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Figure 1: Responsive Transformer (Collaborative Collective 2016)

The paper discusses a result of transdisciplinary cooperation of architectural practice and association Collaborative Collective (Collaborative Collective 2016; Collaborative Collective 2012) structural and mechanical engineering practice Experis DSKM (Experis DSKM 2016; Experis DSKM 2012) and ecologist association CoolLAND (CoolLAND 2016a; CoolLAND 2016b) on competition entry project for an administrative centre of the Forests of the Czech Republic state company (Lesy České republiky 2012; Lesy České republiky 2016): the Responsive Transformer (see Figure 1). The core of the call was innovative use of wood, flexibility in development over time, energy efficiency, sustainability and environmental approach, taking in consideration adjacent forests and villa like area.

Throughout the history, vernacular built environment was tested and modified according to abiotic as well as biotic, including socio-cultural, context over time, generating onion principle of different layers of climatic environments with different penetrations in relation to each other (Davidová 2016a; Davidová 2016b). The project is applying different peels exchanges through bio-morphing wooden screens responsive to weather conditions, coexistence with local, micro-climate modulating eco-systems as well as ground excavated climates. As in the past, such settings were constantly rebuilt for new needs in time, recent fast climate, society and technology changes call for equal response in natural and built environment adaptations. Inspired by the R&Sie(n)'s New Territories pioneering project in the field (Roche 2010; R&Sie(n) 2014), the project suggests options for its robotic architectural retransformations (Petrš 2016) towards fully adaptable design, combining both, biological and material responsiveness with physical computing for the parts, that are not transformable through biology in the current state of research for application in today practice.

1. Introduction:

Traditional architecture has been covering different climatic layers all through its history across the climates, continents and cultures, where their boundaries and thresholds greatly varied in relation to their symbolic connotation and functional specificity, engaging the environment and offering a broad range of different degrees of connection, openness and closeness, and provisions for habitation (Hensel 2012a). This has been often reached by the option of retransformation or rebuilding in reference to actual usage and climatic needs, i.e. Norwegian wooden semi-interior, non-climatised spaces, so called svalgangs (Davidová 2016b) or Cappadocian caves in Turkey (discussed in separate paper at this conference), respectively. This project has been mainly inspired by such performance, generating interchangeable onion principle (Davidová 2016a; Davidová 2016b), manipulated by shafts, inspired from Cappadocian underground cities. Learning from the biology, cells to reach photosynthesis have to have organized polarity of the receptors, covering different membranes of different penetration exchange among different organelles (Cavalier-Smith 2000; Soll and Schleiff 2004). Enclosable fluid transfer is performed through cells of pinewood (Dinwoodie 2000). Sunflowers follow sun in their early development in order to gain maximum energy, while later stay east-facing before facing downwards (Meyers 2010). This performance is based on the plant's own development and its surrounding's environmental changes throughout the seasons. The project's performance ranges from bio-mimetics, through material's bio-morphology to full use of biological systems, positioning it into ecosystem of the adjacent forest and urban settlement.

2. Building's Climatic Performance

Our proposal is based on single mobile cells, that can organize themselves into spatial organisations suitable to current climatic, biotic, including social, and usage performance. Each cell consists of two climatic layers, a) one part, that is fully enclosed, insulated through green roof/façade and climatised; b) and to it ambient semi-interior, non-climatised space, that is airing in dry hot weather trough wooden material-environment responsive envelope Ray 3, which closes in humid cold weather (Davidová 2016a; Davidová 2016b). Through the windows in the green roof, it can generate natural ventilation. The cell can rotate towards prevailing wind and solar radiation, thus manipulate the indoor climate through the ventilation stream. The unclimatized part can also fully open itself and become fully exterior space. The cells are connecting through joints in a grid to service and ventilation shafts from underground spaces. The stream is cooling the above- and under-ground climates from infiltration pool at the lowest level and heating from underground forest wood waste incinerator. Underground spaces have best climatic conditions for computer rooms, meeting rooms, cantinas, sport facilities and archives, bicycle or car parking, while the aboveground spaces serve well for long term daily usage for work or habitation. The local forest species green roofs and ground surface not only manipulate the indoor and outdoor climate and keep the rainwater management, but also extend the surrounding ecosystem. The campus is a gradient between villa like settlement and natural forest, positioning humans as one segment of the overall biodiversity. For its thinness, that is important for wooden construction of the cells, and sustainability of management, the company Living Green City Ltd. (Living Green City Ltd 2016) was selected for next steps local species application cooperation. This architecture proposal aims to adapt to climatic, as well as biotic, including social, development. Therefore, we hope that no more tearing down will be necessary in closed future, such as in current situation.

