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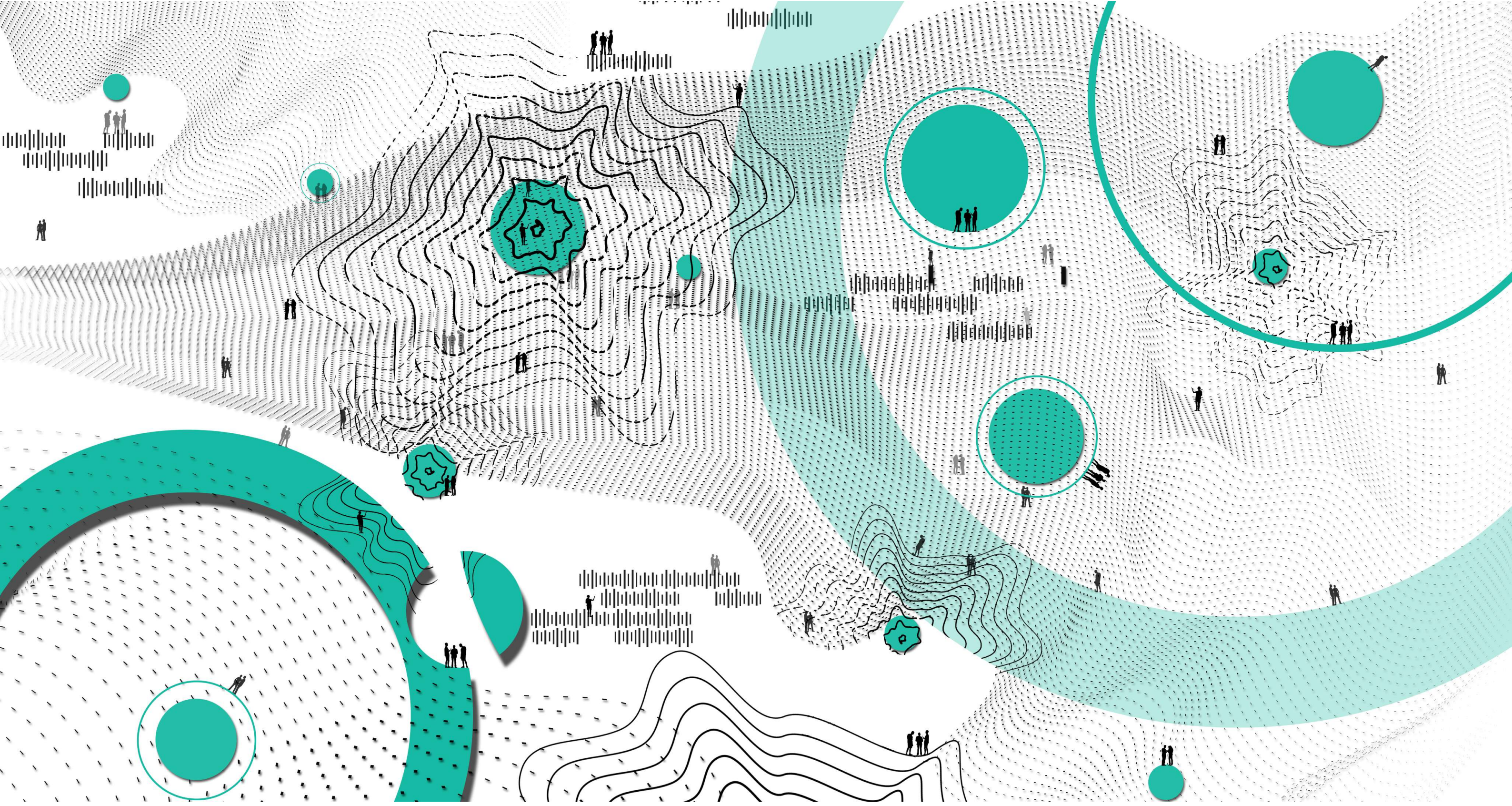
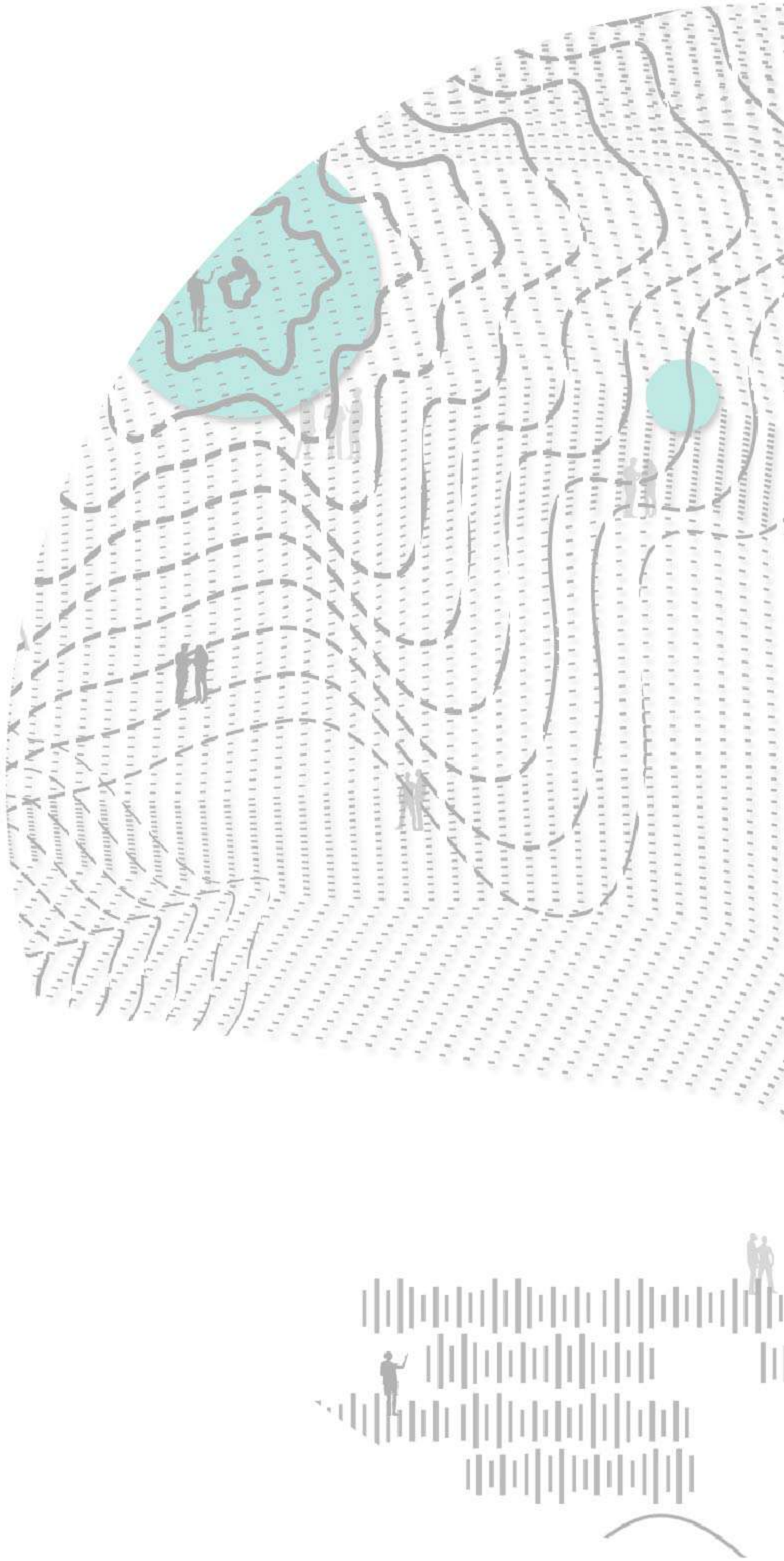
Content

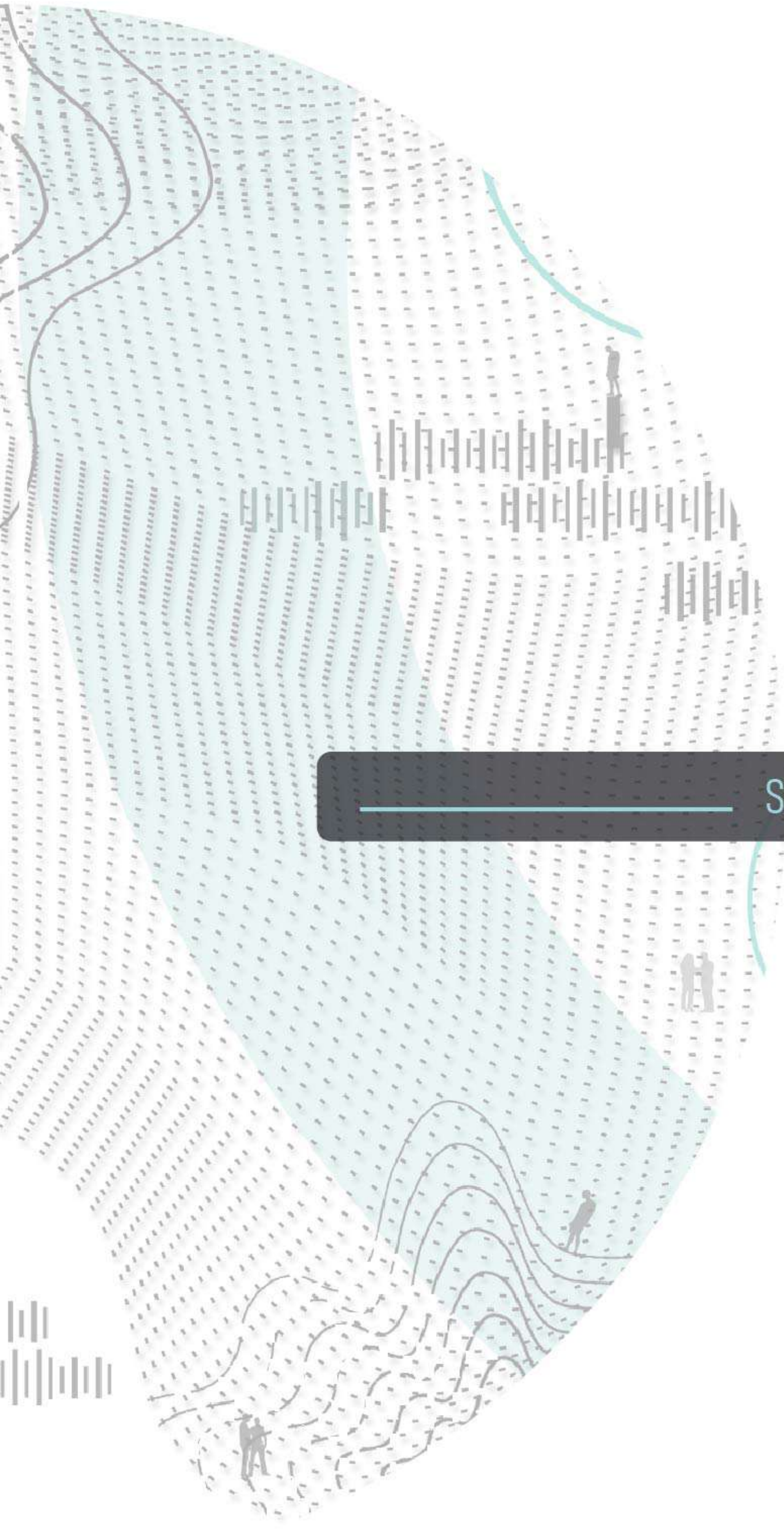


Foreword

Technology has always been pivotal in shaping the society. Advances in information technologies and material sciences in the course of the twenty-first century have irreversibly altered not only everyday life of individuals, so that the structural tenets of societies, but also the design, construction and management methods in architectural, engineering and urban practices. Beyond these alterations, recent innovations in emergent technologies such as Internet of Things (IoT) and/or Machine Learning have started to define unprecedented needs and requirements for the built environments. Moreover, environmental problems like pollution, source limitations, overcrowded cities, climate change, extreme weather conditions and the social crises that they cause on the doorstep require each and every profession to rethink its role in the ever changing conditions of today's dynamic political and economic agenda, make urgent decisions to adjust itself and take immediate actions. Cutting edge technological developments and innovations have the potential of being both remedy and poison for these environmental, economic and social upheavals.

In order to give insights into the role of technology and innovation in the practice and critical theory of contemporary architecture, Yaşar University Department of Architecture organizes the International Symposium of Architecture, Technology and Innovation (ATI) annually. The symposium aims to provide scholars a transdisciplinary platform where theoretical, technical and/or practice-based state-of-the-art research findings revolving around a yearly theme in the larger framework of ATI can be discussed reciprocally.





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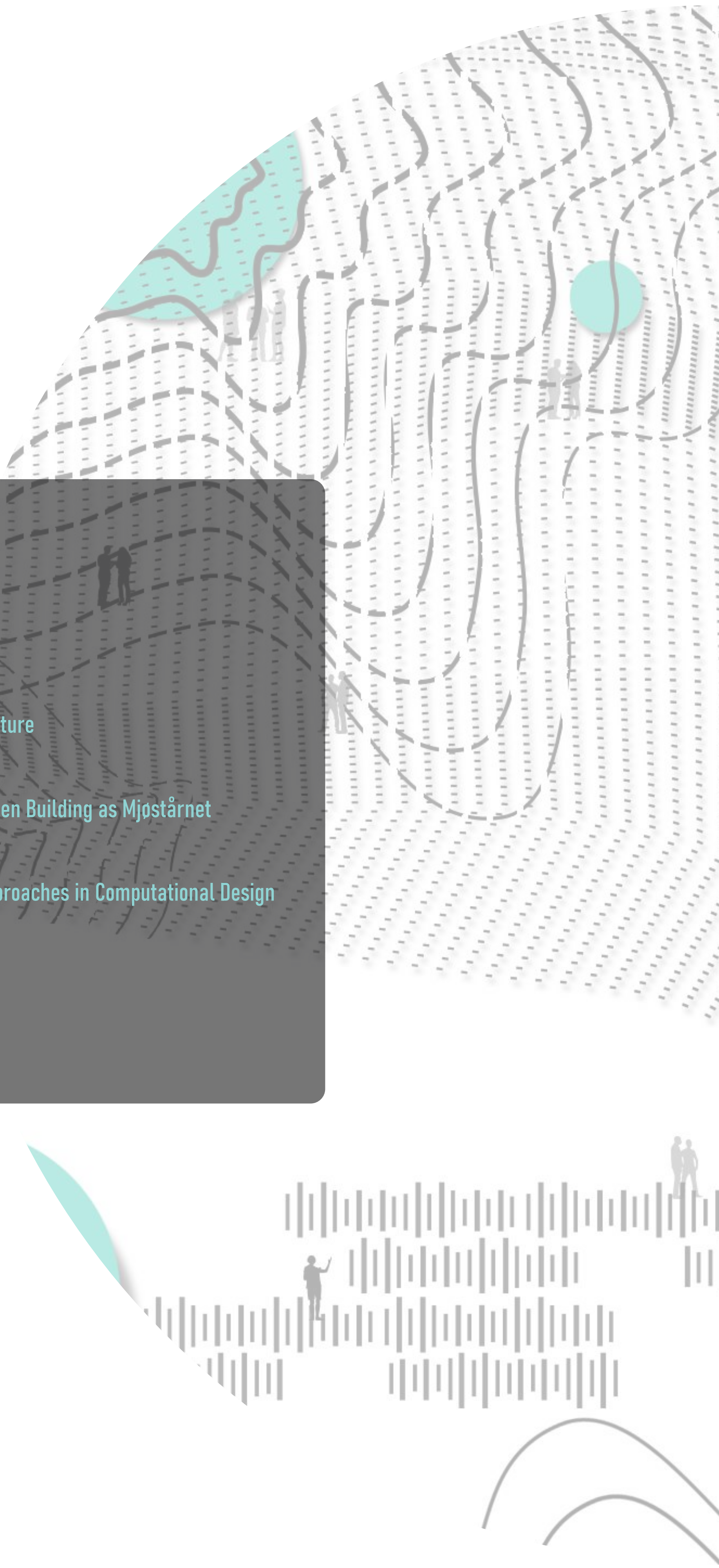

Revisiting Transformable Structures in Architecture

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Abstract
Sustainability of the built environment has been aimed at through the application of related principles of design, architectural features, optimization procedures, as well as adaptiveness and transformability of the buildings and their components. The paper reviews the conception of transformability spanning from the initially introduced architectural concepts to the engineering induced developments of adaptive and reconfigurable structures. This review places emphasis on projects that apply structural and construction principles of modularity and lightweight in addressing performance-based outputs due to functional, environmental, or external loading, time-dependent variations. The paper concludes with a presentation of two classes of a spatial rigid-bar linkage structure aiming at reconfigurability with maximum flexibility, controllability and reduced energy consumption during operation. The reconfigurations are based on a sequence of 1-DOF mechanisms of the planar primary systems (i.e., effective crank– slider, effective 4–bar method), in order to stepwise adjust the system joints to the desired values. The structure may obtain different geometrical reconfigurations from an initial to a target configuration, whereas in between configurations define respective transitional or temporary transformation phases. Thus, the building is equated with a dynamic space of adaptation and transformation, and may provide increased performance and interaction.

Keywords: Adaptive structures, kinematics, linkage structures, reconfigurable structures.

Introduction
Sustainability of the built environment has been aimed at through the application of related principles of design, architectural features, optimization procedures, as well as adaptiveness and transformability of the buildings and their components. From an architectural perspective, initial concepts of transformability in architecture referred to the need of the built environment to be perceived as composition of interconnected elements that acquire a transformative, evolving and interactive relationship with the users and the wider environment (Kronenburg, 2007). In particular, flexibility derived from industrialization, mass production and modularity in providing reversibly assembled, adjustable and mobile components. In this frame, the architectural visions on transformability of the 1960s constituted part of a wider sociological reformation, which accelerated the accumulation of surplus value and increasingly made aspects like flexibility, adaptability, transportability and mobility reflective of modern society, while challenging the conventional view of architecture (Phocas, 2017).

From an engineering perspective, initially favoured was adaptation through building mass reduction and high strength materials of relatively low elastic modulus. Closely related to these aspects was the research conducted by Frei Otto and his team on long-span lightweight tensile structures and elastic gridshells. The work provided the fertile ground for the realization of the Olympic Stadium in Munich in 1972 and the Mannheim multihall in 1975. Both structural typologies comprise form-active systems (Engel, 1999), in terms of their simulation and erection, as well as their load-deformation behaviour (Lienhard & Knippers, 2013).

Although, individual kinetic tensile structures were already conceptualized by Frei Otto and his team, an actual turn towards the realization of kinetic structures was made possible through the introduction of engineering principles for adaptation and transformation. William Zuk and Roger H. Clark demonstrated already in 1970 with their book publication on 'Kinetic Architecture' the necessity for an architecture that is not static; instead, it has the ability to adapt to differing functional, environmental or external loading conditions through systems with embedded actively controlled kinetic mechanism (Zuk & Clark, 1970).

In the last decade, computational platforms of operation and real-time performance simulators provided robust visualizations associated with geometrical digital design and numerical analysis models. In parallel, advances in material design and kinetics on the technological side, and increasing concerns about sustainability of the built environment, provided a background for emerging transformable architectural-engineering solutions, such as deployable tensegrity and scissor-like systems (Escrig, 1985; Pugh, 1976). However, in the majority of examples developed and implemented so far, the resultant system transformations are limited between a 'closed' and an 'open' state. In cases where actual transformability is aimed at, the systems rely on embedded computation and mechanical actuators. Such mechanisms often lead to an energy inefficient and complex kinetic behaviour.

In providing multiple possible target configurations, flexibility and controllability, two classes of rigid-bar linkage structures with either direct or cable-driven actuation have been investigated by the authors in simulations and experimentally (Phocas et al., 2019; 2020). The kinematics of the planar systems are based on the 'effective crank–slider' (ECS) and the 'effective 4–bar' (E4B) concept, whereas the transformation of the structure takes place over successive reconfiguration steps of an externally one degree-of-freedom (1-DOF) mechanism. In extending the kinematics concepts, the present paper presents a transformable spatial structure of rigid-bar linkages. The kinematics and control concepts rely on a reduced number of actuators, positioned at the supports and detached from the main structure body, aiming at maintaining minimum self-weight, structural simplicity and reduced energy consumption. The multistep transformation process followed, provides a number of reconfigurations, i.e., transitional transformation phases, in achieving any target configuration of the system. By extension, the building comprises a dynamic space of adaptation and transformation and may provide increased performance and interaction.

The Architectural Perspective and Industrialization

Initial architectural concepts featuring flexibility derived from industrialization, mass production, prefabrication and modularity in providing reversibly assembled, adjustable and mobile components. Indicative is the preceding work by Buckminster Fuller on the geometrical laws of geodesic domes (Hays & Miller, 2008). Topologies for spherical shell structures were developed that allowed the use of as many identical beam and node elements as possible (Krausse & Lichtenstein, 2000). Similarly, Konrad Wachsmann advocated an industrialization of the building (Wachsmann, 1989). In this frame, mass production meant the embodiment of a virtual system of modular coordination whose components would fit together harmoniously and provide a high degree of refinement and precision, as well as the integration of all the equipment necessary for 'perfect environmental control'. The principle of industrialization also implied all kinds of changes to the methods of procuring buildings, and it meant the transfer of the primary location of building production from the building site to the factory, such that all building elements would be prefabricated in the factory and then just assembled on site. On-site assembly meant that new technologies for joining individual building elements together would have to be invented, and these would need to be both functionally and financially efficient. Thus, the invention of joints became a key feature within the concept of industrialization. In support of this background, in the frame of an international Colloquium on Adaptable Architecture from June 10 to 15 in 1974, held by the Institute for Lightweight Structures of the University of Stuttgart, Konrad Wachsmann stated in his lecture titled 'Building is energy and motion in time and space' that "Building is assembly and should also be disassembly and reassembly… The issue is to apply energy recourses to new scales by new means and new processes, leading to the production of industrialized assembly components, joined in universal systems of any combination… Innovation, research and development are not anymore only embodied in planning and designing buildings or structures as the 'endproduct'. The endproduct is the 'by-product' and therefore a second generation and certainly an incident of subjective outside circumstances. Material and method of the process determine form and function of the increment – the component and subsequently the assembled space and volume configuration" (Burkhardt & Hennicke, 1975). This process referred to every stage of production, material handling, as well as the product itself and assembly.

Architectural designs involving transformability and adaptability, referred primarily to a high degree of flexibility entailed in the functional disposition and operation of the buildings. Principles of an industrialized planning were applied, whereas the building product was hierarchically organized with regard to the primary skeleton structure and the architectural elements that could be freely arranged in relation to the former. In particular, the space frames explored by Eckhard Schulze-Fielitz and Yona Friedman followed these architectural design principles (Banham, 1976; Fiel, 2009; Klotz, 1986). A universal steel framework system would permit high flexibility and spatial appropriation by being adaptive and functionally versatile to any activity and to most forms. Central to the concept was the realization that architecture form is an evolving process, using a set of interchangeable, integrated components. Architectural elements could be added together in alternative combinations, interchanged and replaced by improved components. The latter allowed the introduction of new products through a constantly evolving technology. Therefore, the building form could evolve as the functional requirements changed, and at the same time, new technological and design developments could be employed.

