principle in the environmental design field, generates public-private, semi-outdoor social and physical interactions as known from 'svalgangs'. Ray 2 and 3 has performative capacities through material-environment interaction for regulating the non-discrete space's comfort in relation to climatic conditions, not letting in moisture in high relative humidity exterior conditions, while airing in dry warm weather. In addition, Ray 3 is heat reflexive, thus generating by its warm surface thermal comfort in lower temperatures, while the preceding prototype Ray 2 (Davidová, 2013b, 2014e) is more permeable, thus, a different range of spatial properties might be reached.

This research proposes a shift from recent trends in architecture and the building industry that aims for impenetrable insulations of spaces, in addition often through toxic or energy consuming produced materials (Davidová, 2009). Instead, it introduces case study solutions for non-discrete spaces to be applied as urban design architectures or as a boundary within the 'onion principle' of habitable buildings. Thus generating rich variations of living environments for different opportunistic use and human/biotic activities through indoor-semi-indoor-outdoor interaction of climatic, or generally the physical environment, as well as biotic, namely human, agents.

8.4 SUMMARY

This paper sets the case study research Wood as a Primary Medium to Architectural Performance into the context of architectural and urban design practice. It proposes a different approach to built environment than what is widely-used and supported by today's building laws and markets through suggesting sustainable applications for performative environments and atmospheres. It is exhibiting a range of variety of possibilities of boundary conditions on my, or co-authored by me, today designs/realisations, showing where the research's case projects take place. Such ranges have been common throughout the history as climatic or other physical agents as well as social or practical use adaptation to environment through gradients of boundary conditions. As seen from the 'svalgangs' mapping example, some of these spaces have been also widely transformable according to current need/suitability and/or use. These solutions were developing over generations through a 'trial error' approach while modernism cut this link in most of its specifications and adaptations. I would agree with Jan Michl, that, i.e., functionalism was a merely related special aesthetics movement rather than for any use or general performance (Michl, 2003). This loss causes issues on any liveable aspect, starting from social performance through good physical as well as mental state and/or comfort, understanding an individual's belonging to nature and universe, ending with negative effects on environment that generates feedback loops to all the other aspects. I am not even mentioning the loss craftsmanship's knowledge that relates to all of this and my research had to face it through all its stages. This research does not exclude the relevance of emotional states/interactions, tacit and subliminal knowledge/behaviour of individuals and groups from relation to hard data measurements, that to be honest, in all the cases are rather informative than exact due to the complexity of the conditions.

The four constructed research by design prototypes of Wood as a Primary Medium to Architectural Performance project suggest various range of opportunities for boundaries and its environments, while the latter ones involve the findings of the former ones, thus generating feedback loops within the design research

