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UNDERSTANDING RESPONSIVE ARCHITECTURAL ENVELOPE

Towards design of responsive elements as integral parts of architecture

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ABSTRACT

Article outlines the definition of responsiveness in architecture in an attempt to enable architects to think about the major aspects of responsiveness and explore its potential in architectural applications, which focus on cultural relevance, beyond fascination with electronics and mechanical systems. This paper aims to present a comprehensive and structured framework of classification of examples of responsive architecture, to be able to place the variety of concepts in context with each other. Based on this, and tacit knowledge of the author, from the architectural design practice, the specific design method is proposed and tested through several student experimental projects at elective subject Detail in architectural composition course at Faculty of Architecture in Ljubljana. The goal was to propose responsive building envelopes which would yield qualitatively beneficial effects and cultural impact on the society through redesigning the facades of selected iconic modernistic buildings in Ljubljana. Results of the projects were evaluated through focus group discussion (with students involved in the projects) on the topic of design methods and tools, technology and cultural impact of responsiveness in architecture.

ARCHITECTURE BETWEEN STATIC AND DYNAMIC

The concepts of dynamic architecture are present throughout history of man-made environment as pointed out by Robert Kronenburg “flexible architecture is not a new phenomenon, but a form of building that has evolved alongside human beings developing creative skills” (Kronenburg 2007: 18). We can find historical examples in nomadic yurtas or Asian dwellings with movable partitioning and facade panels. Modern movement was also concerned with flexible floor plans, being adaptable to variety of uses. More detailed concepts of an adaptive, responsive architecture were articulated in 1960s with developments in cybernetics and believes that architecture should enable its users to change it. Archigram’s Walking city (1964) and Living Pod (1966) with Cedric Price’s Fun Palace (1964) are appreciated examples. More recent realisations include Jean Novels’s Arab World Institute (1988) and Enric Ruiz-Geli’s Media-TIC building (2011).

Nevertheless buildings are usually less adaptive, as critically observed by Stewart Brand, “Almost no buildings adapt well. They’re designed not to adapt; also budgeted and financed not to, constructed not to, administered not to, maintained not to, regulated and taxed not to, even remodeled not to. But all buildings (except monuments) adapt anyway, however poorly, because the usages in and around them are changing constantly” (Brand 1994: 249).

Broad acceptation of concepts of ecology and sustainability, constitute political, cultural and administrative attitude towards protecting environment. This is a base for accelerated engagement of architect with responsive architecture, fueled by expansion of accessible technologies (digital and others) which are redefining relation between information and matter.

The concept of responsiveness belongs to the understanding of architecture that considers dynamics and change as crucial aspects of the creation of the space. This challenges fundamental conception of architecture, of being a static artifact to oppose time. Kronenburg observes that “The concept of a movable building appears at first to be an oxymoron” (Kronenburg 2007: 175). Majority of buildings consist of static and dynamic elements and it is up to us to understand and evaluate seemingly paradox relation of dynamic and static constituents of architecture.

The fact is that “everything generally engaged with architecture is of living origin but built spaces remain far from exhibiting vital phenomena” (Kretzer 2014: 16). Possibly, main question would be: what is the role of architecture as the man-made entity, operating with nature and living systems. Responsiveness in architecture resides on considerations of the broader aspect put forward by Kolarević: “how change is manifested in architecture” and “how time should be considered as essential design dimension” (Kolarević 2015:v).

DEFINITION OF RESPONSIVE ARCHITECTURAL ENVELOPE

Great variety of descriptive terms are associated with architecture that change (Lee 2012: 139). Naglaa Ali Megahed provides definitions of adaptable, deployable, intelligent, mobile, performance-based, responsive and transformable/transportable architectures. Responsive architecture is defined as "structures designed to respond to the social and/or environmental stimulation at a specific place" (Megahed 2017: 133). There are two issues especially interesting and different in definition of responsiveness in relation to the other topics. Firstly, responsiveness works with social and environmental context and secondly, it is related to the specific place.