Furthermore, the awarded project of Stadt Ragnitz by Günther Domenig and Eilfried Huth in 1963, was based on a similar syntax of design enhancing flexibility, changeability and adaptability. The utopian ideas of the urban space emerged primarily from the information theory, cybernetics and biology, mainly from the self-sufficient living organism (Wilhelm, 1996). The idea of a network of modularized capsule units plugged in an open framework enabled automation of the inhabitant's life, while more space was available for leisure activities and green areas (Klotz, 1986). In particular, the concept of changeability had been mostly explored by the Metabolists and Archigram. The Metabolists essentially perceived the city as a process of dynamic transformation caused by many urban problems, such as overcrowding, poorly planned urban infrastructure, loss of green areas, environmental and planetary issues. A new urbanism was suggested based on the central idea of metabolism, namely, designing buildings as living organisms capable of constant processes of metamorphosis, adaptation, and evolution (Gardner, 2020). Metabolists' emphasis on change was influenced by the life cycles and the development of building technologies, especially of prefabrication and standardization. In this spectrum, the Metabolists focused on a highly flexible relationship between the structural system and the functional prefabricated capsules with shorter duration that could be moved or replaced (Lin, 2010). On the other side, conceptual explorations by Archigram were interrelated by a number of mechanically, electrically and cybernetically controlled systems. The designs consisted of a primary skeleton structure that also carried the mechanical services, and expendable components, i.e., accommodation capsules conceived as industrial design objects, which could be clipped-on, or plugged-in, removed, or replaced from the main structure. Included in the capsules were clip-on accessories, such as kitchens, bathrooms and wall units, which could be replaced or substituted more frequently and at different time intervals than the capsule itself.

The Engineering Perspective and Lightweight Structures

The development of the Olympic Stadium in Munich, 1972 and the Mannheim Multihall, 1975 is strongly interrelated with transformability throughout the analytical simulation and erection process respectively (Phocas, 2017).

The development and realization of the lightweight structure of the Munich Olympics-Arenas led historically to the first large-scale computer applications. The finite-element method was expanded and applied for the first time internationally for the design, development and analysis of the long-span structure, making the realization of the original 'architectural vision' feasible (Argyris & Kelsey, 1960). In principle, computational analysis of lightweight structures encompasses each individual element with a unified calculation process. At the particular time of the project development, the investigated form of the structure was, at first, approximated and then numerically improved, until equilibrium at the required prestress level was achieved. In general, the origin can even be a flat net that is prestressed between fixed points in plane. The fixed points are then shifted vertically for bringing the net in a spatial curved shape. The calculation is nonlinear due to significant modifications in the net geometry. The prescribed displacements annul the equilibrium state of the cable forces. Therefore, for every displacement state of the supports the related equilibrium form of the prestressed net is iteratively investigated. The procedure can also be described as the numerical simulation for a stepwise hanging of the net from the origin plane. The design and analysis take into consideration the entire transformation process, from the planar to the form-found state.

In contemporary terms, kinematic lightweight technical textiles may even convey the above-mentioned design and analysis process in physical terms. In kinematic form-active membrane structures, the membrane would need to be properly tensioned in a defined range of stages of the transformation, in order to carry external loads independently of the geometrical configuration of the system. A related research project on the design and experimental validation of a kinematic membrane structure, which remains tensioned during the transformation between different configurations by taking advantage of the out-of-plane flexibility of the material rather than the high stretchability is documented in (Puystiens et al., 2016; Van Craenenbroeck et al., 2016).

Following comprehensive investigations conducted by Frei Otto on the concept of elastic gridshells (Liddell, 2015), the prototype structure of the Manheim multihall demonstrated that strained gridshells, based on the use of elastic members, enable a unique and ingenious way in achieving adaptation in form (Burkhardt, 1978).
While the structural shape was approximated through modelling of its funicular, it was the actual erection process of the structure that followed a transformation process of the members, from the planar to the formfound state. The structure was assembled in planar state on the ground and bent based on the 'push-up' technique, in order to obtain its overall shape. Recently, owing to developments of structural materials, construction processes and computational design tools, strained gridshells are extensively studied and constructed in achieving variability in form and reduction of construction cost (Douthe et al., 2010; Harris et al., 2008; Liddell, 2015) through further construction techniques, among others, the 'pull-down' and 'pull-up' technique, applied via the use of scaffolding infrastructural support, cranes and robes, or large inflatable balloons installed beneath the non-deformed grid, forcing the overall assembly to deform and reach its target shape (D'Amico et al., 2015).

Elastic gridshells are also promising in terms of shape adaptation and reuse of the structure for different purposes. By integrating linear actuators in bending-active gridshells, multiple shapes can be derived. In the example of the Hybgrid adaptable system, adaptivity derives by pairing the continuous elastic planar strips with strut actuators. The curvature of the strips alternates by changing the length of the struts. In the '2 Landscapes' pavilion, six telescopic bars provided translational and rotational motion to the overall gridshell system (Filz & Naicu, 2015). Further examples of actively controlled systems comprise an adaptive bending-active plate gridshell, whose configuration is actively controlled by telescopic bars interconnecting the elastic strips and cables of variable length connecting the supports (Phocas et al., 2018), as well as a reconfigurable one, based on actively controlled elastic members and cable segmentations (Anastasiadou & Phocas, 2020; Phocas & Alexandrou, 2018).

Active Structural Control

An actual turn towards the realization of kinetic structures was achieved through research and application of active structural control concepts. William Zuk and Roger H. Clark demonstrated already in 1970 with their book publication on 'Kinetic Architecture', the necessity for an architecture that is not static; instead, it has the ability to adapt in time changes through systems with embedded actively controlled kinetic mechanisms (Zuk & Clark, 1970). The active control concepts proposed by Zuk and Clark, were directly influenced by respective advances in aerospace and mechanical engineering (Yao, 1972). As correctly stated by the authors in the preface of the book with regard to the rather conceptual nature of the proposals made within, "The book is a compilation of existing pertinent material on adaptable architecture furthered by some new ideas for the future. The concepts discussed in the book are evolutionary and are based upon reasonable predictions of trends. The newness of many of the applications to architecture has required that we make use of developments in other areas normally placed outside of architecture. However, by its very nature the book is incomplete, as the process of change is ongoing and unending, and technological developments, as well as explorations into adaptable architecture, are multiplying". Architectural form was envisioned to be free to adapt to changes that take place within the set of pressures acting upon it and the technology that provides the tool for interpretation and implementation of these pressures. Thus, the architect was expected to provide a range of forms capable of meeting a range of input requirement changes.

The specific publication is considered as a significant milestone for the advancement of the design philosophy of kinetic architecture, aiming at the development of timely adaptable systems as to differing functional or external loading conditions, and leading to buildings and components with variable mobility, location, or geometry. Especially significant in terms of the kinetic operability is the development of the structure in two aspects: The structural mechanism that enables different geometrical configurations of the components through among others, folding, sliding, expanding and transforming in size and shape, and the control system that directs the structure towards specified transformations, through pneumatic, chemical, magnetic, natural or mechanical processes. The publication provided a general overview in the area following a respective classification into dynamically self-erecting structures, reversible, incremental, deformable, mobile and disposable architecture.

Transformable Structures

Computational platforms of operation and real-time performance simulators provide meanwhile robust visualization and feedback features associated with digital design modelling and automated numerical analyses. In this frame, design developments at various stages encompass parametric investigations with regard to the form, material and structure. Such iterative steps of design, analysis and optimization effectively bridge architecture with respective performance disciplines concerned; designing thereby becomes interdisciplinary towards form-generating processes, and prototype structures with actual transformability are developed. Different typologies and mechanisms have been developed in recent years for architectural and other engineering applications, primarily in relation to deployable, temporary structures (Fenci & Currie, 2017). Proposed solutions include tensegrity (Djouadi et al., 1998; Pugh, 1976) and scissor-like systems (Escrig, 1985; Gantes, 2001; You & Pellegrino, 1997).

Transformability in tensegrity systems is discussed in (Adam & Smith, 2008; Motro et al., 2001). A prototype example of structural joints' activation for obtaining controlled flexibility is the 'Kinetic Tower', a development of the movable guyed mast vision of Frei Otto (Kilian et al., 2006). The resulting outrigger system of rhomboid shaped core units and vertical interconnecting tension-only members provides different spatial bending shapes through integrated dampers at the joints. In the prototype of the 'Muscle Tower' of six actuated trapezoidal vertically positioned tensegrity units, the actuators are in place of the tension members (Hwang et al., 2006). The structure demonstrates high flexibility due to possible elongation, shortening and rotation of the units. An adaptable structure with integrated hydraulic actuators as primary diagonal compression members comprises the planar truss with lower horizontal elastomeric tubes, presented in (Merali & Long, 2010). Further developments in this direction are the Variable Geometry Truss, a planar or spatial member structure with embedded hydraulic actuators (Miura & Furuya, 1985), an adaptable aluminium tensegrity structure presented in (Sterk, 2003), and a tetrahedral truss with a number of actuator diagonals of shape memory alloy (Sofla et al., 2009).

The use of special elements for achieving increased variability in scissor-like system configurations is proposed in (Akgün et al., 2010; 2011; Hoberman, 1993; You & Pellegrino, 1997). A novel design method that explores the generation of double scissor-pair transformable structures is documented in (Rosenberg, 2009). The method has been experimentally demonstrated based on physical prototypes actuated using sensory-motor control. A new spatial scissor-like component with ball joints is proposed in (Novacki, 2014). The mechanism is modular and enables the linear structure to have a versatile support system with a high pack size and at the same time be highly transformable. The design of transformable hyperbolic paraboloids and doubly-ruled surface structures based on 2-DOF scissor-like mechanisms is included in (Maden et al., 2015). Multiple doubly-curved geometries may be obtained with a smaller number of bars and joints when compared to existing designs.

In all above-mentioned developments where transformability is aimed at, the systems rely on embedded computation and the replacement of primary members with actuators. Unavoidably, the employment of actuation components on the primary structure often leads to increased structural weight, complex mechanisms and energy-inefficient operation.

Bar Linkage Structures

Enhanced flexibility with regard to the transformability of the structure may be provided through lightweight components and modularity. In this respect, kinematics and structural control constitute main pillars for the formulation of an informed design strategy. Linkage-based systems, which comprise continuous series of onedimensional, rigid bars interconnected by lower-order pairs (Thrall et al., 2012), constitute promising systems towards the development of deployable and reconfigurable modular structures with enhanced shape flexibility and controllability. In previous years, the kinematics of deployable and reconfigurable rigid structures composed of a series of multi-bar linkages, with either direct or cable-driven actuation have been investigated in simulations and experimentally (Christoforou et al., 2015; 2019; Matheou et al., 2018; Phocas et al., 2015; 2019; 2020). In the hybrid typology, the primary members are supported by a secondary system of struts and continuous cables of variable length. Thus, the operability of the structure arises primarily from the inherent integrative composition and the dual capabilities of the secondary system with regard to the system's stability and kinematics. The structural concept involves parallel-connected planar linkages, whose intermediate joints are equipped with brakes (e.g., electromagnetic, hydraulic or pneumatic brakes). The operation of the brakes of each planar system is linked to the control system, which receives input from the position sensors (e.g., optical encoders or potentiometer-type sensors) installed on the joints.

Deployment and reconfigurations of a planar system with a pin and a sliding support connected to a linear motion actuator, i.e., 'effective crank–slider' (ECS) mechanism, take place through an appropriate control sequence of stepwise reconfigurations, Figure 1a. In the hybrid typology, a linear motion actuator is connected to each of the cables and brakes are installed on the sliding support. Similarly, reconfigurations of a pin supported planar system connected to a linear or rotating actuator are based on the 'effective 4–bar' (E4B) mechanism, in order to stepwise adjust the system joints to the desired values, Figure 1b. In the hybrid typology, the actuation succeeds by a linear motion actuator for each of the cables. The kinematics approaches require a minimum number of actuators, positioned at the supports and detached from the body of the main structure. Thus, minimum self-weight, structural simplicity, and reduced energy consumption are achieved.

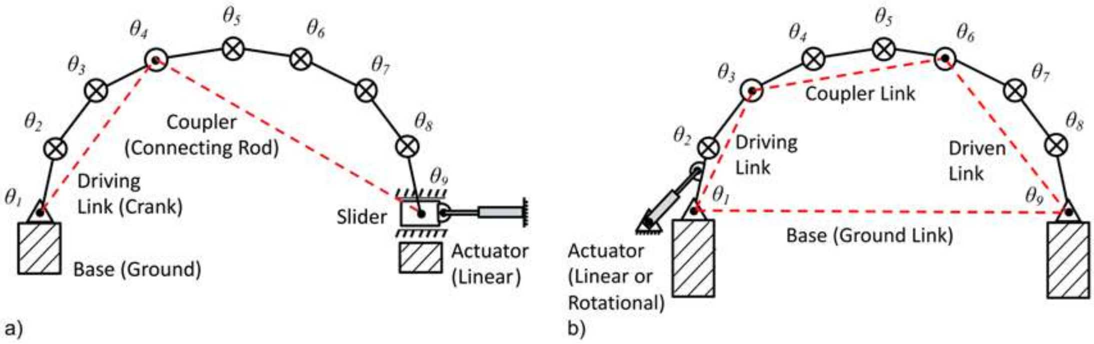

Figure 1. Kinematics approaches for stepwise reconfigurations of a planar system with multiple serially connected rigid links (⊗: locked joint, ⨀: unlocked joint, △: pivoted–to–the-ground joint, □: slider joint, —: physical link, – –: effective link): a) ECS reconfiguration approach; b) E4B reconfiguration approach.

Transformable Gridshell

A spatial structure of hollow circular section serves as a case study in the present paper, Figure 2. It consists of eight pairs of eight bar linkages, radially arranged on each side. The primary linkages consisting of 1.75 m long individual bars are joined in series and interconnected through peripheral links of variable length; the structural members consist of round hollow aluminium profiles of 168.3/6.3 and 101.6/4 mm, respectively. Continuous diagonal cables of 20 mm diameter and variable length provide the structural diaphragm.

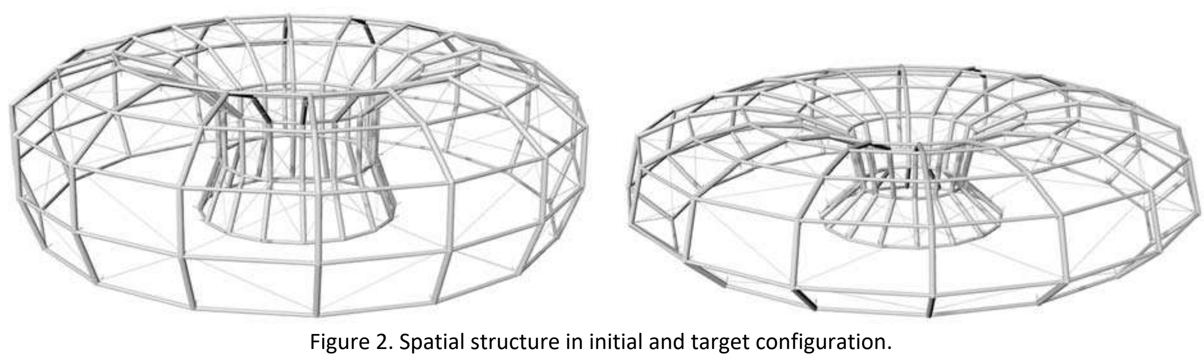

Figure 2. Spatial structure in initial and target configuration.

The building envelope should enable lightweight of the material, structural efficiency, and have exclusive elastic deformations during transformation without stress interactions with the primary structure. In addition, the envelope structure is required to be flexible in order to accommodate for cases of dissimilar configurations assumed by any adjacent actuated multi-bar linkages. An THV-membrane, Terpolymer of Tetrafluoroethylene-Hexafluoro-propylene-vinylidene fluorid, is to be supported on a dedicated secondary structure rather than being directly affixed to the members of the primary structure.

The actuation of the spatial system is simplified, based on the hierarchy of the elements; the linkages in radial directions are the ones activated, whereas the peripheral connecting links act as passive ones. During transformation, the passive links adjust their length according to the active joints' position. Application of the basic reconfiguration approaches to the spatial structure involves coordinated shape adjustments performed on each individual actuated planar linkage. Accordingly, four joint variables of each actuated linkage are determined in each reconfiguration step for the reduction of the system to a 1-DOF mechanism, based on an off-line planning procedure (Norton, 2008). Different feasible motion sequences are possible and a favourable one may be selected, based on specific kinematics and static response criteria. Once a motion sequence is selected, a control system manages in each reconfiguration step the operation of the individual brakes on the joints. In the case of nonsymmetric reconfigurations among the active linkages, the control system may also coordinate the reconfiguration of the overall structure by considering the relative motion of the adjacent actuated linkage systems and possible interferences. The completion of the required reconfiguration steps allows the system to obtain the target configuration. All supports are then locked to act as pin connections to the ground.

In the specific example, the structure is symmetrically transformed from an initial to a target shape of same span to demonstrate the proposed reconfigurations following both kinematics approaches. In its initial configuration of a double quasi-paraboloid elevation shape, the structure has a span of 4.90 m and a corresponding height of 4.96 m on each side; in its target configuration of a double quasi-ellipsoid elevation shape with same span, the structure obtains a height of 3.60 m on each side. The inner circular open area has a diameter of 6.0 m. The initial and target configurations are defined by the following vectors, which include the internal joint angles: $\theta_{i,8} = [111, 158, 130, 157, 148, 157, 130, 158, 111]^T$; $\theta_{f,8} = [141, 115, 125, 165, 168, 165, 125, 115, 141]^T$ degrees. Two different motion sequences of the system have been applied corresponding to the kinematics approaches of the ECS and E4B, based on the maximum break torques developed throughout the transformation of the system, Figure 3. The corresponding reconfiguration steps of the building structure for each kinematics mechanism applied are shown in Figures 4, 5.

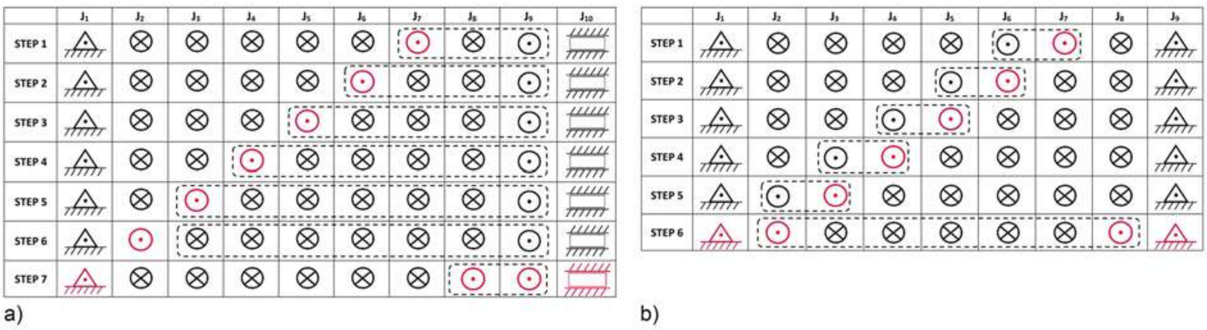

Figure 3. Scheduling tables for the ECS and E4B control sequences realizing the required shape adjustment on the linkages with eight serially-connected members (⊗: locked joint, ⊙: unlocked joint, △: pivoted–to–the-ground joint, □: slider joint). Dashed-line encirclements denote the effective coupler links. The red-coloured symbols represent the currently-adjusted joints: a) ECS Sequence; b) E4B Sequence.

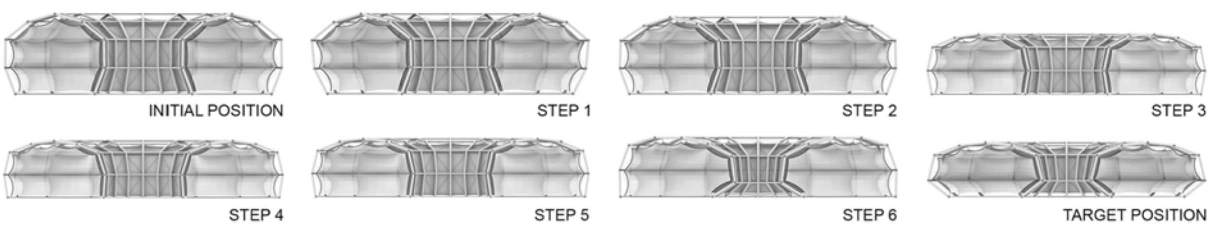

Figure 4. Building structure sections of the transformation steps based on the ECS kinematics approach.

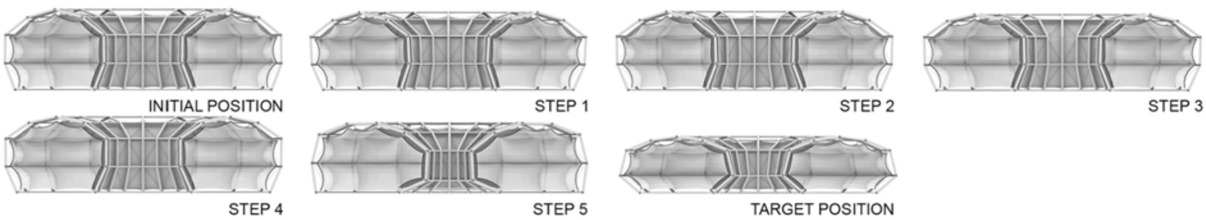

Figure 5. Building structure sections of the transformation steps based on the E4B kinematics approach.

The composition of rigid-bar linkage structures, i.e., multiple bars and interconnecting joints that can be individually locked or released, and the multistep reconfigurations applied based on the externally 1-DOF kinematics mechanisms, provide various levels of control flexibility and transformability. Consequently, the feasible design space increases substantially in terms of the capacity of the structure to undergo transformations and its interaction potential with the users, functions, external loading, environmental or energy conditions. Thus, not only the respective final reconfiguration step provides the structure with its respective final form, but also intermediate configurations obtained throughout the transformation process may also constitute structural forms of specific operational time for the building, Figure 6. Thus, the reconfiguration approach allows the form to continually evolve through a whole sequence of form transformations.

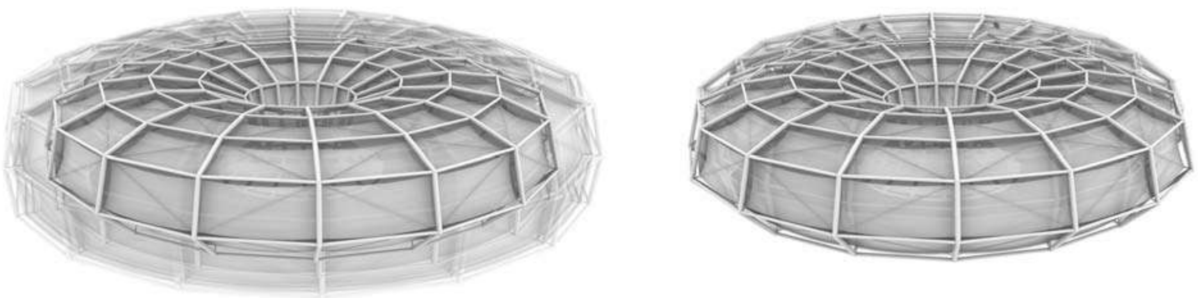

Figure 6. Spatial structure transformation shapes sequence based on the ECS and E4B kinematics approach.

In establishing a suitable framework of transformability, architectural criteria are closely related to the transformation rate of the system. While slow transformations are required by functional, environmental and energy input criteria, fast transformations are required by external loading input criteria, as well as in interactive environments that entail more ‘arbitrary’ intermediate and target structural forms and promise intense experimental and experiential experience to the users. Furthermore, motion planning plays a significant role with regard to the definition of the structural configurations and the motion path followed towards any target position specified. Engineering criteria relate among others, primarily to the maximum internal forces and brake torques magnitude, and the energy consumption for the operation of the actuation system. These criteria are favoured by shortest possible motion paths of the system. A short motion path means that configuration positions with large excursions of the system’s center of gravity are avoided, as well as singular configurations, which affect the kinematics and the actuation effort. In all cases, the nature and operability of the transformable structure requires a shift in the designers’ aims and objectives; the architect is no more designing one form, but an entire range of forms that develop in interdisciplinary context, throughout further configuration flows and motion processes.