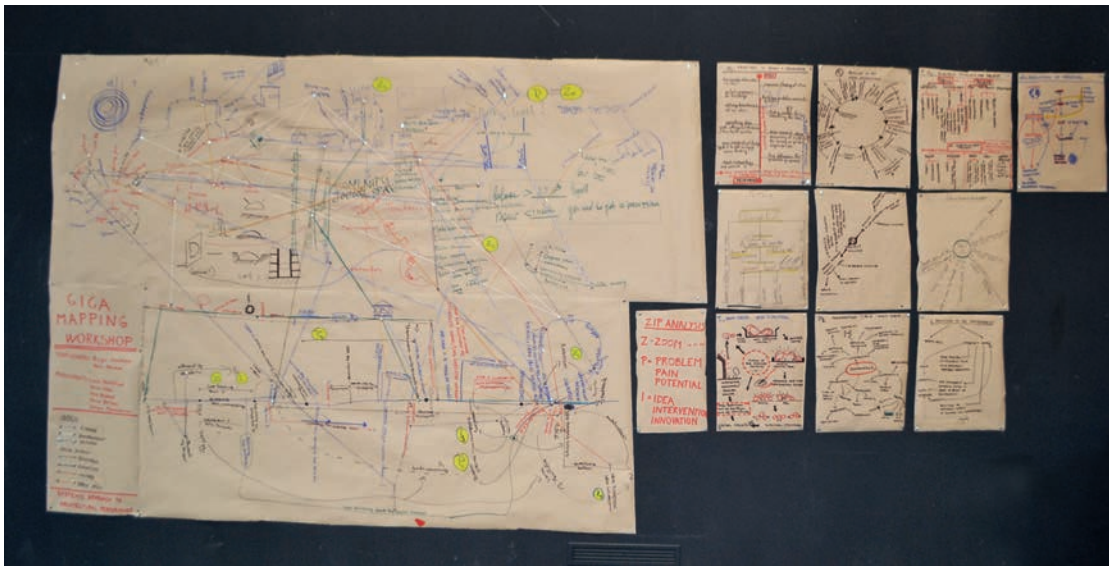


Figure 93: Sevaldson's GIGA-mapping Workshop Result (photo: Málek 2016)

process. These prototypes haven't been just produced, but also actively observed for performance. This includes all different aspects of behaviour, ranging from artistic and other living expressions of its enactment and embodiment (Merleau-Ponty, 2002), through social behaviour observations, to its weathering and aging (Mostafavi & Leatherbarrow, 1993) and 24 hours hourly measurements with a weather station, moisture meter and calliper in various weather/seasonal conditions.

The research claims that this soft and hard collected data are interrelated while none of them are really exact when seen from holistic perspective that can never be reached in total. Therefore it is also of interest of collecting subliminal knowledge in GIGA-maps, such as various uses of recordings, including photography. The majority of data that are linked to our/others interaction with the surrounding environment cannot be truly quantified due to its complexity. Therefore, new ways in relation to particular projects and their observations had to be developed and improvised through the process, not really following any pre-set, as justified by Sevaldson for such situations (Sevaldson, 2005). This covers the methodology of Systems Oriented Design (Sevaldson, 2013b), Research by Design accompanied by full scale prototyping (Michael Hensel, 2013), while involving NGOs (Davidová & Sevaldson, 2016b) and combining physical with digital design techniques (Sevaldson, 2005), social, individual and hard data observations. Thanks to this and also to the researched topic, a new line of GIGA-mapping as well as other research methods and methodologies were performed and developed. The research ranges from programming the material behaviour to how it is perceived and what impulses it generates into endless feedback loops set in matrixes, proposing a shift from today's common approach to building environment, suggesting a small but applicable part into the discussion of generating rich variety of environments for researched location, that ferly relates to today's climatic changes and its implications.

8.5 CONCLUSIONS

If we agree with Jan Gehl that the natural starting point for the work of designing cities for people are, next to human mobility, importantly the human senses because they provide the biological basis for activities, behaviour and communication in city space (Gehl, 2010), we have to consider variations of non-discrete, or semi-interior spaces of different levels of interactions through its boundaries discussed several times by Hensel and others (M Hensel & Turko, 2015; M.U. Hensel, 2009; Michael Hensel & Menges, 2009). Such spaces are common in different regions over the world, always designed for local climatic conditions. Dry, hot summers and cold winters of high relative humidity level are common in the Czech Republic (Tolasz & Coll., 2007). These extremes are even more and more increasing every year with climatic change (CzechGlobe – Global Change Research Institute of the Czech Academy of Sciences, 2016). The Prague Institute of Planning and Development (The Prague Institute of Planning and Development, 2016) has already joined the international Urban Heat Island project focused on recent microclimatic urban phenomenon of overheated cities in Central Europe (Urban Heat Island, 2016) some years ago. Several deaths are reported during the summers and winters due to climatic conditions every year. Such environment certainly does not generate a pleasant ambience for individual or social activities. Therefore, the discussion that the region could benefit from the concepts of architectural performance from both, arid and northern climates while adjusted to local settings seems to be relevant. This seems to support Michael Hensel's argument for "schools of thought' that are not local in terms of their location, yet in their determination' (Michael U. Hensel, 2015b). At the moment, except shopping arcades, the alternative of non-discrete architectural spaces are not mentioned in Prague's Public Space Design Manual released by The Prague Institute of Planning and Development (Prague Institute of Planning and Development, 2014). Also, these values are not considered by property marketing, where only fully indoor spaces