Responsive architectural envelopes operate between environment and users, both of which are fundamentally dynamic systems. Yet most of the buildings are design to be static. We have all experienced that buildings change through time but changes are rarely considered as an integral component of the building design.

Philip Beesley, in conversation with Moore, talks about architectural quality of responsiveness (dubbed sensitivity in his proposal) and offers a caution: "Responsiveness does not necessarily make something sensitive. We walk through a shopping mall and the doors open, don't they? We clap our hands and the light goes on. These kinds of functions are not profoundly revolutionary. When I dwell on the term responsive, I do not mean a one-way responsiveness where things pick up on what we want and are more sensitive to us. I have a hunger to find a mutual relationship with the environment in order to discover new kinds of balances for the future." (Moore 2012). "Responsive speaks of how natural and artificial systems can interact and adapt" (Beesley at al. 2014: 333).

Responsiveness in this article is defined as an active reciprocal two-way relationship between environments and its users, conducted via architectural entities. While the term of adaptive is understood as concentrating on the change of something, responsiveness is more dealing with providing an answer, a content, to the changes within context. It is more about the goals and attitudes of connections and relations of elements, than the act of changing itself.

Zaera-Polo positions envelope as a core concern of a discipline "affecting materiality and construction, environmental performance, energy efficiency and other issues, but it also engages several political forms: economical, social and psychological" (Zaera-Polo 2008: 78).

We understand the definition of the architectural envelope as defined by Matej Blenkuš, saying "the architectural envelope excludes the living space from a neutral environment, materially defines it and gives it an image." At the same time, it is pointed out, that "the role of the architectural shell in the

relationship between the external environment and the inner living space is two-directional, since the entities are being separated and connected simultaneously." (Blenkuš 2003: 110)

Envelope is considered not as a surface (predominantly two-dimensional spatial element) but as the spatial entity operating in depth of the space. Envelope could be understood as a fractal mechanism functioning between spaces of different characters within the same principle of being porous, operational and mediating boundary (for material and information) throughout the entire space which is providing human habitat.

THE CONCEPTUAL FRAMEWORK FOR RESPONSIVE ARCHITECTURE

This paper aims to present a comprehensive and structured classification of examples of the responsive architecture. Framework enables to place the variety of concepts in context with each other and searches for existence of relations between the key variables.

There are several orderings, classifications engaged with the dynamic architecture. Movement in architecture could be divided in four categories: in plan people move in certain way across a building, experience of people when moving through the building; urban implications of movements (patterns of everyday life) and non-physical representation of movement (Brittain-Catlin 2016: 465). Kronenburg is working with four terms describing flexible architecture: adapt, transform, move and interact (Kronenburg 2007). Presentations of "Adaptive architecture" conference (held in London, 2011), for example, were grouped into four categories: dynamic facades, transformable structures, bio-inspired materials, and intelligence. In similar manner, bioinspiration, materiability and intelligence are organizational topics of publication "Alive: advancement in adaptive architecture" (Kretzer 2014: 21).

Evidently, there is a range of proposed groupings of topics and projects dealing with dynamics and change in architecture. Listed topics could be grouped in three categories: typologies of change (move, adapt, etc.), materials (smart, bio, etc.) and non-physical implications (intelligence, representation, etc.).

Based on the overview of existing literature and on-line information about architectural projects dealing with movement, the author proposes that the concept of responsiveness in architecture is considered on five different levels, ranging from quantitative entities (scales, materials, energy) to qualitative entities (incorporation of dynamics into design process, responsiveness being integral part of architectural project).