Conclusions

The present paper examines recent notions of transformability in architecture and engineering. Initial concepts of transformable structures in architecture referred primarily to flexibility in standardized construction and the capability of the spatial skeleton structure to accommodate different functional dispositions. The architectural elements consisted of industrialized components that could be interchanged and integrated within the primary structure. In following, actual transformability has been achieved in the design, analysis and erection of lightweight long-span tensile structures and strained gridshells of elastic, reversibly deformable members. The example of the tensile cable-net structure of the Olympic Stadium of Munich enabled through the development and application of the finite-element analysis, is representative of a subsequent initiation of automatic form generation. In parallel, the realization of the Mannheim multihall entailed adaptability in the form-finding and the actual erection of the gridshell structure through utilization of the elastic properties of its timber members. Further advancements in aerospace and mechanical engineering gave ground for active structural control concepts, but most importantly for the objectives formulation of an architecture that has the ability to adapt in time changes through systems with embedded actively controlled kinetic mechanisms, as encapsuled in the book publication on 'Kinetic Architecture' by William Zuk and Roger H. Clark. Computational platforms of operation and real-time performance simulators provide meanwhile robust visualization and feedback features that can be associated with digital design modelling and automated numerical analyses. In this framework, different typologies and mechanisms have been developed, primarily in relation to deployable structures. The development of the systems to acquire kinetic capabilities succeeds through the replacement of primary members with actuators. Unavoidably, this leads to increased structural weight, complex mechanisms and energy-inefficient operation.

The paper concludes with a presentation of two classes of rigid-bar linkage structures that aim at reconfigurability with maximum flexibility, controllability and reduced energy consumption during operation. The underlying kinematics principle refers to the reduction of the linkage system to an externally controlled 1DOF mechanism in each reconfiguration step of the motion sequence from an initial to a target position of the system. Two related kinematics mechanisms have been applied on a spatial structure of hollow circular section and rigid-bar linkages. The case study demonstrates the high degree of control flexibility and transformation potentialities of the system. Multiple forms can be obtained according to specific criteria followed; moreover, passing through intermediate configurations in achieving the target one means that the form continually evolves through an entire sequence of form transformations. Thus, motion prevails over the static form.

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Tall Timber Architecture: An Opportunity for Green Building as Mjøstårnet

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Abstract
Construction sector greatly affects the increase of CO2 in the atmosphere. Therefore, it is necessary to look into renewable and sustainable construction materials. Construction of tall buildings has increased rapidly in 20th century, they consume a lot of energy in their construction process and the subsequent building usage might be related to climate change. This paper focuses on whether timber might be used as a single material for tall building structure system, or not. In this study, the advantages and disadvantages of using timber as a construction material are being examined. In addition, the economic, social, and environmental impacts of timber usage are also being discussed. The methodology of the research is based on the case of "Mjøstårnet" which is a completed timber tall building in Brumunddal, Norway. According to the CTBUH database of timber tall buildings' list, the Mjøstårnet building is the tallest completed timber building with 85m high. The study discusses the usage possibilities of timber material, its construction structure and its effect on the environment

Keywords: Timber architecture, timber tall buildings, Mjøstårnet

Introduction and Literature Review
Although examples of the tall structures were already seen in structures such as pyramids, temples, mosque minarets, church bell towers, water towers, lighthouses, castles, and clock towers since the first civilizations, clearly defined tall building examples in architecture began only after the second half of 19th century during the industrialization period. The important factor in the development of tall buildings is the industrialization process and the use of new building materials such as iron, steel, and glass. In architecture, tall buildings could be built with the production of iron and steel frames and the invention of hydraulic elevators. After these developments the number of tall buildings increased rapidly in America and in the last quarter of the 20th century they have been built in a lot of different countries, especially in the far Eastern countries. According to the "Council on Tall Buildings and Urban Habitat (CTBUH)" database, while the first tall building is the 55 m high "Home Insurance Building" constructed in 1885, the recently completed "Burj Khalifa" in Dubai is the tallest with a height of 828 m.

On examining the tallest 100 buildings in terms of building materials, according to the CTBUH database, it is determined that 59 of the buildings are composite, 29 are concrete, 8 are steel and 4 are mixed structures of steel and concrete (CTBUH). CTBUH has classified these material qualities into main vertical and lateral structural elements. Currently, tall building's structures can be classified into three categories - single material system, composite system and mixed material system (figure 1). A single material system has the main structural elements of tall buildings constructed principally from a single material like steel, concrete and timber. Composite tall buildings have combinations of all different materials for main vertical and lateral structures. In figure 2, the composite building has a concrete core and limited steel, or timber framing system. Finally, a mixed material building has different levels of buildings having different single material structure systems. For example, a building structure is formed with a full-height concrete core, a lower section of steel framing and an upper section of timber framing (Foster, Ramage, and Reynolds, 2017).

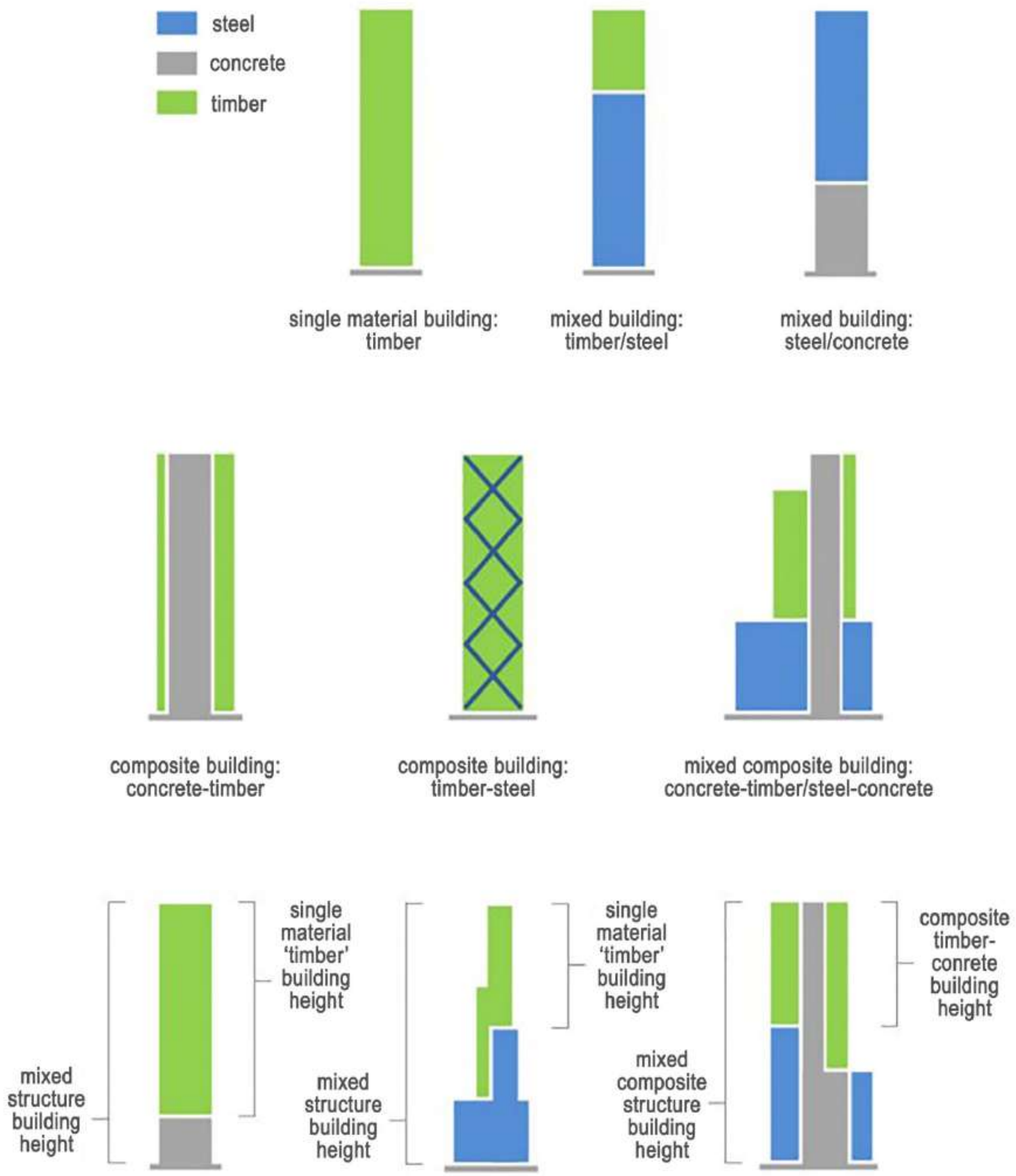


Figure 1. Example of building typology by structural material (Foster, Ramage, and Reynolds, 2017).

Considering all of these, it is being questioned if tall buildings can be built with a different structural material other than steel and concrete? Besides, it has aroused curiosity that whether timber is the proper single material for constructed tall buildings. Although timber has been used as a natural building material since ancient times, there are limited single-material timber buildings. Also, timber is a natural and renewable material and easy to form. Designers have planned to use engineered timbers to cope with direct permanent vertical loads and lateral loads for taller buildings structure systems. Thus engineered timber materials such as glued-laminated timber (glulam), cross-laminated timber (CLT), and laminated veneer lumber were produced for enhanced dimensional stability. Due to the environmental effects on the timber, engineers try to improve the strength of this material. Moreover, thanks to cross-laminated timber (CLT), designs were produced easily and the structure was built quickly and easily with a small team of workers. Thus, timber is a suitable construction material. Architect Joseph Mayo author of "Solid Wood: Case Studies on Mass Timber Architecture, Technology, and Design," expressed that timber is not just a more sustainable choice, but also less carbon-intensive to produce than other materials like steel, aluminum, and concrete (Mayo, 2015).

Advantages of Timber as a Green Building Material in Tall Buildings

Timber is a "green" building material that benefits both the environment and the society. Its availability, workability, environmental sustainability, the flexibility of space arrangement, dry construction, industrial production and comparative cost-effectiveness helps the construction industry (Gregory, 1984; Nolan 1994 and Whitelaw, 1990).

Sustainability, Availability and Acceptability

With the climate crisis, the importance of natural and renewable building materials has increased. At this point, most countries that signed the Paris Climate Agreement have increased their bio-economic development, timber use and forestry activities. Forests can play an important role in the transition to low-carbon economies and in creating a sustainable environment because they are carbon accumulators and wood products have a lower embodied energy than other products, particularly in the building sector, which accounts for 36% of global energy consumption and 39% of CO_2 emissions (UN Environment, 2018). Forestry activities are sustainable because new trees can be added to replace the trees cut for timber use. By using timber as construction material, we conserve forest ecosystems and consequently sustain forest ecosystem services such as water purification, water flow regulation, erosion control, streambank stabilization, carbon sequestration, biodiversity, recreation and cultural heritage values (Ritter, Skog, & Bergman, December 2011). Thus, the use of timber is a sustainable material for the bio-economy, the environment and humanity.

Since timber is a local material in many countries, it is acceptable and accessible. It has been used in architecture since the past and is easy to transport and use. Thus, the use of timber in tall buildings can make them sustainable. In addition, the use of timber in construction reduces the CO_2 emission of tall buildings and supports forestry improving the environment where the building is located.

Workability and Versatility

Timber is one of the most adaptable materials used in the construction industry due to its strong load-bearing capacity. Furthermore, it may be bent easily into any shape, joined to other materials. It is resistant to the elements and can sustain harsh weather conditions. In addition, by selecting timber with the appropriate density, compressive and tensile strength, colour, texture and fire resistance, applications can be more flexibly matched (Anderson, 1970). Furthermore, timber is a durable and workable material for constructing tall timber buildings that are nearly 85m tall. In addition, engineers and architects have worked with timber material for tall buildings structures 300 m high.

Physical and aesthetic qualities

Timber is a popular framing material because of its excellent strength-to-weight ratio. Some timbers are extremely resistant to decay, corrosion and harmful effects of the sea. Also timber, unlike other building materials, can endure corrosive salt and humidity with a little structural alteration. It is extremely durable, and there are varieties of finishes available to maintain and enhance the material's natural beauty. (Sturges, 1991). Moreover, it is a warm and aesthetic material for both, outdoors and indoors. Thanks to lots of texture, colours and patterns, timber has aesthetic qualities tall buildings differ from concrete and steel.

Cost-Effectiveness

In terms of construction cost, as tall buildings are built in large numbers and at high costs, the use of timber supports the bio economy and circular economy through sustainable forestry. Bio economy, circular economy, land use reduction, sustainable use of natural resources, reduction of CO_2 emissions in the atmosphere and recycling are the buzzwords that the construction industry must confront soon, as the climate emergency cannot be postponed any longer. In this regard, the use of wood as a building material can provide an immediate solution to the problem (Sposito and Scalisi, 2019).

Timber is a renewable, sustainable material and ıt is a very useful for bio economy, circular economy and environmental recovery. The usage of timber in construction supports healthy and sustainable forestry. Therefore, forests recover the environment because they decrease CO2 and increase O2 in the atmosphere. Furthermore, it is the natural habitat for lots of living things so that biodiversity is increased.

Disadvantages of the Usage of Timber In Tall Buildings

Although timber is advantageous for sustainability, there are many problems due to its organic structure. They are: shrinkage and swelling, lack of quality control, insects, fungi and vermin attack, fire resistance, depletion of natural resources and insufficient research. However, most engineers and architects have worked on the development of timber materials and tried to solve many problems.

Shrinkage and Swelling

Timber is a material that can shrink and swell due to its ability to absorb water. For this purpose, methods should be used that are not affected by the temperature in the stages of the timber.

Fire Resistance

Although timber is an environmentally friendly material, people are aware that timber burns and steel does not. This situation is the opposite since when a thick timber panel meets fire, the outer layer becomes charred and preventing the timber inside from being damaged. Unlike timber, which gets charred initially, metals melt at high temperatures. Furthermore, large cross-section timber (CLT), will retain its strength, and be more fire-resistant than other materials (Dagenais, White, & Sumathipala, 2012). For most timbers it ignites at 250°C to 300°C and chars at about 1mm at 900°C to 1200°C (Oyetola 2001). Large solid sections can survive longer in a fire than steel parts of comparable strength due to the charcoal that accumulates on the outside (Adedeji & Ogunsote, 2005).

The city of Chicago, which had the most timber buildings, was almost destroyed in a fire in 1871. After that concrete and steel were used building materials especially tall buildings in Chicago. Despite the bad situation in the past, timber developed and resists fire comparably to steel. Also, engineered timber structure does not burn completely, but steel structure melts.

Depletion of Natural Resources

Timber production necessitates the logging of forests. Trees are a finite natural resource and without a replanting program they will be depleted, causing environmental problems such as deforestation, desert encroachment, drought and erosion (Adedeji & Ogunsote, 2005).

Insufficient Research

Academic and scientific institutes place minimal focus on the use of wood in their research. Better funding of directed research and adequate distribution of research findings can solve the challenges linked with the use of timber (Adedeji & Ogunsote, 2005). Even though the government has invested so much in new technologies and product development for other materials, wood has received relatively little funding. Inadequate education, technology transfer and promotional projects prevent timber from being accepted as a "green" building material. The health and vitality of our forests and the important role of timber in mitigating and protecting climate change are not accepted by most authorities and the public (Ritter, Skog, & Bergman, December 2011) However some universities support the research to use timber in tall buildings. To illustrate, the University of Cambridge at the "Centre for Natural Material Innovation" to carry out tall timber building.

Despite many problems of timber usage, it is a beneficial material for "green", sustainable construction methods. In addition, engineered timber and manufactured timber has been developed and in the near future timber will be the most preferred material for sustainable construction especially for the tall buildings.

As a case: Mjøstårnet

Currently, there are 3 completed buildings, 12 proposed buildings, and 18 vision buildings in CTBUH timber tall buildings list. Vision buildings are purposed 300 m tall timber building, which is "Oakwood Tower" in London. According to the council of tall buildings and urban habitat, the Mjøstårnet with 85 m tall is the world's tallest timber building. Thanks to the work of building designers and engineers from around the world, in 2019 Mjøstårnet building, which is an 18-storey with 85 m tall, was built in Brumunddal, Norway and near the lake of Mjøsa. In addition, "Mjøstårnet" in Norwegian language means "The tower of Lake Mjøsa". The mixed-use building contains offices, a hotel, apartments, a restaurant, a swimming pool and a roof deck on a net area of 11300 m^2.

Figure 2. Mjøstårnet, in Brumunddal, Norway (Arcdaily, 2021).

This building designed by Voll Arkitekter Arthur Buchardt was the driving force behind Mjøstårnet 's creation. His ambition for the project is for it to be a symbol of the “green” shift, demonstrating that big structures can be constructed utilizing local resources, local suppliers and sustainable wood materials. (Abrahamsen, 2017). This building is made from about 3500m^3 of timber or about 14 000 trees. Thus Healthy and sustainable forestry are very important. In addition, Brumunddal is famous for its forestry and wood processing industry.

Considering obtained as a result of the examination of the Mjøstårnet building for the use of timber material; The main load-bearing consists of large-scale glulam trusses and also CLT walls are used for secondary load bearing of three elevators and two staircases. Besides high capacity connection, all glulam structures are connected by slotted-in steel plates and dowels installed. Then all glulam surfaces have been painted with varnish to protect the timber from rain and sun (Abrahamsen, 2017).

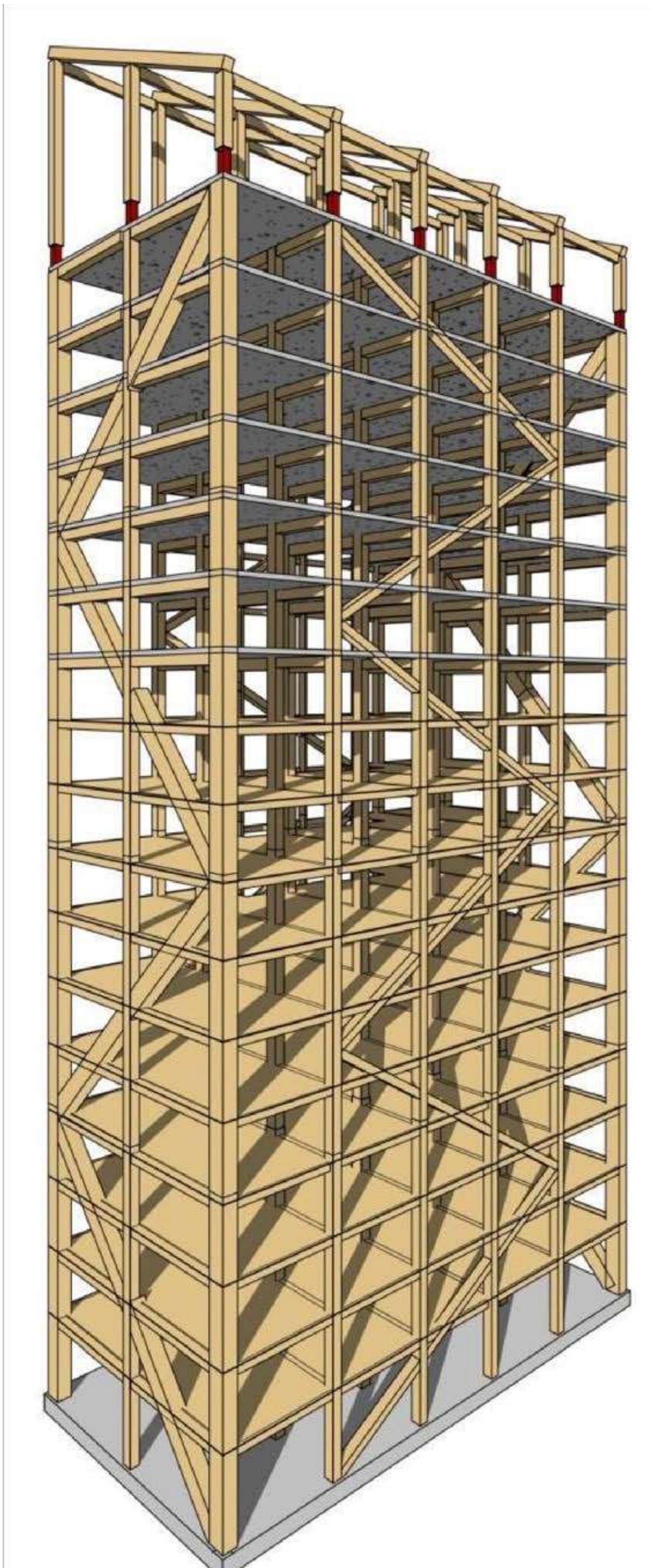
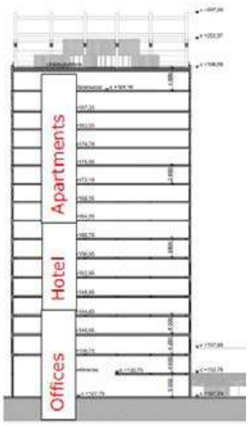


Figure 3. Example of a building typology by structural material (Abrahamsen, 2017).

Table 1 Pros and cons of timber usage for Mjøstårnet

Timber Structure Glulam Beams And Columns Glulam Trusses Typical glulam beams supporting timber floors are 395x585 mm2 and 395x675 mm2. Typical glulam beams supporting concrete floors are 625x585 mm2 and 625x720 mm2. The largest diagonal cross-section is 625x990 mm2.	
Timber Waals And Floor CLT Walls Timber Floors Installing Prefabricated Elements On-Site All Glulam Surfaces Have Been Painted	
Roof Pergola System On The Roof Apartment The Pergola It Is A Large Wooden Structure That Is Fixed To The Concrete Deck On Level 18.	
Offices, Hotel, And Apartments Multi-Purpose Mix Usage Large, Complex Timber Building 18-storey The net area is 11300 m2	

Sustainability, Availability, And Acceptability Forestry Wood Processing Industry Norway's Leading Glulam Manufacturer	

Physical And Aesthetic Qualities Wood Is A Warm Material Decorative Staircase, Door Windows Natural, Organic Material A Lot Of Colour And Texture	
Indoor Aesthetic and Furniture Quality Decorative Colours And Texture Workability For Design Furniture Harmony Of Wood Structure, Plaster And Paints	
Shrinkage And Swelling Water Proof Use Swimming Pool Area Warm Material Effect Natural Aesthetics	

Fire Resistance Large Glulam Columns Are Durable Prevent A Building From Collapse	
Depletion Of Natural Resources Healthy And Sustainable Forestry Not A Blueprint For A Tall Timber Structure Long-Term Sustainability	

Conclusion

To deal with the climate crisis, the ultimate design should be based on bio economy, circular economy, increasing biodiversity, creating the ecosystem, usage sustainable raw materials. Thus, producing timber from sustainable forests and using timber for construction is an urgent issue for the environment. Timber buildings especially tall timber buildings require a sustainable forestry industry and support new forest lands. The importance of using timber in construction is explained below.

- Using timber as a structural material is a very effective way to decrease emission CO_2.
- “Wood Processing Industry” produces glulam, CLT and if timber is sourced from sustainable forests, it is eco-friendly.
- Timber is a strong load-bearing system and organic, warm aesthetic material in both indoor and outdoor areas.
- Glulam manufacturing supports “green”, forestry areas resulting in an increase in biodiversity and a recovery of the ecosystem.
- Timber is a fire-resistant material and does not melt in a fire, preventing a building from collapse.
- Timber is a cost-effective construction material and hence benefits the national economy.
- Using timber develops bio-economy and circular economy.
- Timber is durable and workability of material making it suitable to build multi-purposed, mix used tall buildings.
- Tall timber buildings require healthy forestry and wood processing industry. Norway, United Kingdom USA, Brazil, China, Canada should build tall timber buildings taking advantage of their well-developed forestry industries.

In conclusion, innovative studies are ongoing for timber taller buildings, which are vision buildings at heights up to 80 stories *“River Beach Tower”*, Chicago and *“Oakwood tower”,* London. All these considering, while the material of the 20th century is steel and concrete, timber enhance its attractiveness as a 21st-century building material because of low carbon emission material.