2.1 The Cell Organisation:

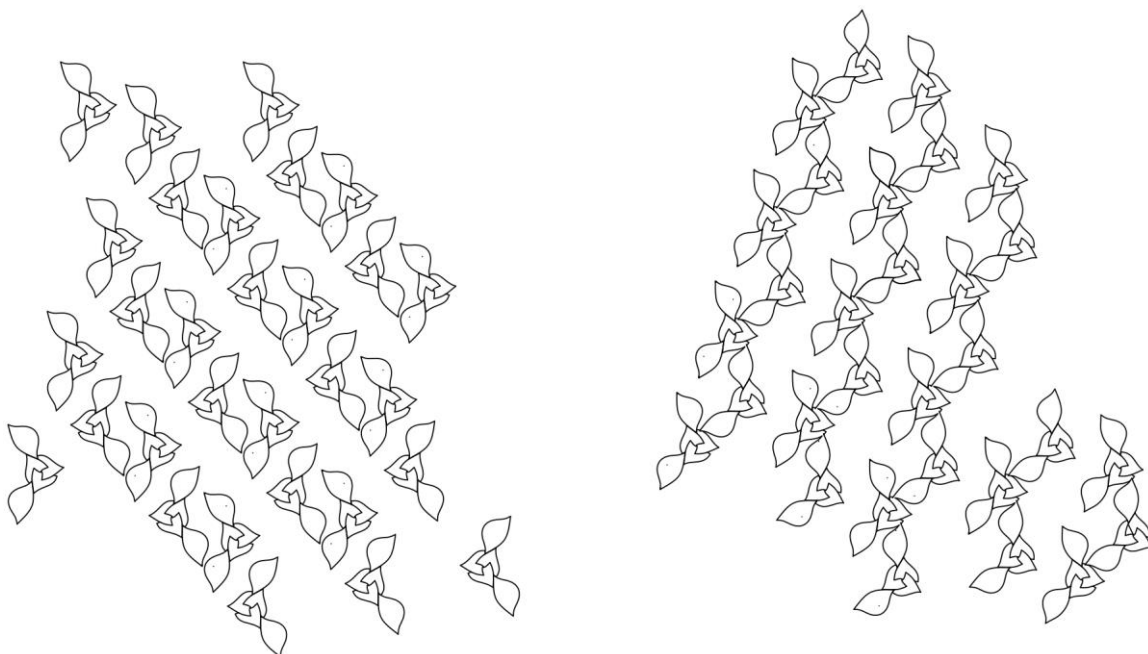


Figure 2: Responsive Transformer: Different Variations of Cell Organisation (Collaborative Collective 2016)

The cell modular system organizes itself in reference to its climatic and biotic, including social, performance and relationship to pre-designed grid with connection to service shafts from underground. It is based on autonomous system, equipped by monitoring environmental sensors, reading the event's calendar of the Forests of Czech Republic company, while it can be freely hacked by its users. The cells can rotate themselves according to prevailing wind, humidity and solar radiation to manipulate their and exterior climate (see Figure 2). By generating enclosures, it can increase its microclimatic humidity

level, supporting in-outdoor climate comfort in hot, dry summer days when the wind doesn't move. This is in reference to usage and biotic, including social, needs, relevant to public/private events, outdoor cantina in good weather, material loading, or needs of different species, grasses or bees and other insects i.e.