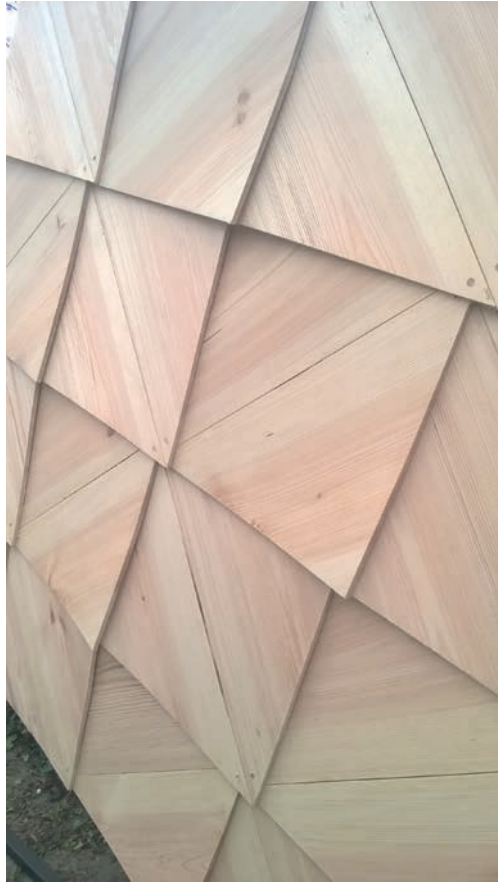


Figure 94: Ray 3 (photo: Davidová)



Figure 95: Ray 2 Performing in the Sun, Being Inhabited by Algae after Three Years in an Outdoor Environment (photo: Yildirim 2016)

are calculated into selling square meters. Though not that common in so many alterations as elsewhere, also not totally alien to Czech traditional architecture these spaces, in different site specific iterations, will become necessity for living cities and/or generally, habitation in the location. Wood as a Primary Medium to Architectural Performance project offers one of many site specific possibilities of spatial climatic performances and atmospheres to be adjusted in design and its site specific settings.

When mapping the different systemic relations in interactions happening in time and space, different agents are involved in feedback loops. Furthermore, these agents are often interchangeable by transformation of the boundary conditions and the environment, caused either by biotic or physical force involvement. This enables more opportunities for use and inhabitancy of all exterior, semi-interior and interior, as they are modulated through different layers of boundary crossings and reflections of the onion principle with different peels. Introducing a soft systemic matrix and gradients in ranges and actions and sorting activities through curvature degrees while applying Sevaldson's codification of relations by line fonts and weights (Sevaldson, 2016c) proved to be suitable tool for mapping of such. Each of the GIGA-map mentioned here is in fact theme specific ZIP-analysis (Sevaldson, 2016d) of each other, mapping the problem in detail.

8.6 FUTURE VISIONS

The research study: 'Wood as a Primary Medium to Architectural Performance: A Case Study in Performance Oriented Architecture Approached through Systems Oriented Design Methodology' covers a small part in the field of Performance Oriented Design (Michael U. Hensel, 2015a). Its main contribution is in sustainability and in relation to practice application for lively built environment through systemic approach, relating both hard and soft data enabled through Systems Oriented Design methodology (Sevaldson, 2013c).

The research discusses down-to-earth strategies such as the moisture content when the wood is cut, as well as its systemic relations to climate adaptations. This means that we cannot exclude ourselves from the discussion of the previously mentioned transformations necessary for the building environment of our future. The relationship of micro-macro climatic conditions starts to be common while its social or biotic aspect within the urban area are rarely discussed in detail, except the dehydration warnings for elderly people, common for at least 15 years or the previously mentioned Urban Heat Island project (Urban Heat Island, 2016).

Through employing new, or actually old, visions of present, I would like to suggest a search for a wide range of designs in different fields with different boundaries penetrations. Not excluding ideas of systems that are, i.e., through wood's moisture content locking into its sockets in high humidity levels, thus totally closing the environment, in the same time accepting designs that are just transferring reflections or even memories or thoughts through air or other media.