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Comparing Biomimicry and Living Materials Approaches in Computational Design

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Abstract
Although biomimicry and living materials approaches are two important methodologies for integrating nature with computational design, they have not been explored, scrutinized and exploited, yet. In a view to alleviate this problem, this paper focuses on the study of comparing these approaches in the context of two case studies in 3D printing. The analysed projects were completed by important scholars in the field and represent best practices. Especially the reason for choosing these studies is that they express the difference of the methods used in sharp lines and they provide the opportunity to be compared with all the details thanks to the expertise of the institutes in which they are made by.

Keywords: Biomimicry, living materials, computational design, nature, additive manufacturing.

Introduction
Computational design can be defined as the application of algorithmic thinking and systems view in design processes. Since the early beginnings in 1970s, computational approaches have been very influential in the theory and practice of architecture and become a main driver of innovation in the field. As a complex, selfregulating and sustainable system, nature has always been a source of conceptualization and inspiration for computational design. The relation between biology and computational design can be traced back to Charles Darwin's theory of evolution (Darwin, 1964) which later led to explanations of variation (phenotype) among population with the same genetic material (genotype) due to environmental conditions (Mayr, 2001). The morphological works of D'arcy Wentworth Thompson is another inspiration for computational design. Thompson developed the "theory of transformations" which showed how the differences between the forms of related species could be represented geometrically. Both investigations have been influential in computational form-finding studies and facilitated the development of a new field called digital morphogenesis which stands for generative processes in which complex shape development, or morphogenesis, is enabled by computation (Menges & Ahlquist, 2011).

A review of studies at the intersection of biology and computational design reveals that their main approach has been based on analyzing, understanding and adapting nature's processes and designs i.e. biomimicry. In 1990s, Janine Benyus popularized the term "biomimicry" (from bios, meaning life, and mimesis, meaning to imitate) in her book "Biomimicry: Innovation Inspired by Nature" by defining nature as the best solution to solve human problems (Benyus, 1997). In 2006, Benyus co-founded the Biomimicry Institute and developed a design process model for bio-inspired design. Biomimicry is a growing area of research in architecture and still has a wide range of unrealized potentials.

On the other hand, the last years of 2010s witnessed the development of a totally new approach to the utilization of nature in design as "living materials". "Living materials" refer to materials composed of living cells that form or assemble the material itself. Such systems have the self-regulating, adaptive, and sustainable features of living organisms in addition to the engineered physicochemical or mechanical properties which enable production and maintenance at multiple scales (Nguyen et al., 2018). Living materials research attracted interest of important research organizations including the MIT Media Lab (MIT Media Lab.), the Wyss Institute at Harvard (Wyss Institute) and the Defense Advanced Research Projects Agency (DARPA) of the U.S. (DARPA, 2016).

This paper mainly focuses on the two terms: biomimicry and living materials in the field of architectural design research. The particular research questions of the study are the following:

1. What are the main arguments of biomimicry and living materials approaches?
2. What are the process steps of applying these approaches in the case studies?
3. What are the advantages and disadvantages of the two approaches experienced in the case studies?
4. What can be the implications of these case studies for further work in biology-oriented computational design?

By the lead of these questions, two different approaches in design are examined and compared. The topic of bio-computational design methods are discussed in this paper by comparing two different case studies on two different approaches. The similarities and the differences, the areas of usage and the advantages and disadvantages of these approaches constitute the contents of the paper.

Bio-Computational Design and Its Use in the Field of Architecture

Biomimicry in Architecture

Earth has an amazing system and order in between the plants, animals and even microorganisms for more than 3.8 billion years since the first bacteria. From the bottom of ocean to the sky, all living creatures established some standards and solutions in order to be able to execute their lives. For example; they managed to turn themselves into different forms to create a living space or found the ways to control body temperature according to the conditions of their habitat. Furthermore, living creatures are managing these without damaging the world by fossil fuels or pollutions in a high rate (Benyus, 1997). In time, humankind started to exploring the nature and figuring out the solutions of it. This enabled them to take steps to adapt what they learned from nature to their own lives and as a result, biomimicry, a concept based on learning from nature, emerged. Some early approaches of biomimicry also can be found in the works of people like Leonardo da Vinci and Filippo Brunelleschi who have important places in the history of world. They both combined art, science and the beautiful work pattern of nature. For example, in the sketches of Da Vinci, it is possible to see the studies which he made on birds, human skeleton and the motion of water, etc. while designing some inventions like the flying machines. To give an example of Brunelleschi's studies, the strength of eggshell was examined and used to design a thin and light dome structure which can resist forces. The mechanical strength of the eggshell comes from the parabolic shape which has a great load-bearing capacity. This is due to the tangential distribution of forces according to the parabolic curves. From the very beginning of history to the present, many scientists and artists have worked on nature as a basis to their studies, art and inventions in a biomimicry approach.

Biomimicry, as a definition of word, means imitating the nature by analyzing an organism or a system. This concept started at the beginning of 1960s by the result of studies on flora and fauna ecosystems. However, the term became popular in the late 1990s by the researcher and the author Janine Benyus. Benyus' book "Biomimicry: Innovation Inspired by Nature" is a main source for the researches on the biomimicry. In this book, Benyus defends that the most of the solutions, that we are trying to find in life, have been already solved by the nature. Benyus believes that the standards of life must be defined by the features of the natural world. Humankind must be inspired by the nature and should improve it according to needs of own. In addition, she also defends that this approach of biomimicry should be based on learning from nature, not by extracting or consuming (Benyus, 1997). Nature provides models like leaves, spider webs, cells, coral reefs and forests. As an example, leaves used as inspiration to the design of solar cells and computers signal systems are majorly based on the cells' feature of transmitting messages (Benyus, 1997). If we need to explain the concept by the words of Benyus which is "doing it nature's way", biomimicry can help us, people, to change the world. In the conditions of using the advantages of biomimicry, it is possible to expect results that will gain energy, time, cost, etc. on the areas of growing food, designing materials and generating energy.

Living Materials in Architecture

Living materials are biological building materials that includes the participation of microorganisms by the collective of biology, chemistry, architecture and engineering fields. Microorganisms, algaes and bacterias may work as a factory for developing building materials by multiplying, healing and absorbing. They mainly have abilities of self-replication, self-regulation, self-healing, self-sustainability and environmental responsiveness (MIT Media Lab.). Living material approach mainly focuses on two main issues; absorption of chemicals and toxins out of the water and air and growing the diagrammatic capacity of organisms by multiplying themselves. Most of these organisms mainly do photosynthesis and use carbon dioxide, sunlight and water. As a result of this, they have a key role on carbon absorbing and cleaning the atmosphere, so, by that, decrease the effects of climate change. Some of them has also ability to remove metals and toxical components out of the aquatic and urban habitats. They mainly focus on the potential of toxicity indication and biosensoring. As the second focus point, these microorganisms have ability to multiply themselves and by filling into the cracks, repair the fractures as a result. This ability of multiplying themselves also used in the area of tissue engineering and printing. That can be achieved by embedding several cell types into hydrogels and patterning differently according to the functional usage of them (Lode et al., 2015).

Microalgaes and bacterias have a great potential on the biotechnology field. The ability of exploiting solar energy and turning carbon into valuable metabolites such as biofuels, food and oxygen provides advantage in terms of use in many areas (Lode et al., 2015). In the field of architecture, living materials are used for assembling the material, extending the expiration and modulating or increasing the functional performance of the materials. For example, they are used as a biofiltration system to remove nutritions, heavy metals and industrial pollutants, which increases as a return of urbanization, from water and air. By the help of these organisms, environment is purified from pollution and this causes an increase in quality of life.

The Process Steps of Applying These Approaches in the Case Studies

One of the projects was conducted by Achim Menges and his colleagues (Felbrich et al., 2018) and it proposed an alternative to the usage of rapid additive manufacturing and fused filament fabrication. These popular methods are quick in both prototyping and production on small scale projects, however, for large scale projects, they are not meeting the needs and therefore it causes some limitations. For this project, shell building process of snails was examined and as a result, it was understood that this could overcome these limitations. Snails produce the periostracum which is a soft and pliable protein based organic film on the shell (e.g. Figure 1). The film works as a form-giving surface and wraps the calcium carbonate layer of the shell after it hardens. This behaviour of the snail shell structure was a biomimicry based inspiration to the researchers and continuous extrusion of free form of periostracum.

In this project, thermoplastic material was used as equivalent to the periostracum. It is a plastic polymer which is pliable and moldable by heating and gets shape by cooling. The extrusion technique was used for giving shape to the thermoplastic. For extrusion, the material was melted and pushed through a die which helped to create very complex cross sections. Thermoplastic mold was extruded by an industrial robot, reinforced by concrete and created as a double layered curved surface.

Figure 1. Snail Shell

Figure 2. Target Surface / First Strip / First Layer

Figure 3. Test Piece, 1.2 mm high/24 cm wide doubly curved composite shell

The other project was undertaken by Marcos Cruz and his colleagues by the collaboration of two different disciplines: architecture and biochemical engineering (Malik et al., 2019). This project took the “living materials” approach and a bio-printing technique was developed by using the microalgae. The microalgae was printed and immobilized into the alginate based hydrogels. Hydrogels are polymeric networks which are filled with water. They maintain chemical and physical crosslinks while they draw a large amount of water into their systems. Viscoelastic behaviour of hydrogels helps them to avoid deformation of the structure. In the project, hydrogels were formulated with methylcellulose and carrageenan, and contained water between 80% - 92.5% concentrations. The variability of water percentage changed the viscoelastic abilities of the hydrogels and this helped them to be more suitable for the pneumatic extrusion system which was combined with an industrial robotic arm as an effector.

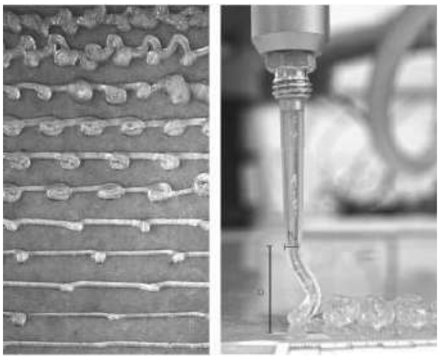

Figure 4. Distance / Nozzle Diameter

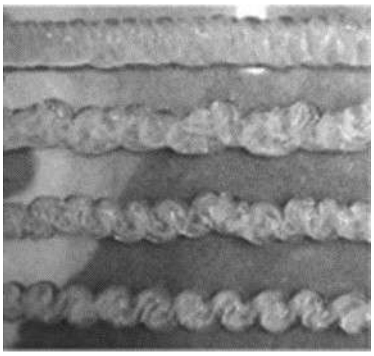

Figure 5. Flow Rate

The hydrogels got into a gelation test and the printing time delayed between the layers to achieve a satisfactory printing resolution. By that, homogenously bind of layers was aimed. In the project, 1000x500mm fibrous hydrogel panel (e.g. Figure 6) was produced to test the system and for 21 days, panel had been regularly hydrated and the cellular growth had been observed. The pattern of the design was edited to get the maximum efficiency from the design and aimed to achieve a multilayered extruded hydrogel with varying resolutions and increasing on both surface area and algae connection with its surroundings. The branched shaped design of the geometry helped the bioremediation by the flow of water over the algae-laden hydrogels' surface. That design like branches was also generated to consist of layers, which have different compositions, on one axis to connect biocompatible layers. According to the branches, the panel shape was divided into three horizontal layers and every layer had its own density and pattern which was fabricated with different hydrogel viscosities and distances between nozzle and platform. The bottom layer was the densest and had 7 layers of 5mm nozzle-platform distances. It also had the highest viscosity of hydrogels. However, besides those, the main difference of this layer was that it has no algae cells. The other layers contained immobilized algae cells of 3 and 6 layers of 5mm distances. The higher water capacity in between the three layers was in the top layer. This layer permitted optimum cellular growth and augmented photosynthetic activities. Immobilization of all three layers had been provided by $CaCl_2$ in the printing, process.

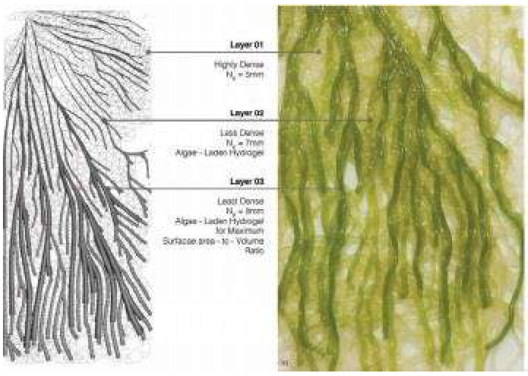

Figure 6. Robotic fabricated algae-laden hydrogel panel (1000 x 500 mm)

This latter work has gained attention as a pivotal project that can form a basis into the fields of algal bioremediation and bioenergy by the interaction between material selection, design and hydrogel production.

Discussion and Conclusion

Both biomimicry and living materials approaches on bio-computational design are still developing and used by the designers and researchers. They both have lots of subtopics under the main titles to examine and produce data to the projects that can be done after. The main advantage of the living materials approach is that the materials used in design are microorganisms and they can easily proliferate over time and get results quickly, as opposed to loss in terms of materials. On the other hand, in the mold based project, it is impossible to use the material after. For that, it may be possible to take another step towards the sustainability of the project by considering the possibilities of reusable materials in mold-based manufacturing.

In the research of “Green bioprinting”, it is suggested that biofabrication will become a dominant technology in the 21th century due to the wide range of potential applications and being out of the traditions (Krujatz et al., 2015). According to that, as architects, we can discuss that in which concepts we can take advantage of the living materials, in how big project it may be possible to include the use of these organisms and how and according to what the usage areas of mold-based manufacturing and manufacturing which living organisms are integrated vary.

These two research case studies are important since they shed light on developments in integrating biology and computational design for architecture. In both studies, the evaluation of the approaches and the results of prototypes and printing revealed some beneficial features in terms of creating large scale built environment projects. This paper analysed these two studies and presented a discussion on biomimicry and living materials approaches within the framework of the research questions posed in the introduction. We conclude that architectural community needs more systematic inquiries into the methodologies used in innovative applications. The authors hope that the detailed analyses presented in this paper would facilitate further studies in this track.

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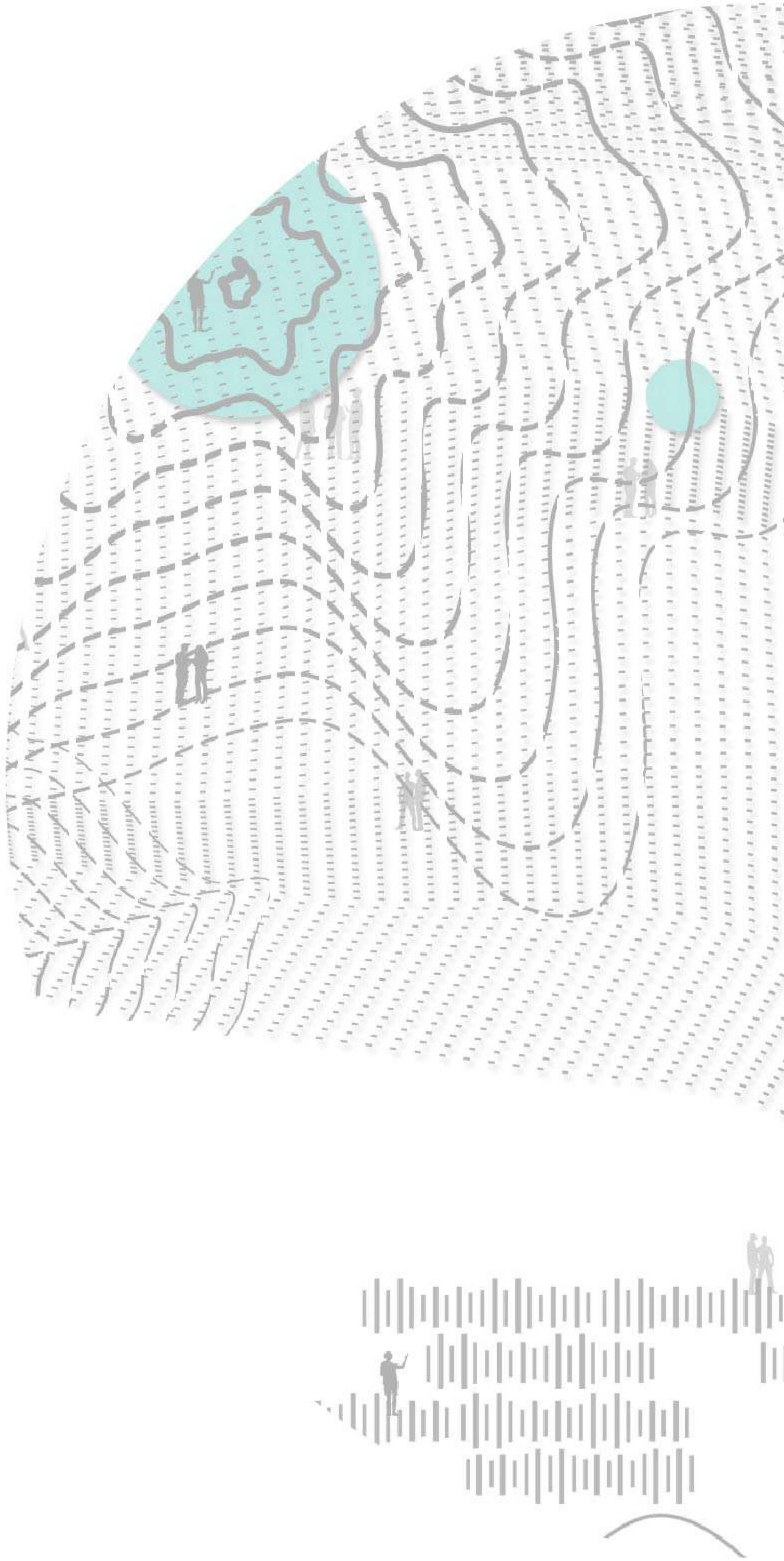

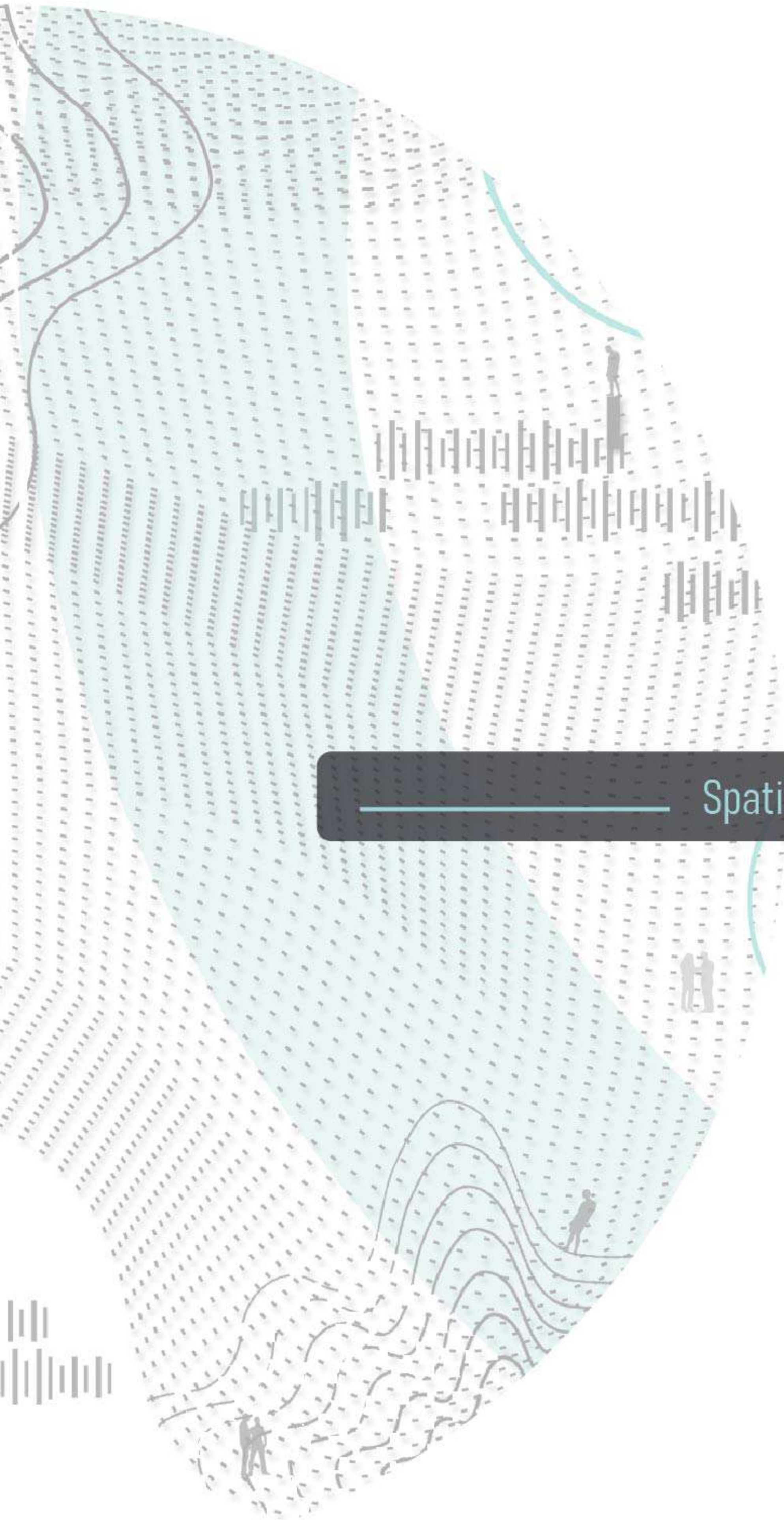

Spatial Practices & Utopias

Spatial Practices & Utopias

Critical Spatial Agencies for Enabling Architectural Design Justice: A Bottom-up Housing Case in Brussels
Rosaura Noemy Hernandez Romero and Burak Pak

Seeking Cities of the Future: Techno-City Visions From The 1960s to The Present
Ayşenur Hilal Iavarone

Use of Mixed Method Evaluation of Interior Architectural Elements that Influence Perception of Spaciousness in Isolated, Confined, and Extreme (ICE) Environments
Berk Diker, Halime Demirkan

Critical Spatial Agencies for Enabling Architectural Design Justice: A Bottom-up Housing Case in Brussels

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Abstract

This study is a part of a Ph.D. project which extends Constanza-Chock's theory of Design Justice to architectural design. Design Justice aims to ensure a more equitable distribution of benefits of and burdens caused through design processes in interaction with the design products; meaningful participation in design decisions; and recognition of community-based, indigenous, and diasporic design traditions; knowledge and practices (Costanza-Chock, 2020). On a similar path, Architectural Design Justice (ADJ) refers to an altered participatory design framework and critical design practices. ADJ looks to understand the socio-spatial impact the design process and future built projects may have on its local community. It explores possibilities on how the benefits and/or burdens can be distributed among the various groups affected by architectural project(s). This research involves the development of novel roles needed for bottom-up architectural design as a just spatial production practice. Building on the discussion above, this paper will present an ongoing housing co-creation case in Brussels. The case is a bottom-up spatial design and production currently in the "making" by activist architects, architecture students, social workers, and citizens. Foyer Bodegem is an all-men's shelter going through an architectural transformation. The project is funded by and organised in collaboration with the Salvation Army (based in the United Kingdom). The project aims to involve homeless individuals in developing their future homes with the collaboration of architect-students: acting not solely through participatory design processes, but as a form of restorative justice, and enabling educational, professional, and personal development processes for all actors involved. Combining theory and empirical findings from this project, this paper makes two knowledge contributions. First, it identifies the novel roles needed to enable architecture design justice and reveals various modus operandi. Furthermore, by introducing a proposal for an operational framework, the '*triple helix of architectural design justice*', it reframes design justice as an alternative educational trajectory for a social justice-driven architecture design and learning.

Keywords: Networked Spatial Practices, Critical Spatial Practices, Design Justice, Service-Learning.