First level articulates scales, describing space and time dimensions, in which changes occur. Loonen and others propose the spatial scales of ad-

aptation of climate adaptive building shells are divided into two classes. Macro scale implies that a certain kind of observable motion is present. Micro scale adaptation directly affects the internal structure of the material (Loonen et al. 2013: 488). Time-scales definition seems straight-forward, divided into seconds, minutes, hours, years. Definition of time-scale, in respect to users, should introduce understanding of time, not as an abstract uniform category, but as qualitative entity of architectural objects in regard to people. For example, diurnal (day-night cycle) and seasonal time-scales could be defined, finding the later the most elegant application area (Loonen et al. 2013: 487). Brand describes the fundamental relevance of time-scales for the buildings with following explanation "Because of the different rates of change of its components, a building is always tearing itself apart" (Brandt, 1994: 13). Time-scales are critically related to the issue of visual pollution and obsoleteness "There is also the ever-present danger of creating "gimmicky" architecture that becomes "boring" very quickly" (Kolarević and Parlac 2015: 87). Overwhelming responsiveness can obviously become tiring for people.

Second level is concerned with the stages in architectural production process. Megahed is putting forward the conceptual framework where main division of kinetic architecture is based on the static approach and the dynamic approach. Static approach seeks virtual movement as an aesthetic effect and does not include real movement of elements of the building. It happens in the design phase using different digital tools and strategies. Dynamic approach on the other hand incorporates transformative structures into the building which literally change or move in space and time (Megahed 2017: 133). Dynamics in architecture can work on different levels of architectural activities, from the design phase, to the way it is build, to the way it is used, to the way it is disassembled. Self-assembly of elements (Tibbits 2012: 69), growth and printing of building materials, biological organisms as structure, are some of the topics being investigated to address the issue of erecting built structures. This challenges the role of an architect with computational, algorithmic and other design methods.

Third level deals with the materials as fundamental property of the built environment, energy as a source of movement and technology as means to bring them together. Three strategies, defining attitude towards technology, are being articulated: high-tech, low-tech and combination of both. High-tech strategy builds upon mechanical part, sensors and actuators. Mechanical parts tend to fail and are subject of becoming obsolete, therefore alternative thinking about responsiveness, in terms of low-tech solutions, is recently flourishing. Low-tech solutions do not have mechanical parts, taking advantage of the material embedded computation properties, to replace machines and to "unfold truly ecologically embedded architecture" (Menges 2012: 58).

Movement of the elements can rely on different types of actuations: mechanical, pneumatic, hydraulic, material-based, manual (Kolarević and Parlac 2015: 71-84), which use different energy sources: produced energy (electricity, hydraulics), environmental energy (heat, moisture) and human activity.

Fourth level deals with a fundamental question of control of the movement, raised by the responsive elements in the buildings. The hybridized model of control is proposed by Tristan d'Estree Sterk, being useful "to produce responses that have adjustable response criteria, achieving this by using occupant interactions to build contextual models of the ways in which users occupy and manipulate space." (Sterk 2006: 498). Possibility of user override of automated response is paramount to nourish human ontological complexities based with gradient of rational to emotional behaviour. Peter Šenk investigates Japanese architecture of Metabolism (Nakagin Capsule Tower) in relation to power, and concludes with "free mobility has rendered (mega) structure management into a matter of the structure of power and control," both of which are fundamental issues put forward by the responsive architecture.

Fifth level is concerned with the fact described by Mark Meagher, that "in rare cases these responsive elements become an integral and poetic element of a culturally significant work of architecture" (Meagher 2015: 159). Jules Moloney sees Zuk and Clarke (authors of Kinetic Architecture book, 1970) as being first to start discussion about describing kinetic aesthetics beyond functional and technological discourse (Moloney 2011: 31,32). Responsive building components have the potential to add to measurable goals of energy-efficiency and become "a poetic, expressive, and potentially subversive element in architecture" (Meagher 2015: 161), following the lead of "recent attempts to shift grounds of the architectural debate away from technology and production toward political critique and ideology are rightly aiming to recover some political ground that has been missing for some time within the discipline" (Zaera-Polo 2008: 76). Beyond aesthetics, we would argue, there is an opportunity for the concept of responsiveness to be connected to the expression of cultural values of community. General ethics, as described by Warwick Fox, would consist of three entities: (1) inter-human ethics, (2) ethics of the natural environment and (3) ethics of the human-constructed environment (Fox 2006: 8, 14). General ethics are referred to as the theory of responsive cohesion, which describes the interaction between people (or objects) and the environment (as the context), somewhere between fixed- cohesion (domination) and non-cohesion (anarchy), being "concerned with identifying the deepest, most general source of value that exist" (Fox 2006: 63).