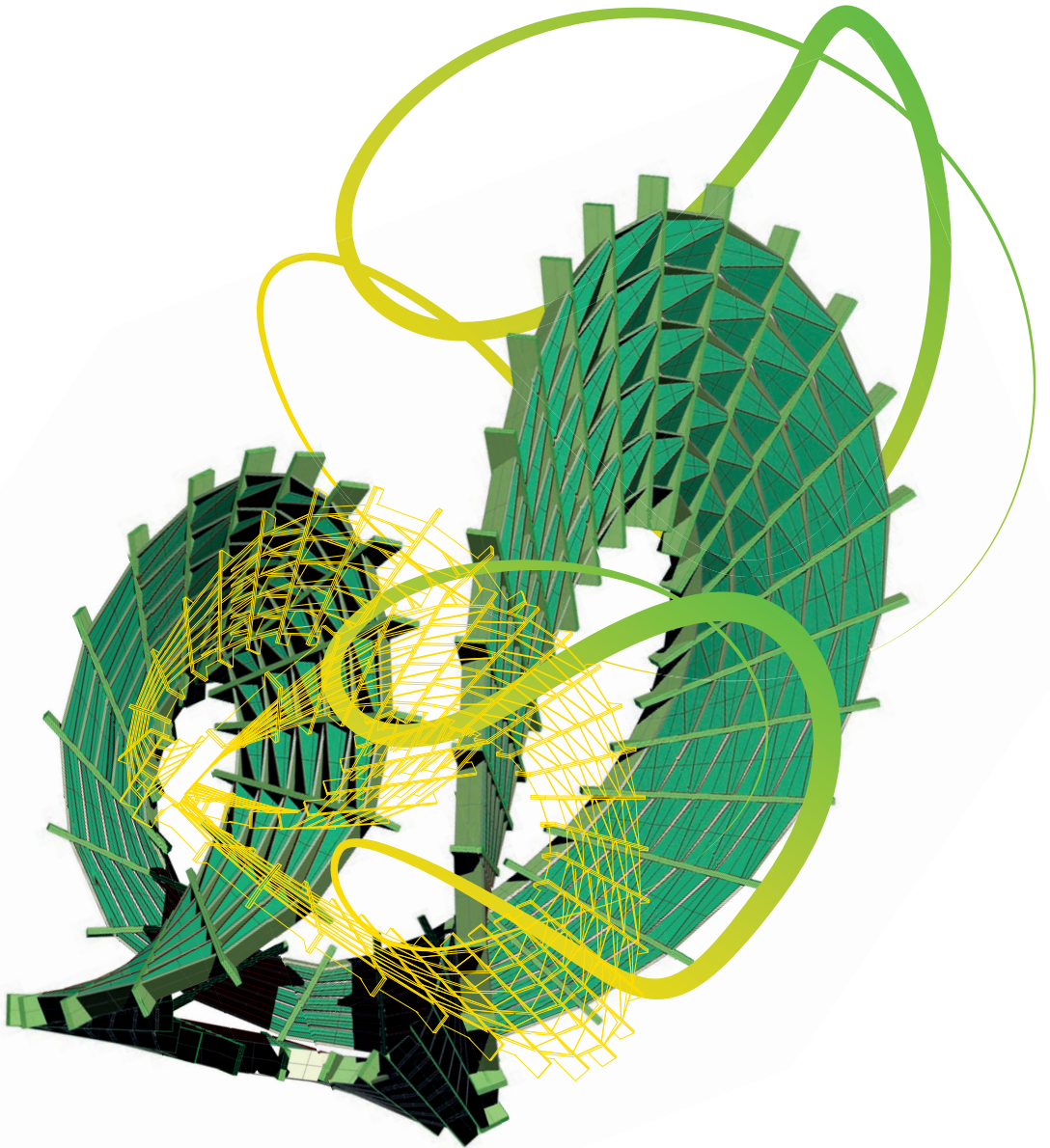
While proposing the use of solid wood for the discussed performance in the discussed location at the present time, I believe that all different variations and applications within the field might be relevant in the future and/or today, in reference to different performance, product, location and technology. This suggests more explorations in all discussed fields, from microscopic to macroscopic; soft and hard data levels, employing environmental performance in all of its aspects, biotic – including social, as well as physical and most importantly, their relations. This seems necessary to be handled through methodologies covering complexities such as Systems Oriented Design (Sevaldson, 2013b) and Research by Design while full scale prototyping (Michael Hensel, 2013). As discussed in submitted paper 'Systemic Approach to Architectural Performance: Handling Data in Creative Design Process: Mixing Physical with Digital', this all, together with participation, could be handled in 'Rich Design Research Space' (Sevaldson, 2008, 2012b) in the future.

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