Introduction

Architectural Design Justice as a response to the social injustices and inequalities of our time

> "Inequality of outcome among today's generation is the source of the unfair advantage received by the next generation. If we are concerned about equality of opportunity tomorrow, we need to be concerned about inequality of outcome today." - Atkinson, A. B. (2015).

In light of the apocalyptic disparities, and the rising levels of inequality the world has experienced in the past year, everyone questions their role and the difference they can make through alternative practices that support environmental and social justice. Urban development professions are being pushed to incorporate participatory practices to create more inclusive methods for designing spaces. Urban renewal programs and city regeneration projects have recently tried to respond to the social-spatial inequalities, but fall short in truly distributing the benefits of these programs, and instead displace the disadvantaged from their homes. The complexity of each city requires the collaboration between formal and informal actors in order to reach underprivileged inhabitants. It is not until recently that Networked Spatial Practices have emerged as another possible way to address these challenges. These operate as an interdisciplinary collective of autonomous practices uniting the formal and informal actors around a shared vision and a common platform, leveraging their skill sets to create a unique value proposition (Morgan & Roach, 2011, p.7). Practices that value solidarity beyond financial gains, and networked spatial practitioners are willing to step beyond their traditional management role. Practitioners that instead act as a public intellectual who mediates make use of networked intelligence and sets a local spatial agency that can continue the co-creative processes (Wigley, 2007, p.47). They explore co-creative processes that lead to a more inclusive design outcome and harness the network resources around a project.

The values in many design fields, especially those relating to high profitable projects, are still those of white supremacists heteropatriarchy, capitalism, ableism and settler colonialism. (Costanza-Chock, 2020, pg 24). Complementary to the networked practices, design justice has been introduced as a movement where “Design” is perceived as a powerful tool for empowering oppressed groups in our society, challenging current leading values of the profession. Asking; what needs to be designed and which individuals get to design it.

As for the design practitioner, a new activist role emerges, the design justice agent. A design justice agent acts to give space for new narratives to flourish, capacitating communities to be able to develop their own spaces. Helping the disadvantaged become aware of their spatial capabilities. Professor Sarosh Anklesaria from Carnegie Mellon School describes the role of an architect as that of “an agent of change”, one that develops critical tools transforming the profession and discipline (Marsh, 2021). The title “Designer” can then be given to everyone, as Anne-Marie Willis, professor of design theory and editor of Design Philosophy Papers, describes it: Design is something far more pervasive and profound than is generally recognized by designers, cultural theorists, philosophers or lay persons; designing is fundamental to be human--we design, that is to say, we deliberate, plan and scheme in ways which prefigure our actions and makings … we design our world, while our world acts back on us and designs us (Willis, 2006).

Following the new perspectives of the networked practices and design justice, the new roles of designers seem provocative for the architectural profession, but perhaps the change needed for a promising built future. In this respect in order to shift directions, there should also be the acknowledgement of the change needed in the formative years of a designer. There is a need for an academic agency to be explored, one that provides socio-spatial guidance and enables young citizens to serve their communities: an architectural design justice track as an alternative educational trajectory for a social justice-driven architect. An immersive track of study where a social worker, an architecture student, and urban policy student find solutions to social-spatial inequalities in their local communities.

Motivated with the above, this paper explores the following research questions;

- What are the novel roles needed to enable architecture design justice?
- How can design Justice be reframed as an alternative educational trajectory for a social justice driven architecture?

This paper starts with a literature review (Section 1) followed by a case study (Section 2), revealing a plethora of roles beyond the traditional ones foreseen and adopted (Section 3). In the agency of networked architectural practices, new roles have emerged out of the open and horizontal processes. Roles that are interchangeable and times and rotate among the multiple partners involved, depending on the specific task and/or phase of the project. In (Section 4) this study will introduce the architectural design justice through service learning: the triple helix framework, and then conclude by drawing future directions (Section 5) on its potentials for enabling Architectural Design Justice.

The proposal for a Service-learning integrated framework for Architectural Design Justice aims at the recognition of inequalities; knowledge gaps, stigmatization, and narratives that each vulnerable individual encounters through participatory action. The paper will discuss the preconditions for a fair representation and redistribution of the burdens and benefits. Recognizing the diversity of inequalities, and elaborating on the agency of altering the participatory design process practices to meet each individual at their own reality and for each actor in the process to take the opportunity to represent their needs and desires.

Literature Review

"Today's demands on architectural production under the conditions of accelerated neoliberal capitalism, oligarchism, and authoritarian populism are extremely averse to an ethics of interdependence. Financialization, commodification, gentrification, touristification, and aggressively iconic specularization dominate the architecture market and dictate the pressures on the profession" (Fitz & Krasny, 2019).

Humanity is at a critical moment, where neoliberal and capitalist interests of the few are washing over the needs and interest over all life, human and non-human. Restoring the balance means changing the narrative and shifting the interest and equality to all life. Shifting daily practices to reflect on what must be valued. Architects, and Urban Designers are paying more close attention to the long term drawbacks of profit-driven urbanism and are now more than ever pushing to pursue community-driven projects relating to the practices of social justice. Educators and architects like Toni Griffin from the research group Just City Lab, explore the meaning of a Just City, and give a coherent definition of Spatial Justice connecting to the overarching goal for enabling Architectural Design Justice within this paper. Toni Griffin describes a Just city as a place where all communities but especially the least not included, have access to networks and environments that offer the opportunities and resources to be productive and prosperous, advancing their social, economic mobility and agency (Just city lab, 2018).

Sasha Costanza-Chock, Design, author of Design Justice, and collaborator of the Design Justice Network asks, *"What is the relationship between design, power, and social justice?"*. In her book, she writes about how "Design Justice (DJ)" is a design approach that allows the design process to be led by marginalized communities, and therefore challenging structural inequalities, instead of reproducing them (Costanza-Chock, 2020). This approach has been communicated worldwide through the Design Justice Network, a movement started in 2010 by a group of designers, technologists, artists and community organizers, at an Allied Media Conference in Detroit. The movement roots to the question of, *"How can Design help to better support communities facing injustices?"*. A well known spatial agency project led by Jeremy Till and Tatjana Schneider depicts "Designers" to be political statement-makers, as their designs become spatial productions, and therefore influence the politics of space in a way that it clearly influences social relations (Awan, Schneider, and Till 2011).

Following this same trajectory, Architectural Designers that are for design justice are also political, as they try to close the design power gap, working in a way that enables a design process where the "power to design" is re-distributed to the users. Valorizing narratives of vulnerable groups and allowing them to claim the role as direct or indirect co-creators of their spaces (Costanza-Chock, 2020). In this paper we refer to the following definition of Architectural Design Justice:

Architectural Design Justice
(ADJ) refers to a particular form of DJ, one focusing on enabling spatial justice through various altered and participatory frameworks. It introduces a set of novel roles and methods that are needed to transform architectural design into a more equitable and just practice.

Foyer Bodegem Case Study

At first glance, Bodegem Foyer seems like an average shelter, just one of many shelters run by the Salvation Army, an international charitable organization that provides aid in many social sectors. Still, Foyer Bodeghem has grown to become more than four walls and a meal for those that reside in it. The shelter provides basic needs such as; accommodation, meals, social, psychosocial, and medical support to help homeless reintegrate into society, but more recently, through the collaboration of an educational partner, the new dynamics of a group of architecture students have transformed the shelter into a learning place. Through new inclusive methods the academic partner has enabled many inhabitants to take part and engage in the current spatial transformation of the shelter. The project is bottom-up spatial design and production currently in the "making" by a consortium of activist architects, architecture students, social workers, and shelter residents. The project has also brought awareness to “housing as a right”, serving as one of the proactive cases embedded in the peculiarities of the Brussels urban context, an alternative rebellious city that harbors numerous solidarity network practices, diverse in culture, and with an expansive universe of spatial activism responding to socio-spatial injustice(s).

Foyer Bodegem was doomed to close its doors in March, in the middle of a pandemic and in a city already lacking shelters. Due to management issues and lack of fundings, the shelter was far from fulfilling the new city building regulations. A call for help has been initiated by the director connected to a solidarity network of research architects, Altering Practices for Urban Inclusion (Alt_Shift group). As a diverse collective of researchers and practitioners, Alt_Shift has taken on the project with the intention to provide a voluntary service and take the opportunity to introduce Service Learning as strategy to interweave the academic explorations of Architectural Design Justice into serving the local communities by partnering with field practitioners, and engaging with society to solve socio-spatial challenges.

Led by the first author, a network of solidarity has been assembled, bringing various actors together, and common goals were drafted to motivate the journey. The main driving goals were; To create an environment that allows each struggling individual that steps through Bodegem Foyer to find a safe place. For residents find their inner power to take control of their lives, finding solutions to their struggles through a collective effort and distribution of the benefits inside the shelter. For the students to be involved in a real life project that would engage them into a real architectural design justice case, simultaneously serving their community. Finally, from the design justice perspective, to recognize that temporary shelters should serve beyond the primary need of housing, and through an inclusive shared agency of the spaces, enable self-care and self-action in the personal development of each homeless man involved.

At the moment, Foyer Bodegem is built as a 'volkshotel', a hotel for the people, but the project aims to change the atmosphere from a hotel for the people to a home for the people. This is a clear move away from housing residents in collective dormitories with a single public cantine towards a novel understanding of a shelter providing private dorm rooms, multi-purpose shared spaces, sanitary upgrades, and a collective urban garden.

Emerging Roles and Tools for Architectural Design Justice

At the start of the project a diversity of meta-roles were accepted into the process; Foyer Bodegem Residents and Staff would present their needs and actively engage into the process. Architekt-nburo joined the network to serve as the signing architect and coordinators of the spatial transformation, academic practice-research group Alt_Shift (Altering Practices for Urban Inclusion) at KU Leuven would serve as participatory design consultants, Salvation Army as the funding authority and the City of Brussels, as the granting authority over building permits. Since then, the funding authority and permit-granting authority have remained the same, but during the project design, there has been an interesting development leading to the emergence of new roles, merging the tasks of the residents, students, architect, and educators. This novel role development came as an outcome of the creation of a multi-purpose workroom at the shelter. This was intentionally designated as a space giving access for the students to work while casually interacting on-site with the staff and residents. The space dynamics and student presence on-site began to change the atmosphere at the shelter, and progressively, the residents began to engage with the students through skill-building activities such as; furniture building, gardening and mural painting.

In the agency of networked architectural practices, new roles have developed out of the open and horizontal processes. The role of an architect, educator, student and resident have merged together to create three interchangeable roles; Networked spatial practitioner, Community skill-builder and Design service-learner. In the following part of the paper these roles are unpacked.

Networked Spatial Practitioner:

This role goes beyond the role of a spatial designer and helps to make connections between actors, and actions, to facilitate negotiation between all actors in order to ensure they work together effectively towards the project goals. It focuses on designing frameworks and processes on which facilitate and support co-creation in networked practices. This role understands and maps networks in collective performance, analysing relationships between actors, spaces, concepts, processes, and instruments (Latour, 2005). The Networked Practitioner develops tools that reveal the relations and capacities between actors, spaces, concepts, processes, and instruments to aid in the context of Co-creative projects. This role constantly looks for opportunities to connect the project into relatable networks to exchange knowledge and form new collaborations.

In the case of Foyer Bodegem, networked spatial practitioner became a shared role between the practicing architect, the architecture student, and the educators involved. All three traditional roles worked together to understand the inequalities the residents were facing. Then, the spatial relationship to these inequalities were analysed through a series of traditional methods like group interviews, social expert interviews, and novel methods such as boundary objects, and skill-building workshops that engaged much deeper with the residents (Figure 1).

DIWO (Dı-It-With-Others) Expert:

DIWO or Do it With Others is a phenomenon of community building strategies which originated from the DIY (Do It Yourself) idea of fostering open source tools and techniques in order for everyone to be able to engage in the maker's culture (Caldwell and Foth, 2014). As Caldwell and Foth (2014) explains, The DIY approach is frequently motivated by an underlying desire to oppose consumerism and help facilitate creativity, which frequently extends beyond the making of material or tangible artifact to include creating experiences.

This role provides particular training or sets of training that will facilitate developing self-construction skills to involve the various actors of the community in DIWO activities. This training can be performed by means of courses, workshops, exercises, with participation and the lead of field experts, subject matter experts, academicians, and/or practitioners. The DIWO expert is not only trained in the specific trade; gardening, carpentry, metalworking, masonry, etc., but is also trained as an educator and community builder. The process of working together is just as important as the end product, and so this is key to the performance of this role.

Design Service Learner:

Known as the evolved role of the Architect-Students, this role is open to learning and exchanging knowledge through providing a service to society (Community Service-Learning). Students learn through multiple community learning methods developing from academic theory and projecting it into practice. This role is discussed further in section 5 of this paper.

Tools for Architectural Design Justice

Boundary Objects

The majority of interactive tools and platforms for citizen participation involve high-cost and exclusive technological solutions which tend to serve authoritarian and non-democratic purposes due to their relation to the capitalist interests of modern media, and create a knowledge gap between vulnerable groups (Gün, Demir and Pak, 2020). The use of cellphones and laptops also removes the attention to the physical surroundings and precarious bodies, making urban life less a matter of public social relations (Argin et al., 2020). Commercial advertising used to fund these strategies also impose authoritarian messages on the public space that allows no room for discussion or expressions of opposite opinions.

Boundary objects, also referred to as affordable media architecture, explores passive methods of engagement, different to those dominating the architecture profession (Fominykh, Prasolova-Førland, Divitini, 2016). From the perspective of design justice, the main aim of a boundary object is not to create technological advances, but to intentionally engage with vulnerable groups affected by the conditions of the accelerated neoliberal capitalist system and to collectively find solutions to the inequalities crippling those communities. We call these boundary objects for design justice. These objects are specialized knowledge representations used to facilitate the conversion between the user and the designer, and serve as a tool for indirect empowerment of the user. For the Bodegem case, boundary objects became the main channels of interaction between the project residents, local neighbourhood and the Alt_Shift group, during Covid-19 confinement. A number of boundary objects were temporarily installed in the cantine, a neutral space for encounterings between the students and the residents.

"The talking wall" was one of the installations that became part of the main facade wall of Foyer Bodeghem. The facade was made up of glass windows, but it did not serve as a welcoming object nor a gateway to the Foyer. The students realized the affordances of the wall's transparent surface, and created interactive installations for the passersby and the residents of the shelter. The interior facade focused on questions aimed towards the residents, exploring their background, pleasures and interactions with the Foyer itself. While the exterior facade was designed to dismantle the stigmatization of the shelter by providing a positive image of the Foyer to neighbors and others who pass by daily. At the very least, the wall created awareness of the shelter's existence, but more importantly, it introduced the identities that lived behind the walls. A series of mapped pictures depicted the interior of the Foyer, and pamphlets exposed the positive attitudes behind the walls. The residents contributed by posting their answers to questions on the wall and elaborated on their story and future life goals. The visual exposure of the installation created a place of discussion and exchange in the Bodegem community, as the residents began to get to know each other and the diversity of their fellow roommates. The images on the exterior certainly made them feel recognized and give a sense of belonging towards the space inhabited.

Another boundary object installation called "Hanging dreams'' became a tool for the homeless and refugees to express their dreams, needs and wants through different visual media; written notes, pictures or drawings. The installation was first designed in a way where it could be situated in different areas as it is flexible in size and space. This tool was designed to learn more about the residents' realities and dreams. The students wanted to give the residents a voice, to give them a chance to express what they lacked, and to integrate them within the thinking process of re-imagining Bodeghem. This installation reflected a journey from reality to a dream. The idea here was to have the users describe any object they are attached to in reality, whether through a sketch or a photo, then moving to think about their wishes and dreams for the near future. This mental transition starts from a physical state, reflecting from the present daily life, but then transitions into a reflection on imagination, hopes and dreams.

Skill-Building Workshop

Design is power, but only those that have power get to decide which design is valorized. Once design became professionalized it became harder to create an inclusive vision of design as a universal human activity, which goes against the realities of the political economy of design (Costanza-Chock 2020). There is a need for more affordable and flexible tools that allow everyone to become a designer, and still be able to re-create their spaces with limited financial means.

"A Place of our own" was the first building workshop at Foyer Bodegem with the aim to refurbish and upcycle the material within the building and turn it into new furniture. This action created a more hospitable environment on the ground floor of the shelter as well as a comfortable space for social exchange between the actors of the project. The workshop allowed participants to learn about upcycling methods and act creatively to reinvent the various leftover materials found around the building. Old metal beds became shelves, and broken room dividers became tables. The furniture building was guided by a DIWO (Do-it-with-Others) Expert, who instructed the usage of electric tools in a safe manner. For the architectural students, this was one of the first times they had access to learn-by-doing, or design-by-doing, learning methods that allow for the student to experiment hands-on with the various materials they constantly refer to in their architectural designs.

Following "A-place of our own", the "Seedling workshop" was planned as a request from the staff. The Seedling Workshop was created with the intention to build community through the act of planting together. The workshop helped capacitate the residents of Bodegem to be able to start building their community garden within their small courtyard, already envisioning its expansion. The workshop was guided by another DIWO expert, an urban gardener who provided the "How to" and the materials necessary to kick start the garden as well as encouraging social encounters through active learning games. The residents learned about the benefits of urban gardens in the city, how to care for plants , as well as which plants are adequate for growing within each season in Belgium. The small act of planting foreshadowed the intentions to cultivate a culture of "care" within the transformation of the spaces in the shelter. A collective act of care and gradual beatification of the spaces, has changed the perspective of the residents to trust the proposition of taking an active role for the transformation of their spaces.

Figure 1. Inclusive design justice methods; group interviews, social expert interviews, and novel methods such as boundary objects, and skill-building workshops.

Architectural Design Justice Through Service Learning: The Triple Helix Framework

The Foyer Bodegem case embedded in the architectural academic context allowed us, the academic partner Alt_Shift to discover new collaborative learning processes combining theory and practice within an interdisciplinary community network. We established a service-learning track in architecture studies which engages students in reflection-in-action and learning-by-doing, always co-creating together with "real" end-users. This Master's level architecture course embedded within the Foyer Bodegem Project continues to serve as a medium to develop the Architectural Design Justice framework, which would capacitate and empower vulnerable end-users such as the homeless, to re-imagine and re-build their spaces, consequently helping the marginalized rebuild their confidence in society for a better future.

Service-Learning is employed in this context as an educational method that aims to immerse the architect-student into a real case scenario within their architectural studies, but focusing on cases dealing with current socio-spatial challenges. This operational framework, which we named "the triple helix of architectural design justice" worked in a series of cycles, driven by the constant exchange and in-dialogue with each other (Figure 2). Architecture students learned from the space itself and the daily routine of the end-user. During each cycle, students dug deeper to understand, negotiate and co-create solutions to the socio-spatial challenges of the project. There were three main cycles; Mediation, Activism and Investigation, each fed into each other to start another series of cycles. Each cycle was performed in 4 steps, following the PAR (participatory action research) structure of Planning, Acting, Observing, and Reflecting in Action. The triple helix framework facilitated the emergent roles identified in the previous section. The Networked Spatial Practitioner guided the students through each cycle as they took their corresponding role as The Investigator, The Mediator, and The Activist. The roles did not follow a particular order but instead, each role is taken as a response to the current context, social situation, and phase of the project. The flexibility of the framework was created to address any unexpected situation, and to also allow the students to constantly make critical reflections on their actions (Figure 3).

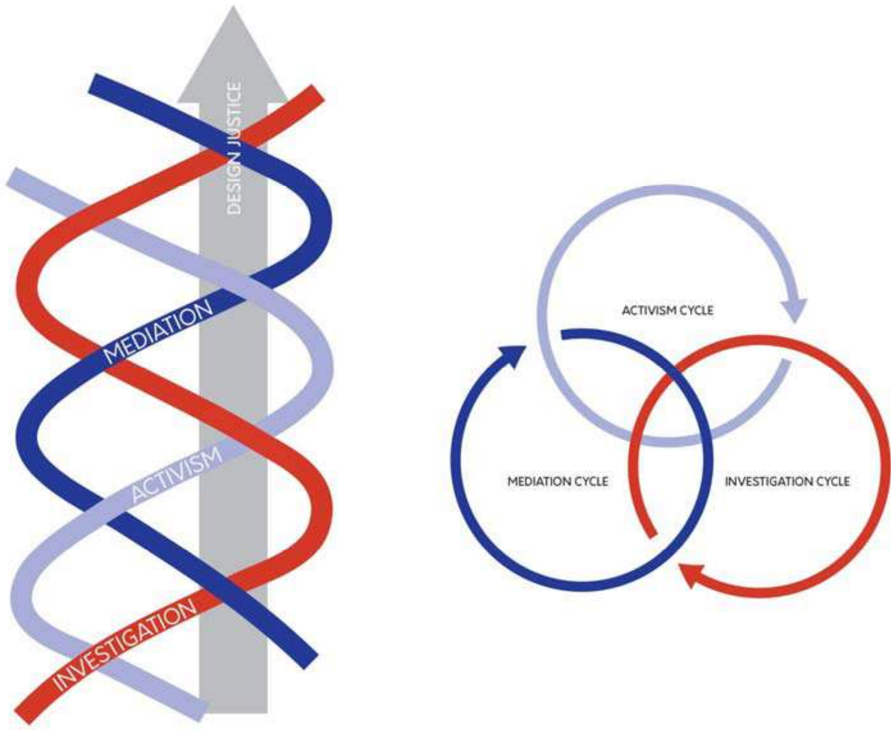

Figure 2. The triple helix of Architectural Design Justice for Academic Integration: Investigation, Mediation and Activism

Design Justice Service Learning Cycles in the Triple Helix Framework

The Investigator Cycle

The goal of this cycle was to identify the socio-spatial challenges of the project. It focused on understanding the context of the project through; theoretical literature, performative participatory practices, and through the lived experiences of the users in discussion with the various actors. These activities included but were not limited to; Spatial investigations, End-user discussions/interviews, and published expert knowledge.

Further through the project, this cycle was again visited through performative place-making actions; ways to interact with the end-user through artistic responses that engaged with the spatial politics of urban change. Spaces were negotiated and re-invented through collaborative temporal performances of imagined possibilities. In this sense, these performative practices went beyond the performance roles of establishing an artist or architect as a performer and the spectator or end-user as a consumer, instead this cycle opened the opportunity for everyone to express and imagine new possibilities (Wolfrum and Brandis, 2015). These activities included but were not limited to; boundary object exercises, focus group workshops, and surveying.

The Mediator Cycle

The goal of this cycle wasperformred by the networked practitioner to establish a common language and knowledge of the project for all the network of actors'. The main intention was to establish a good level of trust between the network actors and end-users. This cycle is about negotiating initial solutions that can inspire change or solve conflicts between the actors, ultimately revealing hidden information about the power structures and social-spatial challenges. These activities included but were not limited to; Design (plans) negotiations, Design proposals, and Scenario proposals.

Later in the project, the mediator cycle spatialized knowledge can be represented through temporal, prototypical spaces, but still adaptable and serving as incremental architecture. It's important to acknowledge the affordability of the prototypes, as it must allow room for error in the further development with the users on site. The adaptability of a prototype must allow for the user to continue to make inputs or to test variations of the design. The DIWO (Do it With Others) incremental architecture, allows for users to comfortably grow in confidence, gaining the power to manage their own environment.

The Activist Cycle

The goal of this cycle is to have critical reflection through social justice and ecological lenses. This cycle was inspired closely by Constanza-Chocks Design Justice principles. The goal was to challenge the proposed ideas, and prototypes, but also to acknowledge who benefits most from the proposed solutions. In this stage, the practitioner can protest, or act to acknowledge the ecological damage or social oppressions any action of the project may be creating. These activities included but were not limited to; Identifying patterns of inequalities, Storytelling Visuals, Mapping reusable resources, and making Inventories.