2.2 The Onion Peels:

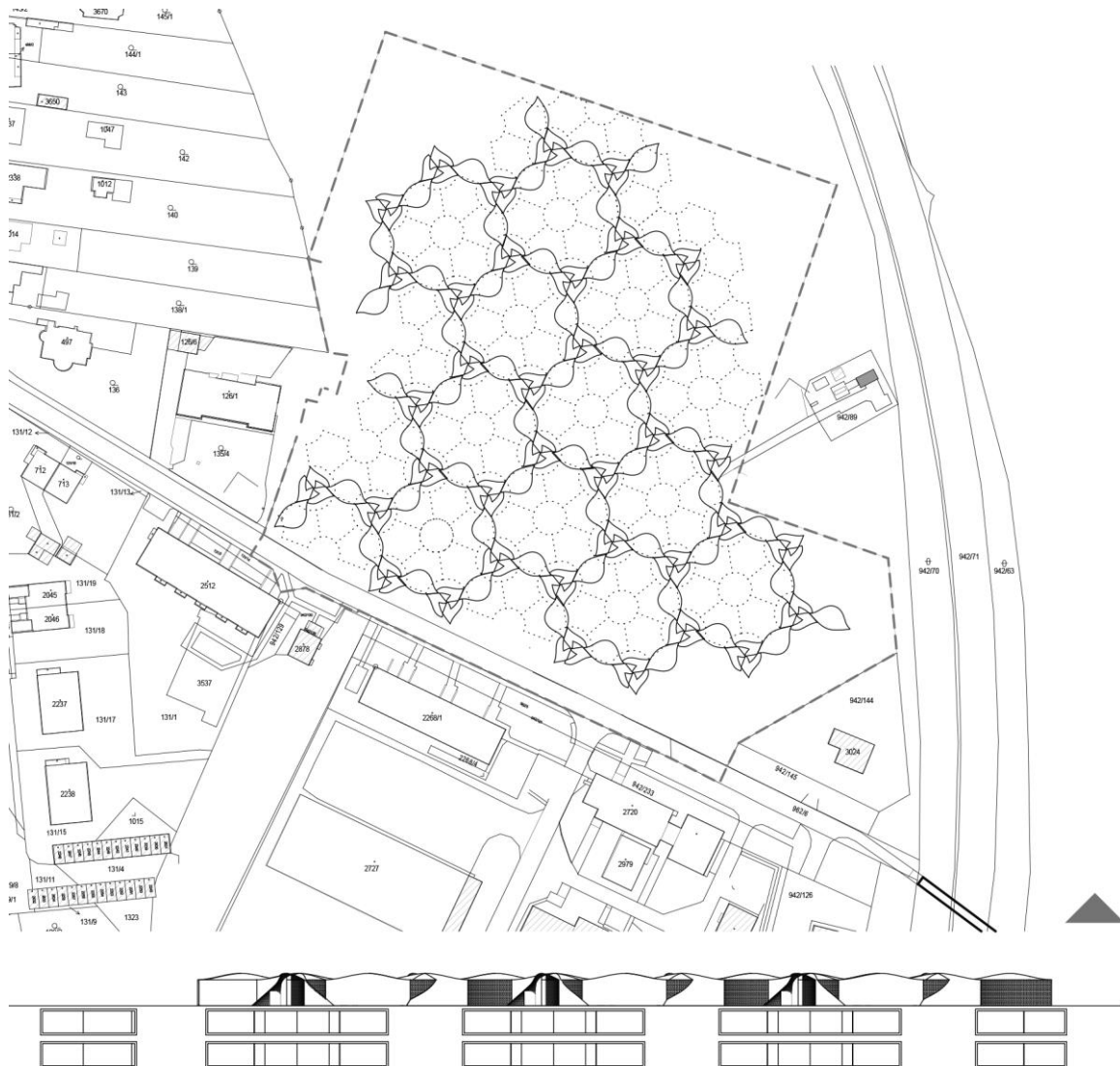


Figure 3: Responsive Transformer: Situation Drawing and Section (Collaborative Collective 2016)