Table 1: Comparison of examples of responsive architecture (using proposed framework) and evaluation of their cultural impact. Table prepared by author on the basis of the works of Kolarević and Parlac (2015), Meagher (2015), Menges (2012) and Besleey (2010). Space-scales (ss): (S) small scale object, (M) medium size buildings, (L) large buildings, (XL) high-rise buildings. Time-scales (ts): (M) minutes, (H) hours, (D) diurnal, (S) season, (P) period. Technology (th): (L) low-tech, (H) high-tech, (B) both; Material (ma): distinctive material used. Energy source (en): (E) electricity, (B) material embedded, (M) manual, (L) living organisms. Control: (D) deliberate, (A) automated, (H) hybrid.

Building	Scales		Materiality and energy			Control	Cultural impact
	ss	ts	th	ma	en		
Al-Bahr Tower AHR Abu Dhabi, UAE, 2012	XL	H	H	textile	E	-	High-rise building with an external shading system, based on a traditional lattice-screen, is controlled by building's management system, triggered by location of the sun.
Media-TIC, Cloud9 Architects Barcelona, Spain, 2011	L	D	B	plastic foil	E B	H	Responsive shading facade, using innovative materials of lightweight etfe air cushions, gained world appreciation and won WAF award 2011.
Arab World Institute, Jean Nouvel Paris, France, 1988	L	H	H	metal	E	A	Sun responsive lens-like facade system of apertures resembles the traditional mashrabiya patterns. Hi-tech solution is currently damaged, not operating.
BIQ House Splitterwerk, Hamburg, Germany, 2013	L	M	B	micro algae	E B	A	One of the first buildings to use a photo-bio-reactive facade that is actually alive, generating biomass and heat as renewable energy resources.
Maison de Verre Pierre Chareau Paris, France, 1932	M	M	L	metal	E M	D	Iconic building with movable furniture and partitioning walls. Mechanical inventions accommodate specific situation and are considered integral to the concept of the house.
Hygroskin Achim Menges Stuttgart, Germany, 2013	S	D	L	wood	B	A	Innovative use of wood produces material embedded Response and gives example of low-tech attitude towards responsive environments.
Hylozoic Ground Philip Beesley Venice, Italy, 2010	S	M	B	proto cells	E B L	H	Mythical landscape that breaths, provide sensitive environment, showing high degree of aliveness. Carbon-capture protocells hold out potential for self-renewing architecture.
Q'iswa Chaka bridge Local comunity Huinchiri, Peru	S	S	L	plants	M	D	Annually reconstructed bridge by collective effort of the local community is constructed with local ropes, produced on site from local plants.

CASE STUDY: RENOVATION OF THE MODERNISTIC BUILDINGS IN THE CITY OF LJUBLJANA

Possibility of designing responsive architecture was tested within elective course The Detail in Architectural Composition at the Faculty of architecture in Ljubljana, led by assoc. prof. Jurij Sadar and assist. Miha Čebulj in winter terms 2016 and 2017, working with undergraduate students of the fifth academic year. The objective was to analyze existing details of selected culturally relevant modernistic buildings in Ljubljana and to develop a new, projective details, with focus on designing dynamic and responsive architecture (in addition to energy-efficient renovation). Focus of investigation was to understand and propose a possible integral responsive architectural elements to the buildings envelope, to maintain and update buildings cultural relevance.