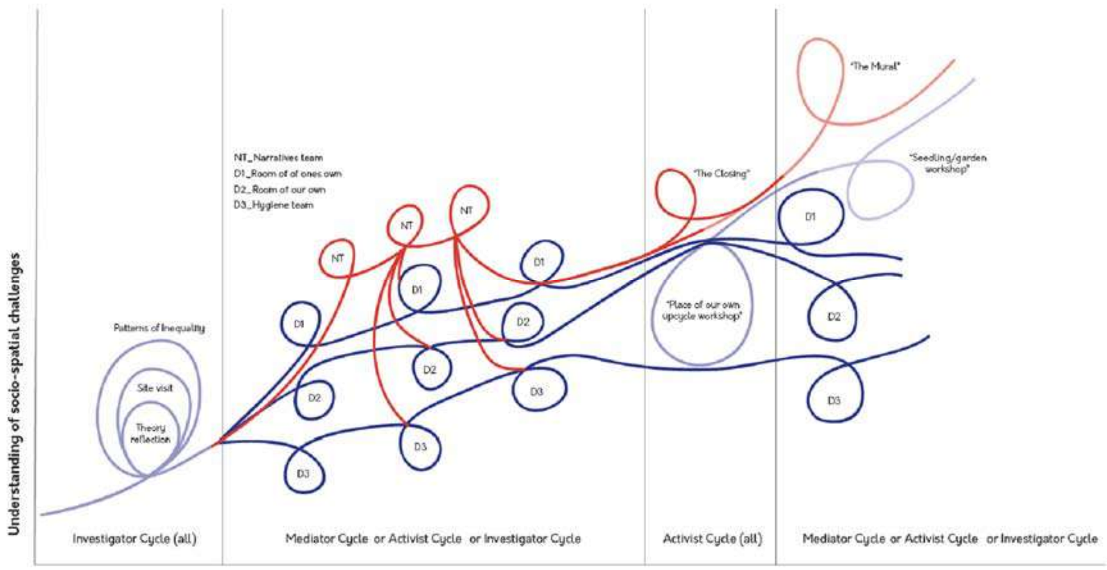

Figure 3. Design justice service learning cycles in action within the Foyer Bodegemcase study.

Conclusions and Future Directions

As design practitioners look to adopt alternative paths towards creating more just cites, networked practices are emerging. These solidarity practices are performed in an open and horizontal manner, revealing novel roles, and methods to navigate design just projects. In (Section 1) this paper discussed the perspectives from leading educators and the ways in which designers have been exploring the relations between design, power and social justice, and movements such as the "Design Justice". Architectural Design Justice is then introduced as an approach that capacitates marginalized communities facing spatial inequalities, by utilizing design as an empowering tool that helps vulnerable individuals claim and develop their own environments. In (Section 2) the case study of the architectural transformation of Foyer Bodegem is introduced, while in (Section3) the novel roles are discussed along with the novel methods of design inclusion. These roles go beyond their traditional modus operandi emerge from the plurality of a network of actors, and their common intention to involve the end-users within the transformation of their spaces. This section continued with critical reflections on the roles and tools employed in a real case in Brussels which are both interesting for designers, academics, spatial practitioners and

participatory design researchers. In (Section 4) this study will introduce the concept of architectural design justice through service learning and the triple helix framework followed by a discussion drawing future directions (Section 5) on the potentials of the introduced framework for enabling
Architectural Design Justice.

The triple helix framework and novel roles developed through this study reveal new ways to approach Design Justice, recognizing spatial inequalities, and more importantly presenting sensitive ways to intervene in and address social challenges oppressing vulnerable communities. In Section 3 this study responded to the research question "What are the novel roles needed to enable architecture design justice?". The role of the networked spatial practitioner is unpacked, and along with the support of the DIWO Expert the Design Service Learner is guided through a series of cycles. The design justice learning cycles are defined to give importance to mediation, activism, and investigation processes that naturally arise when dealing with bringing social justice. The study responds to the second research question by introducing the triple helix as a preliminary conceptual framework as an alternative educational trajectory for a social justice driven architecture. This design justice service learning strategy becomes a strong operational backbone for the realization of an architectural design just project. The academic partner brings an activist but sensitive voice within the network of actors, as in the Bodegem case, but more importantly the students' critical and unbiased stance in the project give way for the triple helix framework to be unanimously accepted.

The research finds capacity building to be central to the development of each novel role and supporting method in an architectural design just project. This involved mutual learning, indicating the willingness for both designers to share their knowledge in an open way that may contribute to spatial production. A power shift in the design practice allows for open-source tools to be made available to vulnerable groups giving access for their knowledge to contribute to the spatial production. Evidently, a variety of challenges arise from the constant power shift between actors, as it requested intensive facilitation efforts, giving risks to burnouts for central actors within the network. The complexity of the project lies in the proper distribution of benefits and burdens, which additionally need to be decided in collective form. Another challenge is also the impact of the interventions which should also be continuously evaluated to verify the extent to which the intended design justice goals are met, prevent ethical concerns and redirect the efforts if needed. The academic partner could serve as the impact evaluator as a part of the PAR cycles, but further studies are needed to develop such parameters and measure standards. More time is needed in order to follow up the afterlife of cases and evaluate the long term effects of the Architectural Design Practice.This study's proposed framework and dimensions of design justice can help develop this further.

Another major concern of the academic partner is that the design justice service learning trajectory requires various resources and practical support to implement such a track. Students are not educated as activists, facilitators or builders, requiring a lot of time to learn these new skills. The hands-on experience needed to work with various materials. This would need to be introduced in the early preparatory years of an architectural education to accommodate learning design justice by doing . This would better prepare students looking to take part in an Architectural Design Justice educational track. This would mean that the educational track would require long term partners, networked practitioners connected to the ground work within the surrounding local communities of the academic partners.

A promising future direction for Design Justice Service Learning would be to establish structural support from academia. This would allow for experimental hybrid design studios to be supported with skill building classes from trade schools, local workshops, as well as transdisciplinary exchanges with social and political science students from surrounding faculties.

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Seeking Cities of the Future: Techno-City Visions From the 1960s to the Present

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Extended Abstract
From a visionary perspective, the concept of the cities of the future creates a fundamental example set that carries dreams and predictions about what future life will be like. Cities are places where the future imagination is reflected (Donald, 1997). Therefore, how the future is imagined and predicted can be read through the representations and projects produced for the cities. This paper suggests that the techno-city visions produced especially after 1960 and the discourses of the cities of the future have the potential to overcome current crises by systematic knowledge and the processing of imagination. Based on the notion that imagination is the key concept of how-to pre-experience alternative futures and how we can prepare ourselves for these futures, the paper focuses on the examples of techno-city productions that have the potential to significantly enrich our relationship between the present and the future. These experimental future city examples, which are considered as attempts to make leaps in the linear timeline, produce discourses about both the atmosphere in which they are produced and the future. With these aspects, they are leaping towards the future from the present, and with the visions they put forward, they increase the environment of criticism and production.

The union of imagination and atmosphere prepares the common ground for the future imagination. When this thought is evaluated in the context of the view of "The desire for a good city in the future is already present in the imagination of the past" (Donald, 1997), the relationship between the concepts of "being visionary" and " city of the future" can be seen. As an example of being visionary, cities that carry dreams and predictions about how the future life will be mentioned.

The techno-city visions produced especially after 1960 and the discourses of the "cities of the future" they produced have the potential to overcome current crises, produced by systematic knowledge and the processing of imagination. The exemplifications of techno-city discussed in the essay are matched with two jumping attempts. Firstly, "dream city of the future" conceived by the positive atmosphere created by technological developments in the years between 1960-1980, and secondly, starting from 90's onward "city of the future dystopias", which came to be as a result of science-fiction and architectural depictions supported by computer technologies and increasing ambiguity in the world. Techno-city visions discussed in the set of examples aim to accentuate the potentials of the theory and the act of design, during that era.

The "city of the future" dream inevitably became the desired item due to the exhilarating developments of the 1960's space, transportation, production, and health technologies. The attempts of jumping in the timeline, driven by the desire to build the future and the ideas and depictions of the future produced by architectural discipline that is tasked to design the "future" (Clear 2009), as well as many other disciplines, provide an idea of the era's definition of being visionary. It can be observed that these visions are concentrated around three basic concepts: balloon cities, megastructures, and first environmental cities. Walter Pichler's "Compact City" (1963), Athelstan Spilhaus's "Experimental City" (1967) and Eric Gauthier's "Biosphere Museum" (1967) can be

associated with the period's space technology developments, depict that the cities were envisioned inside of closed-solid volumes. Megastructures that are being shown in the montage such as Arata Isozaki's "City in the Air" (1962), Peter Cook's "Plug-in City" (1964), Kiyonori Kikutake's "Expo Tower" (1970), Kisho Kurokawa's "Capsule Tower" (1972) can be interpreted as solutions for growing cities with continuously growing population. The post-1960s era, where "possible and impossible technologies" are intermingled (Abbott, 2016), whilst exciting developments took place in fields such as robotics, artificial intelligence, cyber technologies, etc., when we came to the 1970s with the changing political climate, the dream of cities of the future changed from optimistic rhetoric to a disappointing one (Dobraszczyk, 2019). The social response to futurist architecture, political positions, and technological advancements, starting from the 1980s, reality began to resemble science-fiction (Abbott, 2016). It can be observed that these developments changed the "dream of city of the future" to "city of the future dystopias".

The atmosphere created by widespread usage of computers and digital technologies as well as technological advancements transformed the idea of cities of the future from something to be desired to, something to be feared. Considering that architecture shared the goal of 'imagining what the future would look like' with science-fiction it can be understood why the city of the future dystopias began to emerge in the golden age of science-fiction and computers. In the popular science-fiction movies of the period such as Blade Runner (1982), Tron (1982), Back to the Future (1985), Akira (1988), The Fifth Element (1997), the city is represented as a machine filled with invisible web connections, dominated by an un-bodily environment of urban space (colossal buildings, flying cars, etc.) where the virtuality and reality are intertwined. In these creations of "City of the Future Dystopias", cities are often depicted as chaotic, unscaled, and ecologically in despair. This condition is an indicator that future city is no longer approved in the context of technological developments.

In the Internet age, the attempts to jump into a future timeline are also characterized in a dystopian narrative, in which cities are imprisoned by cyber networks. Studio Linfors's "Cloud Skippers" (2009), Bratton's "iPhone City" (2009), Saraceno's "Cloud Cities" (2011), Young's "New City" (2015), and Myers's "Cyber Monday" (2018) are illustrating an image of a future city that surrendered to media and networks. Thus, "city of the future" no longer describes a dream; it starts to describe a nightmare.

In the context of techno-cities, "city of the future visions" which create a ground to discuss being a visionary, are inspirational in the architecture and design fields in terms of the discourse they create and the representations they produce; and they present a brave and critical position by their attempts to jump in the timeline. The atmosphere of the era, imagination, and knowledge can create both desired city dreams and dystopias. In both cases, the visions created in the attempts to jump in the timeline compels us to contemplate new ways to live and design.

Figure1: "city of the future" dream & "city of the future" dystopias

Innovations provided by architecture and design which pursue city of the future, are thought to be crucial in terms of critical thinking and creative production. Beginning from the end of the 20th century, the extent of the discourse produced by the designs that attempts to jump in the timeline, pushes us to examine today's future visions. Hence an unavoidable question arises: how do we imagine a “city of the future” today? What the dreams of the future cities have become can be interpreted as capitalism challenging the lack of imagination in modern times. Whereas future visions discussed in this set of examples demonstrate that the act of thinking and designing helps to endure adversities created by environmental and social changes. The attempts to jump in the timeline promises solutions to overcome the current crisis.

Keywords: Imagination, visionary architecture, techno-city, utopia, dystopia.

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Use of Mixed Method Evaluation of Interior Architectural Elements that Influence Perception of Spaciousness in Isolated, Confined, and Extreme (ICE) Environments

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Extended Abstract

Several psychological occurrences can be observed in individuals and groups exposed to isolated, confined, and extreme (ICE) environments and are often the focus of researchers. However, there is a lack of research on the impact of the physical environment on people and the subjective experiences of those who reside in such environments. Due to most ICE environments locations, most research on these issues is performed either on analogous environments (submarines, arctic stations) or in small-scale simulated environments. An environment designed to increase the perception of available space could improve the well-being of both individuals and groups that occupy the environment. Architects and designers have developed various design techniques to address similar issues in different environments and identified some architectural elements that could influence an individual's perceived isolation and confinement to treat the negative effects that are bound to appear. However, their validity in ICE environments is not tested and evaluated noticeably.

According to previous research (Jager, G., & Postma, 2003; Ruotolo et al.,2011), there are a certain number of cues that are inherent to us, which helps the brain create a cognitive map of an environment, a model. These cues are often manifested in the interior as architectural elements such as colored surfaces, windows and openings, lighting fixtures/modes, etc. In addition to creating a functional environment, these elements create a certain degree of stimulation and interest for the occupants. Based on these elements, designers and researchers have established some 'tricks' commonly used when designing environments with limited opportunities for spatial cognition. These tricks could be used to create a sense of spaciousness or reduce the feeling of confinement. Some of these methods are commonly used when designing day-to-day environments with low square meters. Their main principles could be imported to the design of more controlled interior environments and tested. Simon & Toups (2014) previously summarized such methods used in 'tiny house designs', which could be applied to many different ICE environments. These methods could further be examined individually, and their impact on spatial cognition could be discovered through experimentation.

The research hypothesis is that the presence of and changes in interior architectural elements could influence the perceived spaciousness of an ICE environment. The research uses a mixed-methods (qualitative and quantitative data analysis) approach to evaluating habitat design in ICE environments by examining multiple experimental habitats built to simulate long-duration missions in extreme environments. The aim is to compare the findings within the literature with the architectural design of these habitats to uncover the relationship between the perceived spaciousness of these environments and interior architectural elements used within.

Three simulation habitats (HERA, HI-SEAS, SIRIUS/NEK) are selected to evaluate their interior environmental characteristics. The selection was based on the functional similarities of these environments. All three habitats are simulations of extreme environments in which crews simulate various scenarios with maximum fidelity. The interior architectural features of the habitats are categorized as geometry, furnishings, lighting, and surface properties (materials). Exterior openings are not taken into consideration due to their lack thereof in selected

environments. In-depth examinations were performed on the three chosen habitats by the researchers to identify which of the architectural elements were important contributors to positive and negative changes in spaciousness.

Fourteen interior designers were selected through focus sampling methods and asked to perform evaluations by viewing selected photographs of each environment through a monitor. After viewing each group of images, they filled out the Spaciousness and Crampedness Scale (SCS) (Imamoglu, 1986). They estimated the square meters of the area photographed, which would be used to calculate the relative estimation of error in an area (von Castell et al., 2014). The SCS evaluations are examined and ranked under three factors as appeal (SF1) with four items (uncomfortable/comfortable; repelling/inviting; disturbing/restful;unlivable/livable), planning (SF2) with five items (poorly organized/well organized; poorly balanced/well balanced; poorly planned/well planned; poorly scaled/well scaled; uncoordinated/coordinated;), and space freedom (SF3) with seven items (cramped/roomy; small/large; restricted space/free space; tiny/huge; crowded/uncrowded; closed/open; narrow/wide).

The results indicated that there was a significant difference between the evaluations of the three habitats. SF1 and SF3 factors of the Spaciousness and Crampedness Scale provided the most insight, while the SF2 factor did not significantly contribute. This may likely be due to one of the unique characteristics of such ICE environments. The overall planning and functionality of the habitat are prioritized due to the limited resources, volume, and restrictive mission requirements.

The HI-SEAS habitat with the most preferred characteristics was also ranked the highest on SF1 and SF3. It was the most appealing compared to the other two habitats and perceived to have the most space available for living. On the other hand, the SIRIUS/NEK habitat ranked the worst on SF3 evaluations, although it had more area and volume than the HERA habitat. This is likely due to the geometry and the use of color and texture within the environment. However, although the HERA habitat contains an elevator shaft in the middle of the habitat, which blocks the occupants' line of sight, it was evaluated to have more space freedom than the NEK/SIRIUS habitat. Field of vision may also be factored in since the latter habitat's tubular shape is more restrictive than the open cylindrical geometry. HERA habitat was evaluated to be the least appealing out of the three. This is likely due to the habitat's more mechanical, machine-like appearance and its overall brightness being the lowest. The relative error results in the estimation test indicated that the SIRIUS/NEK habitat was perceived to be the least spacious, while the HI-SEAS habitat was the most spacious. The perceived spaciousness of the HERA habitat had unexpected results, in which the relative error was smallest. This seems contradictory to the expectations at first since it ranked the overall lowest score on SCS evaluations. However, when looking at the SF3 evaluations, HERA habitat ranked second. This may indicate that the relative estimation error has a higher degree of correlation to SF3 than the rest of the items or the overall spaciousness evaluation. The rest of the estimation directions were as anticipated.

The various architectural elements explored in this study have a large background of research and testing across multiple building scenarios but often were not considered for ICE environments studies. With the utilization of qualitative and quantitative evaluations of such environments, enough awareness can be raised to consider the more nuanced aspects of an interior environment that is not immediately apparent. Although limited in its scope, this study attempts to establish these evaluation methods for further analysis in the future. With immersive viewing technologies, higher data accuracy can be achieved, and more in-depth explorations into how the occupants perceive spaciousness in various ICE environments can be explored.

Keywords: Design evaluation, habitat design, interior architecture, isolation and confinement, Perceived spaciousness.

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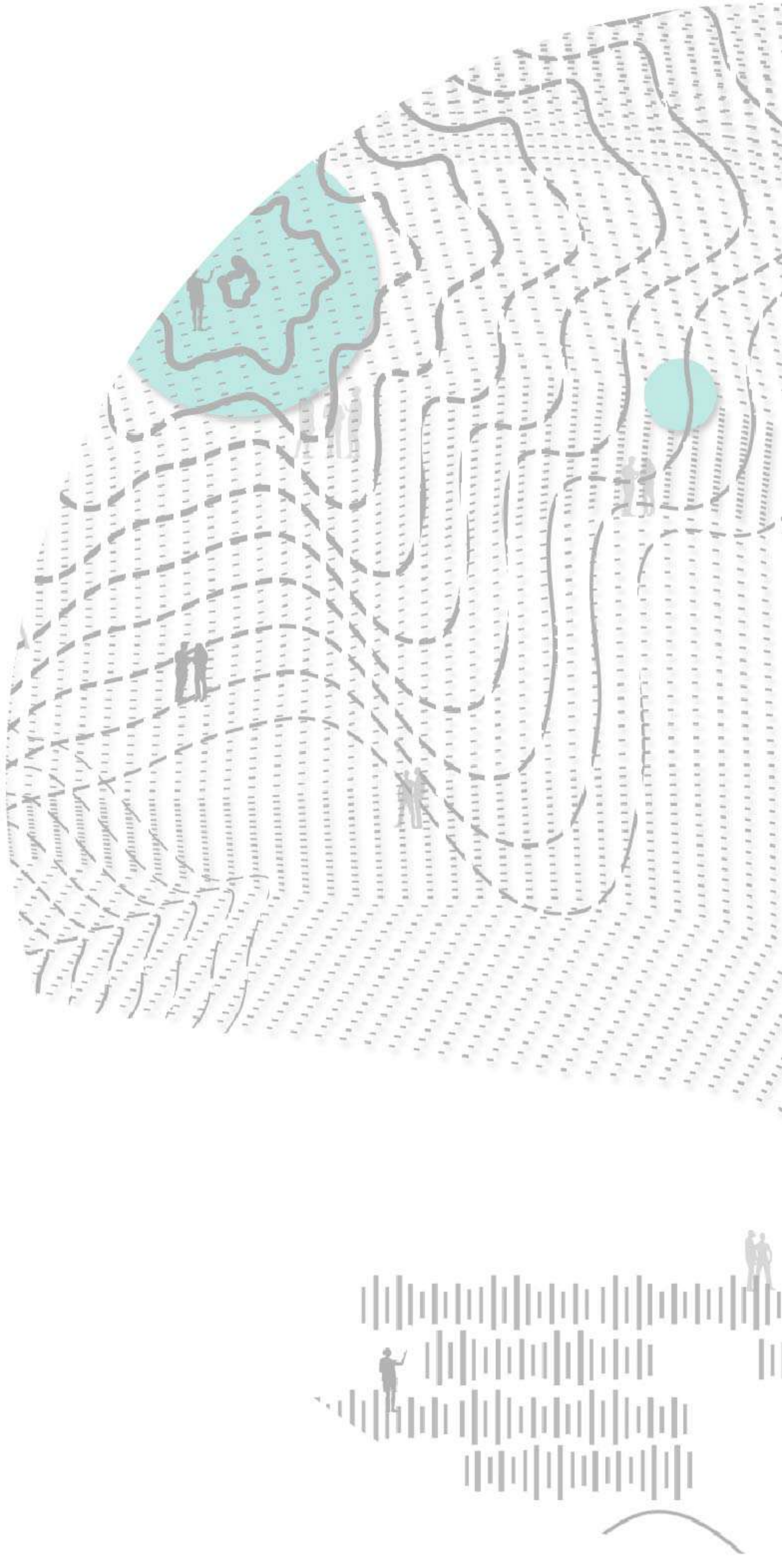

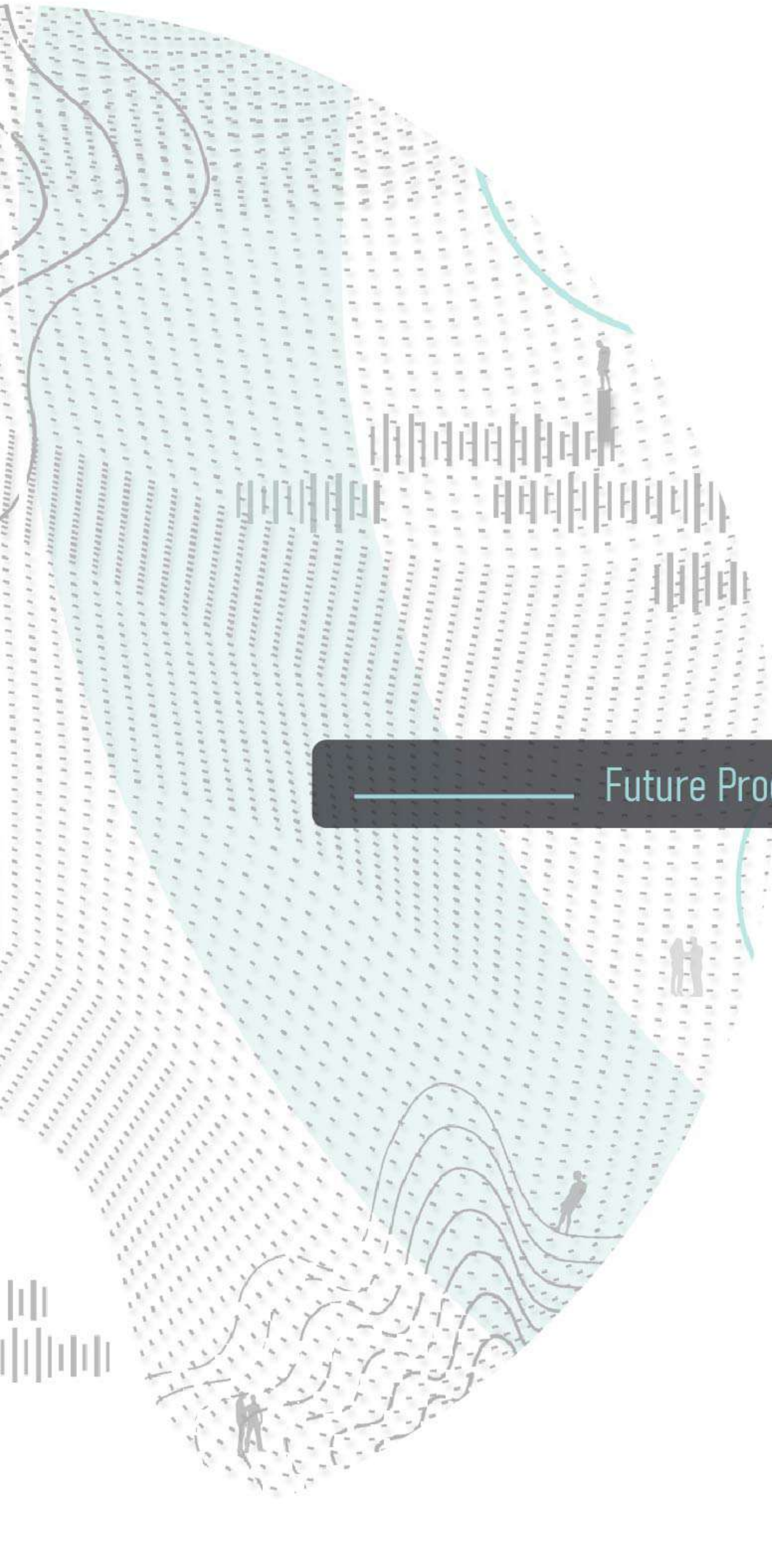

Future Proof & Extreme Scenarios

Future Proof & Extreme Scenarios

Universities Amid the Pandemic: How Architecture Can Help Better Manage the COVID-19 Pandemic?