The transformable area has got several peels of climates (see Figure 3). From the larger perspective, there are several urban options of cells' organisation, generating squares, yards, streets and soliter urban fabric, all in combination with landscaping. These constellations offer variability of microclimates of enclosed, semi-enclosed and open outdoor environments, thus regulating wind streams, sun shine, privacy and through the hygroscopic envelopes Ray 3, green roofs/facades and green ground, also the relative humidity level. The cell has got semi-interior space (Figure 4), operated through the Ray 3 performative envelope as an exchange with exterior climate and heat leakage from the ambient climatized space. The climatized, through green surface insulated space towards outdoor, space can open to the semi-interior and through its roof windows generate ventilation stream. In addition, it can reach cooling or heating through the underground ventilation shaft. The underground has forest waste incinerator for heating and energy and infiltration water pool of groundwater, that serves as cooling ventilation, fire tank, as well as the water source for the area. The service spaces and spaces with low frequency of use are placed underground that insulates them, lit by the fans. While the cells relate to villa like area from the west side, the green surfaces are already part of the forest's ecosystem. This transition is placing the human settlement back to the nature.

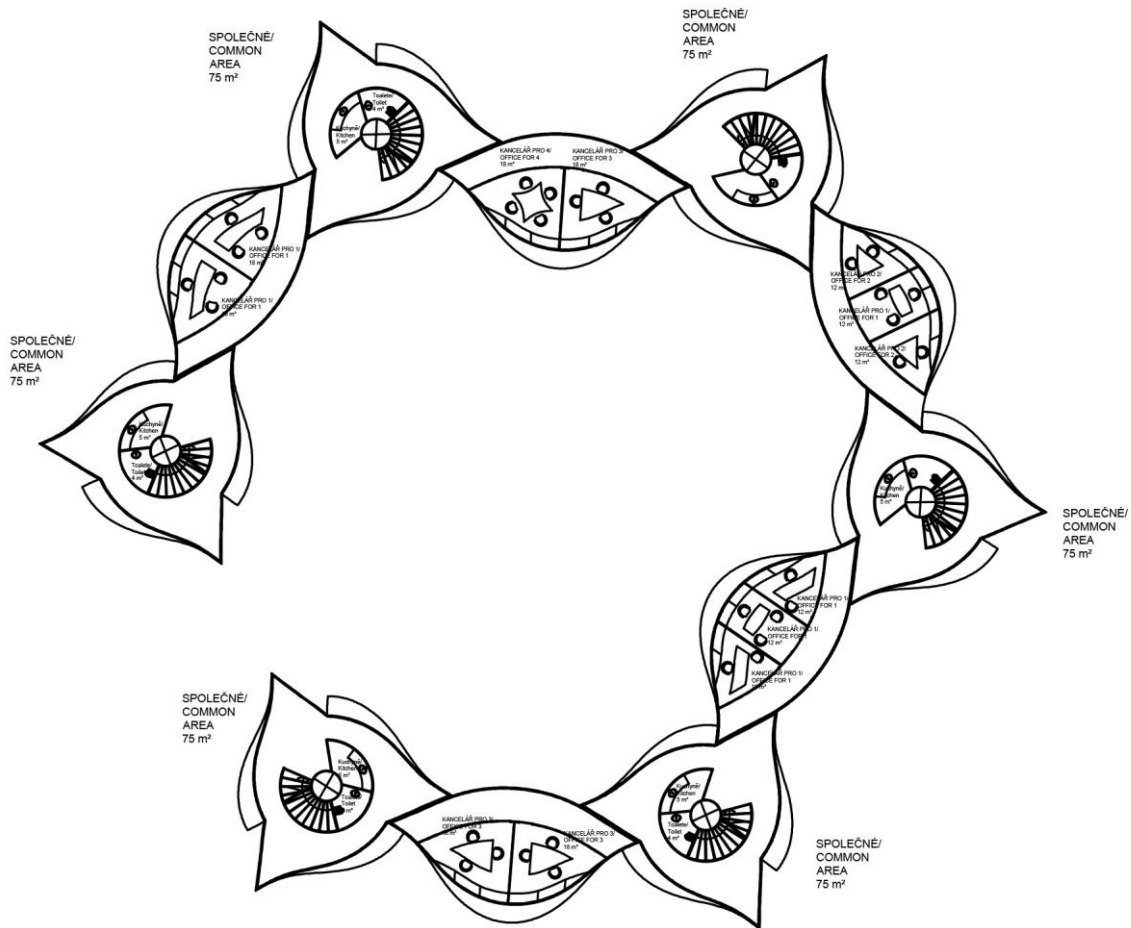


Figure 4: Responsive Transformer: Example of Offices Floor Plan (Collaborative Collective 2016)

2.3 Ray 3 Envelope:

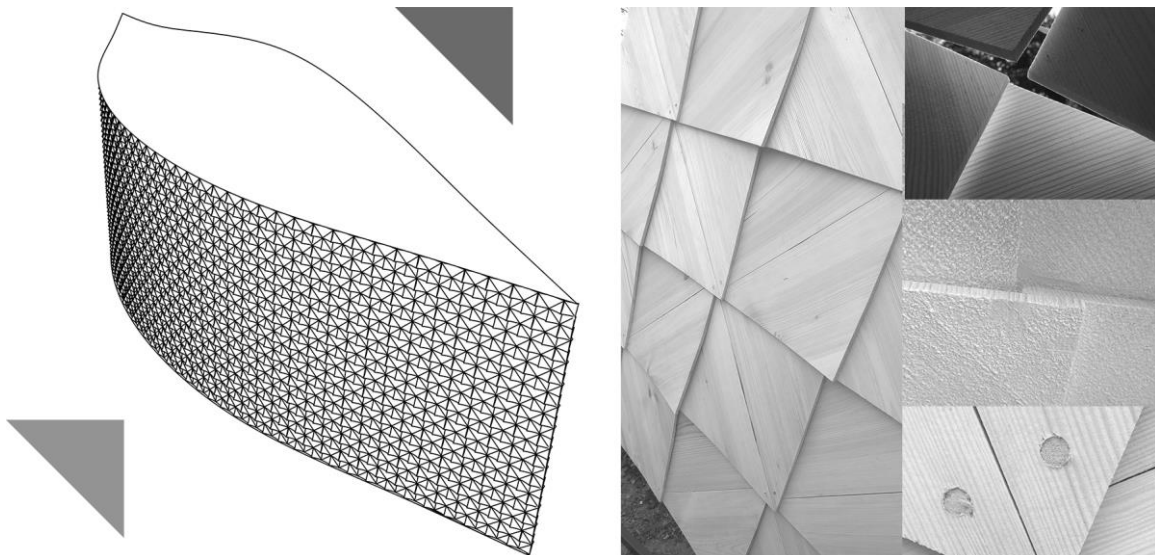


Figure 5: Ray 3 – Responsive Envelope: a/ left: Ray 3 Applied to Cell; b/ central: Ray 3 Prototype; c/ right: Details of Ray 3 Prototype: c1/ top: Open Gap in the System Ray 2 Prototype; c2/ central: AZ TR Coat on Ray 3 Prototype; c3/ bottom: Joinery on Ray 3 Prototype (Collaborative Collective 2016 and 2013)