Design method

It should be mentioned that proposed design method is to large extent the articulation of authors 10 years experience with working on numerous architectural projects of different scales (from furniture to large scale buildings). Proposed design method is not a set of rules but a dynamic system of (1) design attitudes and tendencies, (2) goals and decision mapping tools and (3) cyclical evaluation process of architectural effects.

The method consists of the analytical part and the project part. Both are directly linked in repetitive circular processes, informing each other. Both parts use parameters as a basic strategy to think about dynamics and responsive-

ness in architecture. Diagrammatic evaluation matrix, as the articulation device, brings design goals, concepts and strategies in relations to each other. Tools of textual and diagrammatic articulation of the concepts, images banks, digital and physical models and technical drawings are used accordingly.

Inclusive design method uses technology pragmatically (such as parametric design and digital manufacturing) and is rather focusing on the architectural concepts, dealing with the materials and geometries in innovative way.

Evaluation of the architectural proposals (applied continually during the design process) is based on three levels, as proposed by Blenkuš "(1)metric evaluation based on calculations and measurements, (2) empirical evaluation (based on perceptual-recognition processes) and (3) semantic evaluation (based on culture)" (Blenkuš 2003: 168).

Architectural design process consequently operate on the objective, the subjective and the collective level. With an aim to include sociological, psychological and cultural dimensions to the projects.

Results of the case study

In the first group of projects (winter term of the academic year 2015-2016), the emphasis was put on the articulation of material, texture and scale attributes of the existing facades, which constitute the building's identity. Selected materials (concrete, stone, bricks, etc.) were investigated in terms of new techniques of the material processing. Buildable geometries were proposed, to enable spatial effects and expressions, based on and responding to the material, emotional and cultural entities. For example, the projects for the renovation of The Museum of Modern Art in Ljubljana, employed new technology of ultra thin flexible natural stone, to change different textures of the existing stone (as prevailing facade material of the existing building) into performative three-dimensional facade apertures, controlling quality of the light penetrating the gallery, lobby and offices. First group of projects were introduced to design method which gives a way to think about dynamics in architecture.

Second group of projects (winter term of the academic year 2016-2017) were introduced to the concept of literally moving parts of the building. The project Twisted Curtain (elaborated by Ines Galun) provides sensor controlled shading system of the multi-layered ETFE cushions to negotiate between facade envelope functions. Simultaneously being a mechanism to control light atmosphere in the gallery space and the interactive boundary responding to act of the visitors entering the building (see figure 1). Reference to the existing building, with expressed vertical shading, was adopted but changed in scale to providing improved light ambience of the space.

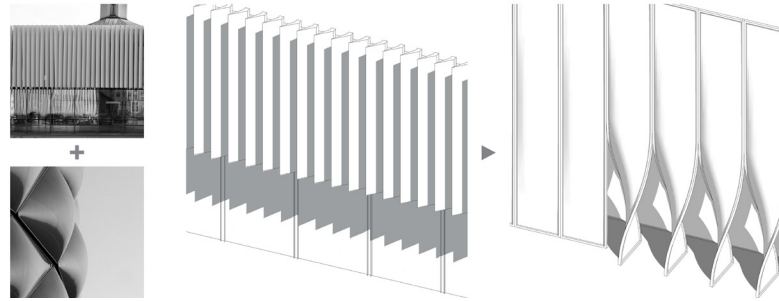

Figure 1: Twisted Curtain project proposes renovates HALA C building (architect Milan Mihelič, 1967, Gospodarsko razstavišče) by using movable multi-layered ETFE foil curtains, negotiating between controlling light condition and entering the building.