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Abstract

Universities have been impacted significantly by the COVID-19 pandemic. Many students have been affected due to school closures in response to the pandemic. In addition to the impact of the pandemic on the education system, some social and economic consequences have also emerged due to student mobility and social life in universities. There is an urgent need for a set of principles to open universities up safely. The paper aims to offer a set of principles that enables universities to develop in a smart and sustainable way in order to be able to respond to the problems that occur especially in pandemic times.

Keywords: COVID-19, pandemic, universities, spatial recommendations

Introduction

The pandemic that began in Wuhan, China, has had an impact on our daily life. Despite the fact that numerous standard precautions are being taken to halt the spread of COVID-19, the increasing transmission of COVID-19 has heightened the worry. For decades, in buildings, particularly with significant mobility and occupancy, environmentally driven routes for infection were a concern for various viruses. Since many higher education institutions are multi-unit environments, with students, academic and administrative staff, and members of society interacting on campus, universities are ideal environments for virus transmission. As a result, limiting viral spread and transmission, as well as adapting to the "new normal" in its built environment, is vital in this environment.

When assessing the risk status of universities in terms of the spread of the pandemic, two major variables can be identified. The first are risks coming from the institution's features, and the second is dangers arising from the attitudes of the persons working in the institution (YÖK, 2020). In this context, the risks arising from the institutional environment include the gathering of academic and administrative personnel from all over the city on campus, the presence of employees using public transportation, the use of the same environment by researchers in academic and R&D activities, the common social and dining areas, the presence of different educational environments, and the presence of different educational environments. In other words, these are places where the efficient design of the built environment can aid in preventing the transmission of the virus.

The purpose of this article is to provide a set of principles that will assist universities in developing in a smart and sustainable manner in order to adapt to new problems, notably during pandemics.

Methodology

To provide that, the article aims to make a meta-analysis of the literature that seeks answers to the issue of postpandemic spatial measures in the built environment and provide historical data on this subject in order to determine the set of principles. This scientific research technique is a thorough and unbiased way of synthesizing research literature (Cook *et al*., 1997). To incorporate enough papers, the research databases "Web of Science," "Scopus," and "EBSCOhost" were employed. The articles published between 1990 and 2020 were analyzed to better understand the consequences of the virus's emergence, development, and transition into a pandemic and to examine the impact of prior pandemics on today's built environment. As research terms, the keywords

"COVID-19", "Built environment", and "Pandemic" was searched in the entire article, publication titles, and/or keywords.

Lessons from Past

Pandemics have shaped the built environment at all scales, from the smallest to the largest. To reduce the danger of contagious diseases, interior design, architecture, cities, and infrastructure have been adapted for pandemics.

In the 17th century, Europe's bubonic plague pandemic fostered large-scale urban planning design and construction of sewer systems, as well as the development of new transition concentration zoning regulations to protect employees and decrease the danger of infection (Lilley, 2015). In the nineteenth century, hundreds of thousands of people lost their lives in six cholera pandemics alone. The last three of the seven cholera outbreaks sparked a worldwide health movement (Harning, 2015). The push for health reform was influenced by cholera and typhoid. The pandemics aided in the development of water and sewage systems to combat infections, ultimately leading to hygienic innovation and requiring streets to be straighter, smoother, and broader in order to build underground pipe networks(Lai et al., 2020). In the twentieth century, modernism was seen as a cure for TB, typhoid, polio, and Spanish flu outbreaks. They have promoted urban growth, slum removal, housing reform, and waste management (Lubell, 2020). Modernist architects designed the built environment with pure form, rigorous geometry, contemporary materials, and a rejection of ornamentation to be free of disease and pollution, both literally and metaphorically. In addition to their artistic appeal, these components symbolized modernist preoccupations with the healing effects of light, air, and nature. Modernism in apartment buildings and suburban housing was inspired by balconies, terraces, flat roofs, and big windows utilized for patient rehabilitation (Campbell, 2005).

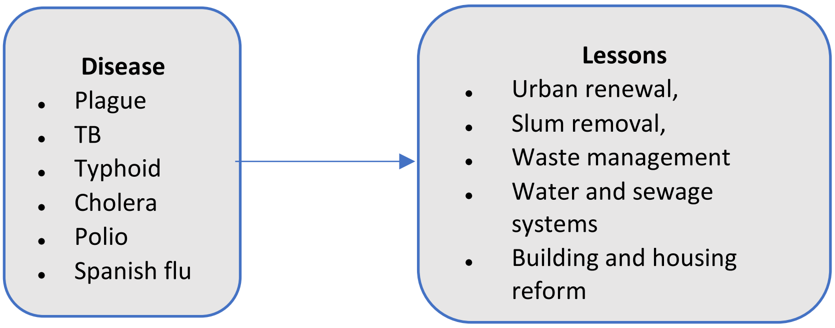

Figure 1: Lessons from past

COVID-19 has been added to a lengthy list of infectious diseases which are quickly spreading over the last century, such as bubonic plague, typhoid, polio, and Spanish flu, a challenge for architecture, to efficiently develop and to become a healthy built environment.

Discussing Sustainability: Lessons from nature

The importance of reconnecting with nature and its therapeutic properties cannot be overstated. The pandemic is still underway, but in the sphere of urban and architectural development, the COVID-19 pandemic has already exposed numerous design ideas and evaluated key assumptions. One of them is sustainability. Here are some key topics to consider.

- Urban settlements should grow horizontally. During a pandemic, there are additional hazards in the proximity of densely crowded cities. The greater the population, the more COVID-19 is concentrated in cities. With regard to the influence of social distancing, planners and architects may create more open places that might be critical to avoid infections and diseases from spreading according to widening horizontal approaches (Liu, 2020).

• Cities should be less densely populated. As social distance measures are vital to containment efforts, the density of cities was accused of quick spreading of illness and of being the safest suburbs. Urbanization might make a step forward towards improving towns and suburbs (Nicola et al., 2020).

• There should be fewer cars on the road, as well as greater opportunities for cycling and walking. Walking has shown both ecologically friendly and excellent for the physical and mental health of inhabitants, as an important means of transit and physical activities (Zhou et al., 2019). Cities should be more secure for walking and micro-mobility than simply dependent on mass public transit in the battle against infection and preserving a social distance. Although it is an excellent environmental solution for pollution reduction, public transport is not an ideal answer when a pandemic occurs, because it might help to transmit diseases among users (Campisi et al., 2020). Roads might need to be redesigned to accommodate multimodal transportation demands, which would make roads healthier, safer, greener, and more livable (HoneyRosés et al., 2020).

• It is necessary to focus especially on green places during self-isolation. Gardens, terraces, and green roof systems provide many sustainability benefits and are able to overcome most of the difficulties of selfinsulation (Megahed & Ghoneim, 2020).

• Air quality should be reconsidered. Following forced self-isolation and more spent interior use, methods such as higher natural light, better ventilation, reduced toxins, and the incorporation of plants and other natural materials are essential to enhance health (Megahed & Ghoneim, 2020).

Lessons
- Grow horizontally
- Less densely populated communities
- Less cars on the road
- Cycling and walking
- Green spaces
- Improved air quality

Figure 2: Lessons from sustainability

Looking to the future: How technology can help

Globalization has led to significant growth in human and commodities movements, the speed with which ideas and the potential for infectious disease transmission can be spread (Pinheiro & Luís, 2020). Today, more people than rural people live in urban areas (UN, 2019). The effect of infectious diseases and the creation of circumstances for the growth and spread of novel micro-organisms change urbanization (Reyes et al., 2013). The population has concentrated in fewer places, in some cases with poor health conditions, while technology enables hazards to be mitigated (Mikanatha, 2020). Here are some essential issues to think about.

• Artificial intelligence (AI) and touchless technologies have received a lot of attention. Automation, speech technology, and facial recognition based on AI might all affect post-pandemic architecture. As contaminated surfaces account for 80% of infectious illnesses, touchless techniques can develop into a novel interface that prevents the need to push or contact a surface physically (Tan et al., 2020). The postpandemic principles support more contactless methods, such as lifts from a smartphone without touching automatically open buttons and doors (Khan et al., 2021).

• Modeling simulation can contribute to reducing the COVID-19 effect. A global pandemic raises a slew of issues and challenges, not simply those concerning disease transmission, each of which needs a unique response. With simulation models of the built environment, it is feasible to develop solutions without encountering the challenges associated with the COVID-19 pandemic. Simulation models can help decision-makers make the best decisions possible (Currie et al., 2020).

- Hygienic construction materials must be focused on. It should be taken into consideration when designing spaces such as houses, offices, universities, etc., which not only meet human needs in functional areas but also serve as a protective atmosphere for isolated individuals. A specific effort is made in the building environment, touched by humans, to reflect on every potential site and to think about the risk of infection. Hygienic antibacterial material, technologically advanced cleaning strategies, and nano-solutions have been highlighted (Zaher, 2020).

Lessons

- Hygienic construction materials
- Artificial intelligence
- Touchless technologies
- Modeling simulation

Figure 3: Lessons from technological advances

Recommendations for Universities

Universities confront a unique dilemma, in order to balance the advantages of training on campus and at home with the dangers and expenses associated with the pandemic. On the one hand, the capacity of universities to prevent the spread of a virus on campus is highly restricted: students, professors, and staff all have personal interactions regularly occur in a small area and institutions have limited resources to screen and isolate students. At the same time, administrators also regulate the boundaries of many of these contacts exceedingly highly and are able to identify which students meet in what courses and with which students engage in a residential setting. Because of this complexity, it is not safe to use only one method to reduce the probability and extent of such a pandemic. Instead, an antivirus-generated environment with a multi-layered security approach to the defensive system should be deployed. Designers have to create an anti-Infection paradigm that prevents the spreading of the virus. In order to effectively handle the pandemic response at all levels and dimensions, both in the architecture and urban development, this paradigm must develop new tools, alternatives, or methods that are more flexible, integrated, and responsive.

While pandemics are disasters for humanity, they can be an opportunity for architecture and urban planning to adapt to future problems. It is clear that the knowledge gained from coping with numerous infectious diseases, as well as the development and spread of past infectious diseases, has enabled today's built environment to adapt more effectively to the current/next pandemic. The current pandemic has benefited by allowing designers and architects to reflect on previous experiences and learn what can be improved for future responses. Because of infectious diseases such as plague, TB, typhoid cholera, polio, and Spanish flu between the 14th and 20th centuries, various developments such as urban renewal, reforms in sanitation, construction, and housing have been documented to reduce the danger of infection. Covid-19 might have similar effects on the evolution of architecture and urban planning. (Saadat et al., 2020). Here are the recommendations learned from some past pandemics, sustainability debates, and the benefits that technology has/will provide.

- In this pandemic, putting human health at the center of the built environment as one of the goals of sustainable development is one of the most important implications. From a conceptual point of view, adding human health to the broader concept of sustainability is inevitable for the environment to be established after the pandemic (Hakovirta & Denuwara, 2020). In addition to that, several aspects tried by the built environment to ensure sustainability should be placed in the heart of today's built environment production process. It should make the transition to a greener, and more sustainable built environment, particularly in places that work/operate like a congested small city, such as a university.

For example, creating outdoor gardens, courtyards, nature walks, pathways, and open space available to inhabitants; creating access to terraces, balconies, and operable windows if possible, and connecting them to nature and fresh air for each space.

- As technology has become more prevalent in everyday life, the built environment, like many other sectors, has been profoundly impacted. Technology has advanced dramatically in recent years. This shift should be reflected in post-pandemic design and planning methods. More than ever before, technology and architecture must be linked. The modeling and simulation community should now take account of its role in helping both to improve the knowledge of the disease and prepare for improved decision-making and its effect. The modeling environment offers the chance of performing multiple silicon scenarios instead of testing with real populations and frequently helps create much better knowledge of the system as a whole by building models.

- High density, particularly in universities, can imply spatial compactness, longer queues, and larger campuses, with longer commute times. It is important to create rules for density-specific social distances in classrooms, workspaces, dining halls, on-campus public transit systems, pedestrian sidewalks, and green areas in post-pandemic campus planning.

- Green spaces have an impact on the risk of the spread of diseases (Zhang et al., 2020). In Campus design, green space requirements, which usually focus on the pro-rate provision, must be revised to make vast areas more accessible.

- The spatial configuration and design of closed public areas deserve specific attention, particularly during pandemics. Because university campus buildings, in particular, combine high mobility and congestion. In any case, the emphasis should be on decreasing pedestrian traffic throughout the building by ensuring visitors follow the social distancing rule.

- Transport is a critical element of campuses and hence frequently a doorway to disease at the time of pandemics. To limit the spread of pandemics, there have been major restrictions on public transportation (Du et al., 2020). On the university campus, transportation was substituted for walking. Activity-friendly surroundings can be important for combating COVID-19 since the connections between physical activity, better immune protection, and lower susceptibility to infection with COVID-19 have been developed (Simpson & Katsanis, 2020).

Conclusion

The outbreak of the Coronavirus threatens the entire world at the start of 2020. To restrict the spread of the pandemic, the whole world's population was compelled to stay at home and quarantine. Education, like many other aspects of everyday life, has moved online, as university campuses aid in the spread of the virus. However, in the new normal, university campuses are being debated. Many students have been affected due to school closures in response to the pandemic. In addition to the impact of the pandemic on the education system, some social and economic consequences have also emerged due to student mobility and social life in universities. Therefore, limiting the spread of the new coronavirus on campus is a key problem for universities that want to open up for face-toface education in autumn. The goal of this research is to provide a vision for preventing the spread of the virus or reducing its impacts in crowded places such as university campuses, based on lessons gained from previous pandemics and sustainability debates with the help of advanced technology.

Coronavirus is not the world's first pandemic; millions of people have died as a result of previous pandemics such as bubonic plague, typhoid, polio, and Spanish flu. COVID-19 was added to a long list of infectious illnesses that spread fast in the twentieth century. It marks a new challenge for humans to properly design and turn the spaces where they live into healthy built environments. History constantly recalls the links between infectious diseases and the characteristics of the spaces where we live. During the previous pandemics, some cases led to improvements in urban areas (cholera), such as improving infrastructure, sanitary facilities or even urban planning and cities adopted housing reforms to improve living conditions in tenements and other low-income housing. The other cases lead to building adaptations (tuberculosis), with the development of novel architectural features. Today, with the outbreak, sustainability and nature-friendly approaches are revisited. Nature-friendly strategies can play a role in reducing risk and making communities more resilient to pandemics. The integration of light, nature, and airflow into the architecture of a structure was viewed as a cure-all for sickness and disease. In addition. the role of Artificial intelligence (AI), touchless technologies, and simulations in architecture becomes ever more essential when populations are confined inside limited areas per capita. Smart technologies can make facility management more efficient and contribute to safe and healthy environments. Since universities are complex built environments, relying on a single method may not always be effective. Instead, applying a multi-strategy that provides a broad perspective, in which benefiting past experiences, considering current debates, and blending them with technological advances will make universities more resilient against future pandemics.

This article also highlights possible topics for future research. Because universities function as "mini-cities", addressing the criteria at the level of regulations, zoning plans, and development plans can be a continuation of this research.

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Evaluation of Post Disaster Temporary Housing Units in the Context of Covid-19: The Case of 1999 Marmara Earthquake

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Extended Abstract

The disasters that interrupt or change the flow of daily life are the inevitable realities of the 21st century with the high probability of occurring at the same time. The second most frequent kind of disasters that occur are earthquakes in Turkey with a 55 percent victim ratio in all other types of natural disasters (Gökçe et al., 2008). According to the MSK (Medvedev-Sponheur-Karnik) scale and the degree of damage in various building types depending on the intensity, earthquakes that happened in Turkey during pandemics with intensity above VI have been researched because of higher damage ratios (Tabban & Gençoğlu, 1975) and results have shown that; an earthquake occurred, the epicenter was (in a Greek Island, Samos) 23 km from the Seferihisar district of Turkey's Izmir province, with a magnitude of 6,9 and lasted about 16 seconds (1900 - 20xx Deprem Kataloğu, n.d.). Even in a short period (since COVID 19 pandemics had started in March 2020) intense earthquakes may happen, so in cases where there is no prevention at the post-disaster sheltering places, increasing the rate of spread is predictable. Therefore both in Turkey and worldwide, disaster management should be reviewed considering pandemic conditions.

Within the scope of the study, 1999 Marmara Earthquake prefabricated temporary houses' plans are evaluated in the context of pandemic resistance. Thousands of prefabricated houses can be produced when needed, which means any of the mistakes can be repeated thousands of times. Therefore self-built shelters that people can utilize are excluded from the study. One of the objectives of the paper is to demonstrate to designers how the pandemic or any other respiratory disease can affect the architectural design. Thus providing resilience to the temporary housing plans, the effect of conflicted disasters can be mitigated or prevented by the study.

The method is followed in the study to evaluate post-disaster temporary housing plans in the context of pandemic resistance in means of convenience; the literature review, determining and weighting the criteria that can reduce contamination caused by design mistakes and lastly examining the case of 1999 Marmara Earthquake temporary housing units. Coefficients of the criteria are determined with a multi-criteria decision-making method (Analytic Hierarchy Process) via a pairwise comparison matrix. Then, the related plans are introduced and gathered in an evaluation matrix.

To prevent the spread of the pandemic during rehabilitation and reconstruction periods of disaster management phases, criteria have been determined based on the question of what the design decisions can be for the post-disaster temporary houses. Convenience to the pandemic context can be thought of as mainly the decrease of spread and motivating people to stay at interiors and both are aimed in this study while investigating design decisions. In this investigation it is reasonable to discuss the subject at two scales: Temporary housing scale and site plan scale.

It is also reasonable to divide the preventions that can be taken to reduce the transmission by air and physical contact at the scale of temporary housing into two categories: planning of the house and architectural detailing. Criteria that may have a positive impact on planning are; considering spatial solutions that will ensure the effective use of natural ventilation, providing areas that have the potential to be stored in order to prevent contaminated items that can carry the disease, considering remote working conditions that have become widespread with the pandemic, to have a small entrance area in order not to carry viruses to inside of the house,

having at least one bedroom to isolate any infected person at home, and positioning of wet spaces as close as possible to entrance for sterilization.

AHP is the preferred method for the study because even though it may have some problems of interdependence between the criteria and alternatives resulting from pairwise comparison, it is scalable and easily allows weighting coefficients and comparing alternatives (Velasquez & Hester, 2013). The phases of AHP are respectively; determining the aim and criteria then the degree of importance of criteria by scoring through comparing them with each other, getting the final score by multiplying the scores of alternatives with coefficients of importance.

The importance sorting of the criteria according to pairwise comparison matrix is “Number of rooms > ventilation > entrance = remote working > wet-block > storage”. To determine the weights of criteria, a normalized pairwise comparison matrix that is written. Then the criteria weights (priority vectors) are determined. The consistency of the process is critical to find accurate results so the consistency ratio (CR) is 0,035 which is plausible since it is way too small than 0,10. Thus the evaluation of plan types can be held on these priority vectors (Akdede, 2018).

According to TTB (Turkish Medical Association), 161,994 people were accommodated in 41,425 temporary residences built in Bolu, Düzce, Kocaeli, Sakarya, and Yalova, after the 1999 Marmara earthquake. 29.246 (70.6%) of these houses consist of prefabricated buildings (TTB, 2001). Therefore, it is possible to claim that approximately 110,000 people stayed in prefabricated houses after the earthquake. Within the scope of the study, five different plan types of prefabricated housing units are examined and evaluated with the criteria to determine the preference scores (Table 1).

Table 1: The evaluation matrix (1: Excellent, 2: Good, 3: Fair, 4: Poor, 5: Bad, 6: Very Bad).

	Type 1	Type 2	Type 3	Type 4	Type 5	Criteria weights
Ventilation	2	4	3	5	3	0,239
Storage	5	4	2	4	3	0,029
R. working	5	2	3	1	4	0,113
Entrance	6	3	4	2	5	0,113
Number of rooms	5	2	5	2	4	0,453
Wet block	5	1	6	1	1	0,053
Preference score	4,40	2,60	4,15	2,61	3,69	

The result of the evaluation shows that Type 2 and 4 are the best types according to defined criteria and their importance, respectively followed by Type 3, 5, and 1. Also, Type 2 is slightly better than Type 4 and Type 1 is the most repetitive one is the worst option.

As a result of the evaluation, this study developed knowledge about post-disaster temporary housing design in a pandemic context. Although the differences in the sections may affect the ventilation performance, the evaluation is carried out on the planimetric plane since all the houses are similar in the sections. Therefore plans become quite instructive to evaluate the pandemic performance of the temporary buildings.

Although the designs including corridor entrances and separations between spaces become more successful considering preference scores, ventilation performance is not favourable as separated spaces obstruct providing cross ventilation to every space. Therefore, the optimum system should aim for maximum separation while providing maximum clean air to each place (including corridors). This approach may cause unfavourable spatial results, it is possible to get qualified housing unit types with different design solutions at section planes and different typologies than detached buildings (preventions can be taken at the site plan scale in order to solve a problem at housing unit scale).

According to the study the correlation is determined between preference scores and area of plan types except for type 3. It is predictable if the area of the plan becomes bigger than 60-70 m^2, it doesn't get a higher score. Also, optimization of score and area may be approximately determined via the correlation. This study examines the housing unit scale that stands out between the site plan scale and architectural detailing scale. Further works may be carried on the site plan and architectural detailing scales that can be examined elaborately.

Keywords: Pandemic resistant design, post disaster, temporary housing.