Ray 3 (see Figure 5) is an environment responsive pine wood envelope. Its panels are cut in tangential section, therefore they warp in dry hot weather, while narrow down in cold humid one. They are organized so that the envelop is airing in targeted climatic conditions while in the other ones it is enclosing. Its semi-interior surface side is painted by thermo-insulation paint AZ – TR Coat that performs based on reflection of electro-magnetic heat radiation through NASA’s technology 3MTM Glass Bubbles (AZ-TECH s.r.o. 2016). Its joinery is based on under-dried plugs that expand when exposed to relative humidity of

the natural environment. The wood is treated by soaking in brine, an old traditional Norwegian technology against biological decay. Such panelling lasts for more than 200 years even in very wet oceanic climate of north-west coast of Norway. The product is fully recyclable, without any harm to the environment.

For reaching the most of the usage and social performance, the envelope can also robotically unfold, when special events require it. Thus the space becomes fully or partly open for occasions such as public/private festivals or material loading.

2.4 The Green Roof/Façade and Ground:

Today 54% of people are living in cities while this number is expected to increase to 66% by 2050 (United Nations 2014). Living in new urban environments means new challenges and increased pollution. A conventional average car produces about 4.7 tonnes of CO₂ per year. At the same time up to 12,5 to 40 sq. m of living wall can cover annual oxygen consumption of one human being and absorbs up to 0,46 kg of CO₂ per year (Office of Transportation and Air Quality - United States Environmental Protection Agency 2014). Street-canyon vegetation may reduce concentrations of the two most harmful urban air pollutants, nitrogen dioxide (NO₂) and coarse particulate matter (PM₁₀), by as much as 40% and 60% respectively. Average reductions over a year ranges around 7–30% (Kessler 2013). Latest development of hydroponic cladding systems provides also noise reduction by up to 15 decibels (Azkorra et al. 2015). Green surfaces are seriously reducing urban heat island effect through the material absorption and humidity evaporation (Wong et al. 2016).

As a cladding/roofing material we are proposing modular hydroponic cladding system made by Biotecture (Biotecture 2016) in cooperation with Living Green City London (Living Green City Ltd 2016). This 600x450mm modular system is based on plants fitted within rockwool panels irrigated by sophisticated remotely controlled irrigation system. The ground level uses regular soil material. Both, the cladding/roofing and the ground are overgrown by local species. In the underground hexagonal grid, there are left unbuilt spaces for rainwater infiltration.

2.5 Species selection

2.5.1 Current ecological characteristic

Origin vegetation type: *Molinio arundinaceae - Quercetum*

Current vegetation type: *Carpinion* as. *Carici pilosae-Carpinetum betuli* (Neuhäuslová, Moravec, and et. al. 1997)

Vegetation gradient: 3rd vegetation gradient (Culek 2005)

Climate character: T 2 - warm climate (Quitt 1971)

Natural forest area: Polabí (Forest Management Institute Brandýs nad Labem 2012)

The area is located on flat area of bordering of urban area and urban forest. . Ecotone between these biotopes is consisted of nitrofile species such as *Sambucus nigra*, and *Rosa canina*. Nitric and ruderal character of both ecosystems also indicates *Impatiens parviflora* and *Urtica dioica* in the ground. Ruderal species are characteristic for the urban area but can be also found in the forest. Some parts of the forest ecosystem are close to original vegetation type. Both species *Quercus petraea* and *robur* with *Carpinus betulus* dominate there.

2.5.2 Species selection



Figure 6: Selected Species; from left to right: Raspberries (photo: Motl n.d.; with the courtesy of Motl); *Calluna vulgaris* (photo: Motl n.d.; with the courtesy of Motl); *Alchemilla* (photo: Zimová n.d.); Grasses *Poaceae* (photo: Zimová n.d.)