The project Bending Belts (elaborated by Emmanuel Ganzhorn) works on the office tower providing beautiful views over vast territory. Temperature loads, deriving from the inefficient shading system, is the main problem of the building. Idea of small responsive components, providing movement of larger spatial elements, was introduced by shading system with responsive bimetallic joints moving vertical louvers (see figure 2). Material embedded response yields a need for additional control systems to enable user override of the movement of louvers.

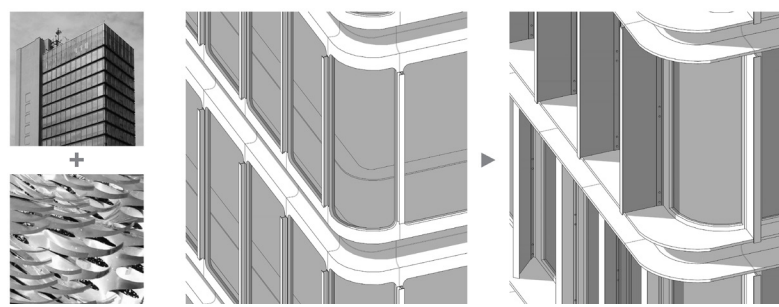

Figure 2: Bending Belts project proposes renovation of S2 building (architect Milan Mihelič, 1980, Bavarski dvor) by using bimettalic joint components to move larger scale louvers by material embedded capacity.

Evaluation of a case study

The focus group method is a form of group discussion where participants are directly involved in the participation and expression of their opinion. Focus group session was conducted at Faculty of Architecture in Ljubljana (cabinet no. 19), on Wednesday 22nd of February (from 13.00 to 14.45). Four student, who were the most successful at the subject course, attended the focus group session (two of Slovene and two of French nationality). Debate focused on five main topics: (1) responsiveness in architecture, (2) technologies and materials which enable responsiveness, (3) do we need specific

design strategies and methods to design responsive architecture, (4) scales of responsiveness in space and time and (5) can responsiveness become an integral part of architecture with broader cultural impact.

Students were not familiar with the concept of responsiveness before the course. They were familiar with some examples of responsive buildings, but did not understand responsiveness as projects main architectural issue. When defining responsiveness in architecture, students talked about the ability of architecture to affect people and the environment and the ability to interact with the context. On the topic of relevance of responsiveness for architecture, answers differed from responsiveness being understood as useful (in sense to keep up with constantly changing world), interesting (with scepticism about problems when responsive elements fail) and offering new possibilities. They did not find it necessary, for responsiveness, as a design goal, to require special design tools and strategies (but they found usage of digital techniques helpful). Students did not understand the relation of responsiveness and technology as mandatory but optional. When trying to define the spatial scales, which would be the most suitable for realisation of responsive elements (furniture, partitioning elements, rooms, facades, on city scale), opinions were scattered and not unified. Nevertheless, the scale of building facade was rated as the most appropriate for integration of responsive elements. Student did see potential to apply the concept of responsiveness in the public buildings, where it could contribute to broader cultural impact of the buildings, but not as the primary architectural issue.

CONCLUSION

Responsiveness as architectural concept is not new (Lee 2012: 11) but it is gaining momentum due to the advancement of technology and new materials. Presented paper aims to shift attention from technical issues to psychological, sociological and cultural aspect of the concept of responsiveness and bridge the gap between “those who believe architecture is a mere social construct and those who believe that architecture’s facts are determined by the inexorable laws of physics, economics, buildability, climatology and ergonomics” (Zaera Polo 2008: 76). Student projects of renovation of relevant modernistic buildings in Ljubljana show possible way to introduce the concept of responsiveness as integral and potentially subversive architectural concept. At the same time, our findings point to the responsiveness as not being a mature concept. It is lacking, for example, articulation of the typology of operational processes (seen as possible future research topic) and further development of favorable cultural atmosphere, to achieve architecture “that correlates living with nonliving, passive with dynamic, sustainable with self-adaptive,” (Collet 2014: 8), which would be able to work with, and gain from, the ontological challenges of dynamic habitats we live in.

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