The main motive for the selection of species (see Figure 6) is forest environment, formed to generate natural like biotopes, which ease and please human presence. Such polyfunctional biotopes are usually used for example in ecological restoration in damaged areas (Aradottir and Hagen 2013). For this reason, only the species growing in Czech forests that can survive design's geotope are used. The overall greenery has more functions: a) water retention; b) biotope for pollinators, c) food for people using area, d) aesthetical landscape scene. To reach this, these species were selected for these locations: a) ground: *Bryophyta* in as species variability as is possible. Dominate species are *Polytrichum*. The other ground species are *Poaceae* with domination of *Nardus* and also *Juncus* in more wet sites, b) west and east orientation and ground: Ground with *Sphagnum* and fruits hedges of *Blueberries* (*Vaccinium myrtillus*), *Cranberries* (*Vaccinium vitis – idaea*, *Vaccinium*

oxycoccus and Raspberries (*Rubus idaeus*). These species generate bushes areas and offer fruits, serving as food for animals and people. Robotic harvest will be used during season; c) South side: Moor with *Calluna vulgaris* and Birch tree (*Betula pendula*). Heath generates natural whole year blossoming carpet, that collect well water and solidifies slopes. For better solidity is also used stunted birch. The moor need permanent trampling and disturbance of the top layer, which will be performed by robotic cells; d) north side: The main task of northern side will be water retention. Species such as *Alchemilla* or *Plantago*, which actively collect horizontal precipitation, are used. To this *Juncus*, a long term collector of rain and underground water, will be added.

For pollination of fruit bushes will be built bumble bee houses. All the greenery system provides food for pollinators during whole vegetation season. Selected species diversify blossoming seasons, which is suitable for allergic people. Vegetation accessible by people will be enriched by spices Melisse (*Melissa officinalis*), Sage (*Salvia officinalis*) and Rosemary (*Rosmarinus officinalis*), suitable for food and drinks.

2.6 The Underground:

The underground and green surface (see Figure 3 and Figure 1) insulates the occasionally used spaces. Therefore, the energy usage for keeping their climate is lowered to minimum. The climate is operated by ventilation shafts, cooling from underground pool and heating from underground forest waste bio-mass incinerator. Both, above- and under-ground, the shafts can be opened and closed in reference to its climatic needs. The hot air can leave through the fans that also serve as skylights and visual connection to landscape with greenery. The infiltration pool on the lowest level of the build-up area is a reservoir for fire security as well as a source of its water.

3 Structural and Mechanical Performance

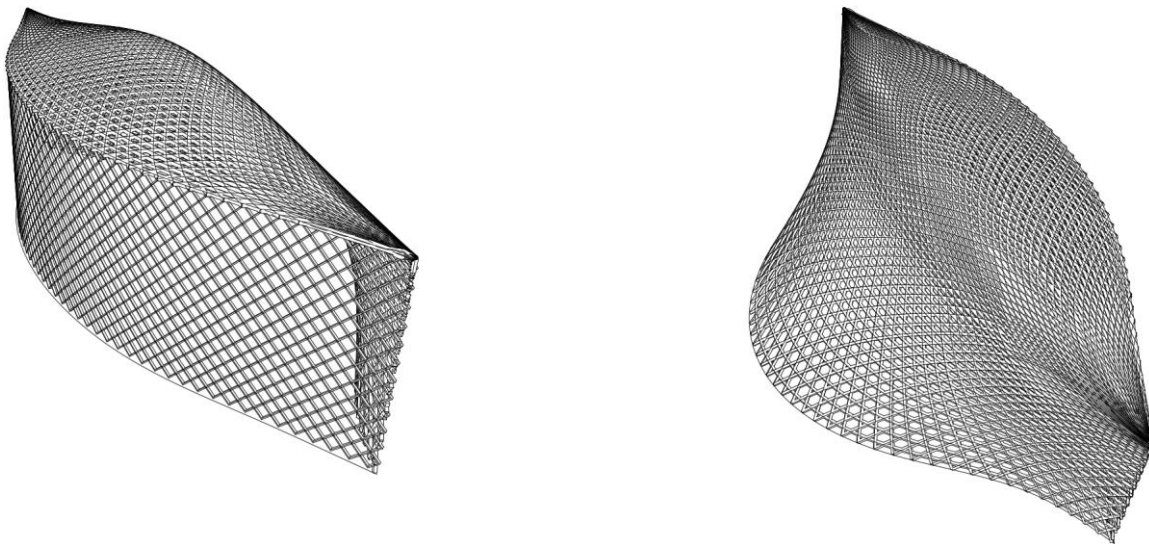


Figure 7: Wooden Shell Structure of the Cell (Collaborative Collective 2016)

The structure itself is divided in two parts: surface and underground. The underground part of the structure consists of hexagonal grid of reinforced concrete cells, with different purposes and roles in the structure. Some cells in the grid are accessible from the surface, others are only accessible from neighbouring underground cell. The cells themselves vary in number of individual levels, some are only one level deep while others can reach deeper underground levels. The cells are placed in position in an open excavation pit and assembled together. The entire structure can also be broken into individual cells when necessary, their positions can be modified and their quantity can be changed in both ways, increased or decreased as necessary.

The surface structure is not actual structure in traditional terms, but a set of movable interlockable elements. Elements above the underground cells with surface connection can rotate in position like a turntable. Other elements can crawl on the ground and form different arrangements and shapes. The elements when locked open their doorways and create larger structure accessible through the docking ports. Utilities are connected through these ports, with units connected with underground acting as distribution hubs.

The structure of the elements themselves is a curved wooden shell (see Figure 7) with horizontal framework forming the floor of the structure. The structure is supported by retractable supports and pivot wheels. When the wheels are lowered, the structure can crawl to a new position, when the supports are lowered, the structure is locked in place. The wheels allow for translation and rotation of the structure, as they can be rotated in tangential direction relative to the axis of rotation or set parallel for translational movement. The unit itself, while not settled in the locked position with neighbouring hub unit uses batteries as power supply for the actuator motors, with the possibility of external power source when the battery runs low. Under operational condition of the building, these batteries are used as power banks for solar generated energy to compensate for the power surges.

4 Discussion and Conclusions:

The project was the fusion of architectural performance, environmental science and mechanical and structural engineering field where transdisciplinarity was secured by equal roles of either participant's research's aim (Hensel 2013). Therefore, the project entry result does appear to be "weird," looked upon from traditional architect centred perspective. To our experience, this approach brings new insights to complexity of human settlements in relation to overall ecosystem, where the designed system has no clear boundaries. The system boundaries here are understood as a platform for exchange of the "inner" and "outer" system (Hensel and Turko 2015; Hensel 2012b) and always engaged in real-time adaptation on multiple levels with the use of biology itself, material-biological responsiveness and physical computing. Living in more climatic layers with other species seems to be natural and basis for humans and others, though rejected by today western building laws. It occurs to be possible to design non-human centred, or non-anthropocentric (Hensel 2013; Hensel 2015) eco-system, where humans play an equal role next to the other species within abiotic environment and therefore we suppose it is less likely to collapse and therefore sustainable. There is of course clear lack of prototyping in the work as it is purely concept design speculation, gathered together from several partial researches and fare more investigations would have to be done to bring this to practice. In addition, it has been argued by Koffka that the whole does not perform as sum of its parts in Gestalt Psychology (Kurt Koffka), followed by Systems Theory. This has been also elaborated by the first author with Sevaldson in relation to her experience with full scale prototyping (Davidová and Sevaldson 2016; Davidová 2016b). However, it has been argued for by Sevaldson for open-ended design process through and after it's so called realisation in his upcoming publication on Systems Oriented Design (Sevaldson, n.d.). We believe, that this project is a clear step forward to such design processes, handling synergy of humans with their surroundings, where architect is not playing central role, but by the proposed adaptability is opened endless space for co-design (Szebeko and Tan 2010).

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