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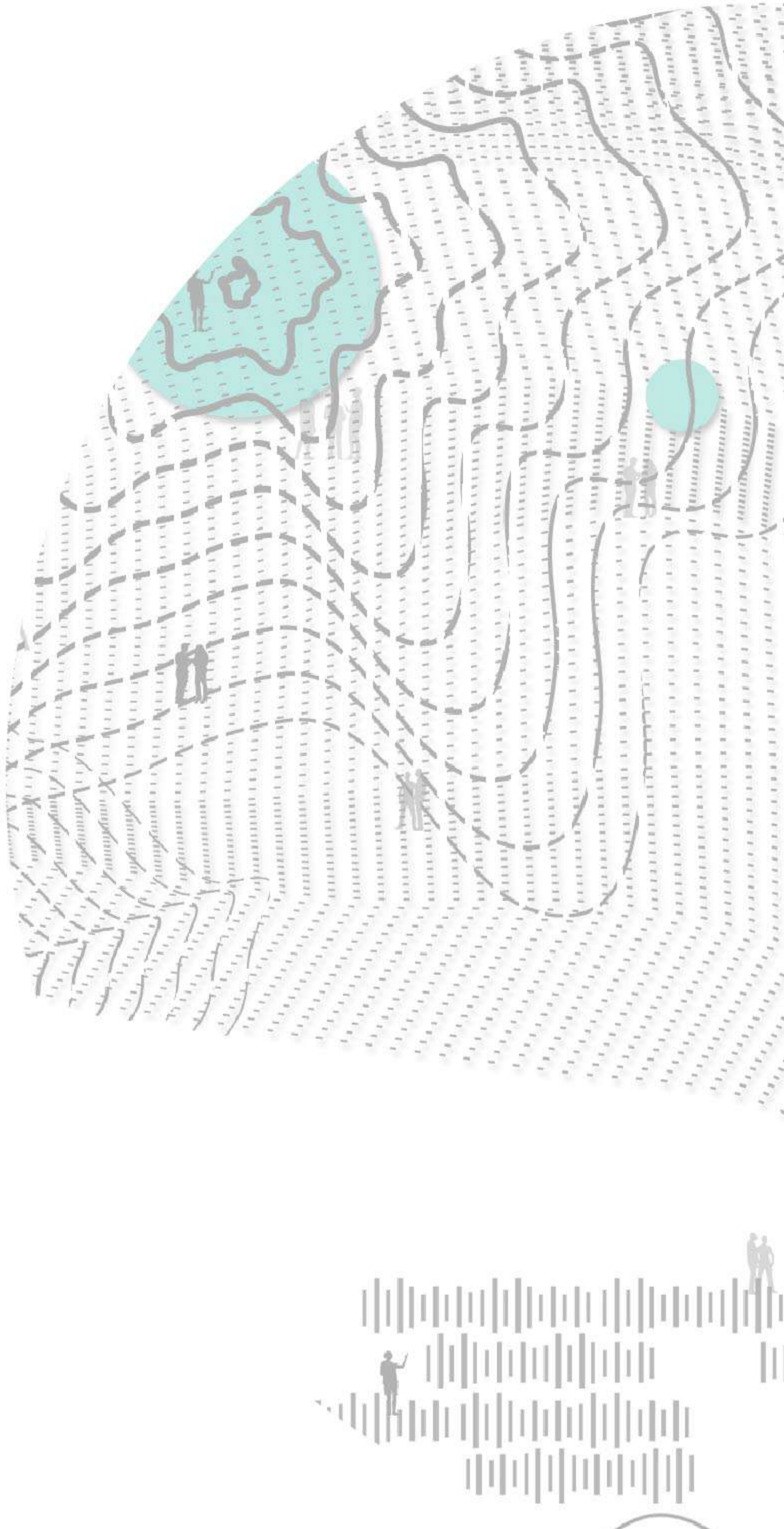

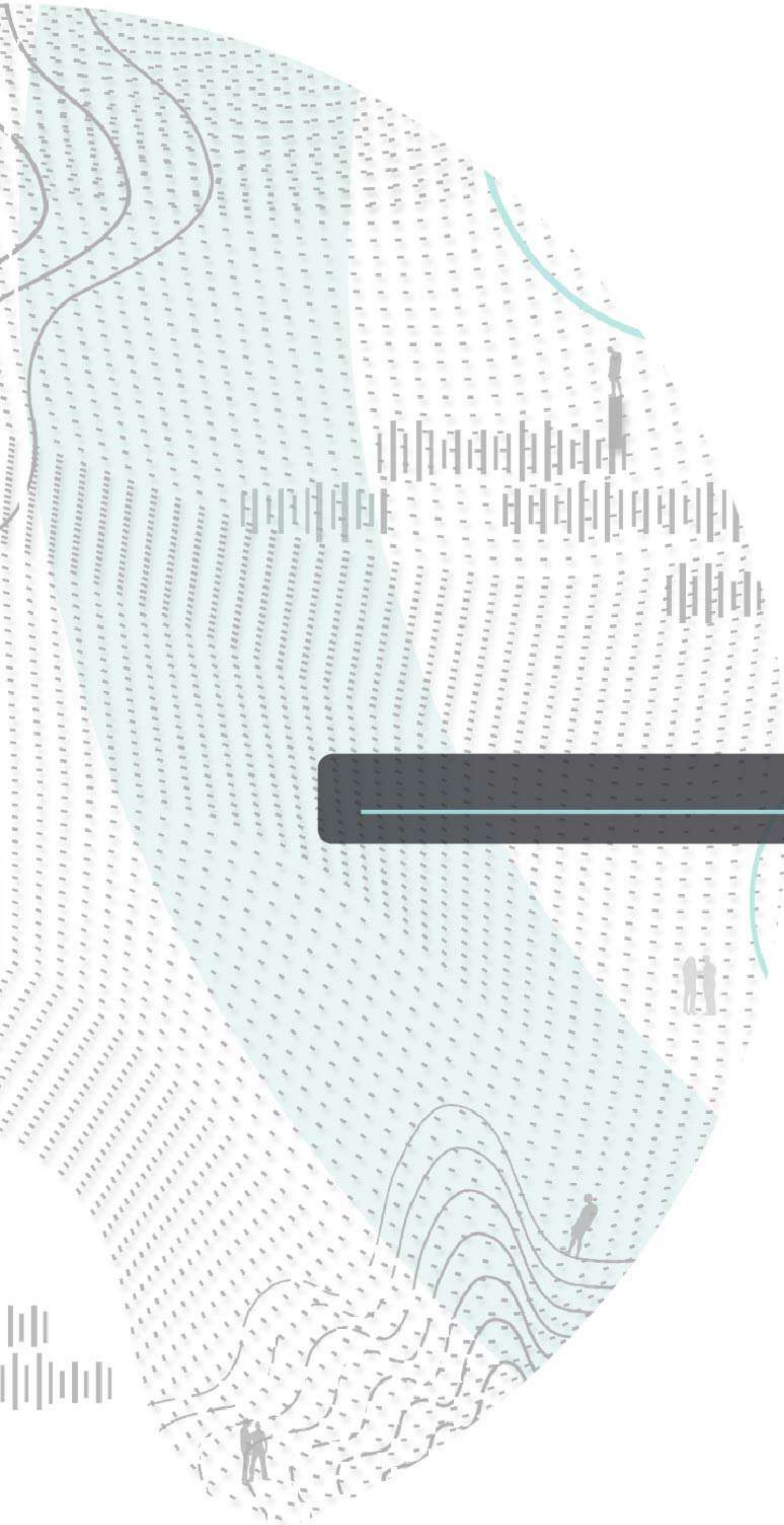

Energy Efficiency

Energy Efficiency

Developing an E-Planning System Compatible with Smart City Design Principles – Case of Bayraklı
Tuğçe Altınkilit, Muhammed Aydoğan

Towards More-than-human Participation: Rethinking Smart City
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Industrial Ecology Self-Organization System and Its Adaptation in Chinese Urbanism
Minjoo Baek

Mind The Space: Using Meteorological Architecture to Define The Life of Public Spaces
Jale Sari

Developing an E-Planning System Compatible with Smart City Design Principles– Case of Bayraklı

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Extended Abstract

The concept of smart cities has been used as a popular urban planning tool by city managers in recent years. The use of smart cities in urban environments has brought new technologies such as social media, artificial intelligence (AI), internet of things (IoT) and big data to cities. The success of these new technologies in smart city applications has placed the concept of smart cities in the first place in the solution of urban problems in a short time. It is thought that rapid population growth and related urban problems will negatively affect sustainable development in the coming years. As stated in the 2018 revision of the UN World Urbanization Prospects, there is a risk of inadequate basic services such as energy, transportation and housing, especially in developing countries (United Nations, 2018). In the beginning, smart city projects carried out by technology companies consisted of the use of new technologies to solve urban problems. Today, however, smart cities have begun to be used as a more participatory and citizen-centered concept to achieve sustainable and livable city goals. Researchers defines smart city as a city that infrastructures and services of this city are combined with the digital networks like high technologies such as new generation geographic information systems, information and communication technologies and mobile sensors. Smart cities aim that energy production for more sustainable cities, more efficient logistic management to create a global and more competitive economy, high environmental conditions with ecological smart city practices and policies. Therefore, smart city offers adaptive and technological decision-making instruments for whole stage step of urban planning such as disaster management, transportation and preserving natural resources (Dameri, 2013).

By smart governance, which is one of the important components of smart cities, big data in the city is collected and analyzed with new technologies such as ICT and IoT. In this way, it is aimed to serve the participatory society by providing more transparent and efficient communication both between citizens and institutions and between institutions (Giffinger, 2007). Further, e-planning concept refers to an electronic (e-) transformation of city planning utilities such as analyzing, collecting and projecting whole data and geographic information of a city by using new technologies for gaining more effective, holistic and rational qualifications of planning (Budthimedhee et al., 2002). Considering the future of cities, the research subject is extremely important because of that the smart cities' power to reform daily life and urban areas with produced and marketed urban technologies and different accessibility levels to these new technologies due to socio-economic disparities in the society (Velibeyoğlu, 2016).

Within the scope of this study, the main target question is how conventional planning process should convert into 'e-planning' approach in considerably different urban patterns such as central business districts, conventional housing areas or squatter settlements. Accordingly, to classify e-governance potential of residents who live in these different urban patterns and have different technological skills is the main purpose of this study in order to participate them in city planning fairly. As the case area, Bayraklı district in İzmir has been chosen. This is because Bayraklı Municipality has declared Bayraklı may be potential smart city pilot area in cooperation

with Siemens. Besides, Bayraklı district has different neighbourhood patterns including high income luxury residential towers as well as low income squatter areas.

In order to evaluate the potential of smart governance needed for e-planning in Bayraklı district, the main methodology of the study is to map and spatially analyse the use of online municipality services in urban areas with different socio-economic characteristics in the district. With this approach, the location information of residents who use online communication tools of municipality in Bayraklı was used by the researchers. Looking at the online services of Bayraklı Municipality, two active and available digital communication tools were detected. These tools were a mobile application and an official website. Since the mobile application was not used very actively, data from e-service section of the municipality's website were analysed for this study. It was built a spatial database via GIS including the the transaction information, location information of these residents and access level to the technology of residents who use the online 'application-request-demand' section in the 'eservice' section of the municipality's official website during 2020. Hence, the online interaction level of residents who are located in different urban patterns could be evaluated.

To conclude, in order to determine the level of readiness for smart governance and smart urbanization in Bayraklı, transaction numbers of the citizens with the municipality over the municipality's official webpage were examined within the scope of this study. Researchers were able to identify the relation between transaction numbers of the citizens with the municipality and who live in different urban areas such as central business districts, squatter settlements and conventional housing areas on digital maps and have different social, economic, technological and physical characteristics. The findings of the study will provide information to city managers about potential e-participation capacity for future smart city applications or e-planning processes in Bayraklı.

Keywords: Big Data, E-governance, E-planning, smart city, urban planning

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Towards More-than-human Participation: Rethinking Smart City

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Abstract
The smart city concept, understanding the city from a technology-centered perspective, affects the formation of different ways of seeing by limiting the relationships in the city to human-centered interaction. Maintaining the human-centered approach is deepening the crises because of the pragmatist perspective in which every nonhuman being is seen as a resource to be exploited for human needs. However, this approach also reveals the necessity of new participation and collaboration systems with an understanding of the limitations of humancentered practices in dealing with the urban and environmental crises experienced today. Therefore, in order to move away from the human-centered, it is important to establish a more-than-human understanding. The new perspectives generated by the concept of more-than-human on city-related issues open discussions on new questions for urban designers. The most critical question is, what is the role of urban design in rethinking the city with more-than-human participation? This research focuses on understanding how urban design practices affect the interaction between humans and non-human beings in the city. The aim of this research is to question the requirements of an alternative design approach that considers the city as a more ethical and equal place for all species. A multiple-case study method was used to help understand how design approaches and designers' roles affect the interaction between humans and non-human beings in the city. Consequently, this research considers smart cities beyond anthropocentrism and critically explores how design could develop inclusive and ethical relationships for the post-human future of cities.

Keywords: Anthropocentrism, human-centered, more-than-human, participation, smart city.

Introduction
The prevalence of the modernist idea that nature is a place considered wild and unsuitable for humans has led to the definition of cities as physical settlements away from nature (Steele et al., 2019). Regarding this, thinking of the city apart from nature and focusing on making it the most suitable place for humans has increased humancentered approaches and interventions. Increased human interventions in the Anthropocene epoch that we are living in are seen in natural ecosystems, geological complexes, and even the climate (Zaera-Polo, 2017). This also explains the consensus that various critical issues such as climate change and biodiversity loss are linked to human activities (Luusua et al., 2017).

Environmental and urban crises, which are among the main concerns of the Anthropocene epoch, are increasing the vulnerability of cities and revealing that current human-centered approaches are insufficient to deal with them. While these crises prompt national and international organizations to find solutions, technological advancements are seen as effective instruments in understanding and managing these processes. Therefore, this motivation is encouraging the seek of smart ways for cities and increasing the interest in smart cities (Chourabi et al., 2012). As the smart city approach is defined in various ways in different parts of the world according to changing conditions, there is no consensus about a common definition (Nam and Pardo, 2011). While the exact definition varies, the term ''smart city'' has been used to express the use of information and communication technologies to support and improve the development of cities in various fields, in particular public services and economic development (Schaffers et al., 2012, p.11). Furthermore, smart cities play an important role in monitoring and developing processes of increasing the service quality of basic infrastructure to provide advanced city services, including transportation, water, and communication (Hall et al., 2000). The digital technologies (e.g., hardware sensors, software, and big data) used in these processes are used to understand and manage complex city systems as well (Aurigi & Odendaal, 2020). In other words, the smart city concept can be characterized as powerful tools in which technological solutions are integrated into urban and social problems from a technocentric perspective (Wang, 2017).

The use of this power in a way to encourage economic growth and development by creating the image of a healthy and clean city establishes a close relationship between neoliberal policies and the smart city. While this relationship causes increased top-down control of neoliberal urban policies in the city, it also deepens the inequalities in access, representation, and participation among species. Therefore, smart city approaches, which represent an important initiative to contribute to urban development, contain many contradictory and faulty situations (Clarke et al., 2019). Among these situations, anthropocentrism has a critical role in deepening the mentioned crises. In the basic definition, anthropocentrism is defined as human-centered thinking. This way of thinking stems from the Western contemporary dichotomies: e.g., human/non-human; nature/culture; mind/body; city/nature, etc.) (Heitlinger & Comber, 2018). Also, maintaining anthropocentrism is deepening the environmental crises because of the pragmatist perspective, in which every non-human being is seen as a resource to be exploited for human needs. Therefore, in order to move away from anthropocentrism, it is important to establish a more-than-human understanding. In recent years, there has been an increasing interest in 'more-than-human' in environmental, social, and scientific studies, and it has connected to many concerns, particularly climate change and environmental crises. Because the multi-layered environmental and social crises of the Anthropocene epoch require an expanded understanding of the interconnections between humans and non-human worlds (Castree, 2014). Nonetheless, while many governments are developing participatory approaches to environmental challenges, these approaches still remain limited to anthropocentrism (Clarke et al., 2019). The only way to reduce this limited understanding of participation is to encourage non-human beings' involvement with their own voices, rights, and freedoms (Roudavski & Rutten, 2020).

The new perspectives generated by the concept of more-than-human on city-related issues offer opportunities for different collaborations. The scope of these perspectives is broad and interdisciplinary and opens discussions on new questions for urban designers. The most critical question is, what is the role of urban design in rethinking the city with more-than-human participation? A further question to consider is, what is the ethical responsibility of the urban designer in the relationship established between humans and non-human beings in the city? This research focuses on understanding how urban design practices affect the interaction between humans and nonhuman beings in the city. The aim of this research is to question the requirements of an alternative design approach that allows thinking of the smart city beyond anthropocentrism as a more ethical and equal place for all species. A multiple-case study method was used to help understand how design approaches and designers' roles affect the interaction between humans and non-human beings in the city. Case studies were determined from projects that use the digital technology and infrastructure systems of the smart city concept and include non-human beings in project design approaches, and animals were referred to as non-human beings in the selected case studies. Besides, these case studies were evaluated in view of the more-than-human, anthropocentrism, closed and open systems concepts by aiming to create contrast and look at the urban design process from different angles. Consequently, this research considers smart cities beyond anthropocentrism and critically explores how design could develop inclusive and ethical relationships for the post-human future of cities. Even if the post-human future of our cities might sound unusual today, it might be the last opportunity to prevent urban ecocide and protect the existence of humans and non-human beings on our planet for the future (Yigitcanlar, 2018; Yigitcanlar et al., 2019).

More-than-human Approach

The thinking that nature and society are ontologically separated from each other, is closely related to other dichotomies of the Enlightenment and modernism (Dyer, 2008). The idea that human is a being above everything came to the fore with the Enlightenment movement, and it has also been supported by people working in different fields, such as philosophers, scientists, politicians, and educators in the historical process (Beavington, 2016). The main purpose of Enlightenment humanism is to prevail the understanding of providing a world service to humans by expanding ethical issues and responsibilities (Metzger, 2012). This way of thinking deepens the misconception that everything in the world exists to serve human beings. In other words, this increases human exceptionalism and causes the ignoring of intertwined relationships with non-human beings. The fact that this understanding has reached a point where it has lost control in the Anthropocene epoch causes rapid global and planetary changes. Moreover, these changes threaten life in terms of humans and non-human beings, and it reveals the necessity of regaining lost control. At this point, the "more-than-human" approach, which rejects the superiority of humans over non-human beings and believes that life consists of interactions created by the collective relations established between humans and non-human beings, provides a critical opportunity to regain lost control. The more-than-human approach seeks to solve the distinctive dualism of the Western tradition of thinking (e.g. nature/culture, subject/object, and human/non-human beings). Also, it tries to understand human interaction with the environment by investigating non-human beings (e.g. animals, plants, and objects). In simple terms, the more-than-human approach encourages understanding the world as a multi-dimensional and multicultural place from a holistic perspective.

More-than-human studies have been extensively debated and developed in various fields, particularly, in geography, feminist studies, science and technology, and political science (Steele et al., 2019), and these studies have various intellectual and political origins. These are mainly concerned with object-oriented ontologies, which argue that non-human objects and reality are independent of human existence (Umbrello, 2018), and hybrid geographies that evaluate the social and natural worlds without separating them (Driessen, 2017). Furthermore, these could be expanded to political ecology, which considers environmental issues from social and political perspectives (Kull et al., 2015), and to posthumanism, which advocates blurring the boundaries between humans, animals, and technology (Bolter, 2016). Exemplifying studies encouraged by these theories are: "becoming with" others by encountering and recognizing each other (Haraway, 2008, p.19), and "vital materiality", which emphasizes the kinship between humans and non-human beings (Bennett, 2010, p.112). For Deleuze (1977, p.69), the important thing about this kinship is not the similarities, but the heterogeneity brought together by the differences. Furthermore, Latour (2005, p.46) states that while trying to understand this heterogeneity through "actors", he emphasizes that a single actor cannot be defined in these relations, and their roles cannot be explained clearly. These theories draw on nature and society as complex and hybrid forms, not separate from each other, and emphasize the participation and role of non-human beings in the formation of these forms (Choi, 2016). The common discourse in more-than-human literature advocates the inclusiveness of non-human beings by rejecting the superiority of humans within the framework of ethical responsibility.

The necessity of this understanding is clear from the criticisms of the scholarships working on the more-thanhuman theories. According to the scholarship of "more-than-humanism", non-human beings pay the price for the spread of the idea of human supremacy, being excluded from ethical and political issues (Metzger, 2012), and the inequality and power relations created by capitalism cause symbolic and material exploitation of nonhuman beings (Ogden & Gutierrez, 2018). Therefore, the critical point is to identify methods that enable and develop thinking in more-than-human societies without any conceptual or material distinction between humans and non-human beings (Srinivasan, 2018). This means that it is necessary to consider that the non-human world includes multispecies entities, and they have a flow that includes different dynamic processes shaped according to their own rules and causality (Ogden et al., 2013). Following Commoner (1971, p.16), we can consider that "everything is connected to everything else," but it is necessary to understand these connections by taking into account the rights and freedoms they have. Only from this point of view, can it be possible to talk about the future beyond anthropocentrism.

Beyond Anthropocentrism

In the Anthropocene epoch, the future is radically being restructured by human interventions on the environment (Houston et al., 2018). However, it is hard to interpret this restructuring positively, especially by looking at the destructive environmental changes such as global warming, loss of biological diversity, and deterioration of habitat areas. Therefore, it is critical to understand the anthropocentrism that plays a crucial role in the formation of these changes. Anthropocentrism is defined as human-centered thinking with its basic definition and is often used synonymously with the term "human exceptionalism" in which human superiority stands out (Gribben & Fagan, 2016). Although 'anthropocentrism' is commonly used as a human-centered term, it also refers to human-centered values that have not existed in other entities (Kopnina et al., 2018). The separation of human beings from the rest of nature with characteristics such as spirit, language, and mind and associating ethical values with only humans are effective in deepening the understanding of anthropocentrism (Hayward, 1997). In other words, this point of view accepts that humans are privileged because they have features that other entities do not have, and that it is not an ethical problem to use other entities as a tool for human service even if they suffer from this (Srinivasan & Kasturirangan, 2016). Also, this understanding shows the ethical dualism dominance that privileges human beings in the relationship between humans and non-human beings (Srinivasan, 2018). According to Beavington (2016), the relationship established between humans and non-human beings resembles an asymmetrical marriage in which one partner ignores the rights of the other. Therefore, this kind of relationship makes it difficult to talk about environmental justice and ecological restructuring (Haraway, 2018).

Despite the recent increase in interest in more-than-human approaches to environmental crises, this attention is limited because it generally focuses on situations and concerns that affect human life (Akama et al., 2020). Therefore, this human-centered perspective makes it necessary to consider more-than-human participation inclusively. For this kind of inclusive participation, first, it is necessary to overcome ethical dualism and remember mutual responsibilities. According to Barad (2007), ethical responsibility is not only about establishing appropriate relationships with the marginalized, but also about taking responsibility for the relationships of which we are part. For this reason, it is important to consider the world we live in as a whole, consisting of hybrid, dynamic, and complex relationship networks. It means taking into account that heterogeneous relationships of various scales and sizes are produced and changed by different actors (Law, 2007). Otherwise, when we focus only on ourselves and establish a relationship with the environment in this way, ethical distances and distinctions become clear (Tschakert, 2020). Changing attention to more-than-human encounters in cities offers an opportunity to understand these complex relationships and the networks of communication between humans and non-human beings (Ogden et al., 2013). For this, first, these key questions should be asked: How can these multiple ways of seeing be integrated into the city? Who are the actors, and what are their roles in making the interaction between humans and non-human beings more inclusive? The answer to these questions is important for considering the future of a city beyond anthropocentrism. Therefore, to move towards such a future, we need to discuss what we could and should do—and how.

Rethinking the Smart City

The smart city approach, which is seen as an effective solution to the environmental and urban crises, uses advanced infrastructure and technological systems (e.g. IoT, ICT, and AI) to generate smart, clean, and healthy city visions. The cooperation of this approach with private companies to increase urban development and service quality causes urban infrastructure services to be discussed on privacy, governance, and ownership matters. Moreover, among these discussions, there are concerns about increasing social segregation, the decrease in the privacy of private life, and the institutional power that undermines democracy (Brock & Roudavski, 2020). According to Kitchin and his colleagues (2019), smart city technologies (e.g. government, security, transport, energy, etc.) are used for control and management purposes in city infrastructure and services directly affect society. Furthermore, the fact that such top-down approaches have an impact on the social structure creates the perception that the city is a controllable and closed system. It means that this closed and controlling system ignores cities' dynamic structure and diversity, leading to a monotonous perception of the city. Contrary to this perception, cities represent a complex and open system characterized by uncontrollability, incompleteness, and unpredictability (Sennett, n.d.).

The growing debate that top-down and economic approaches used in smart cities limit citizens' participation in urban issues has recently increased technology-supported participation initiatives, especially in decision-making processes. However, these initiatives, which emphasize the concept of "cities for people" (see Gehl, 2010) and aim to create democratic environments, only allow humans to participate in the process, excluding non-human beings. Although the interaction between humans and non-human beings can be easily noticed in everyday life, ignoring this interaction creates a contradictory situation in democratic participation and makes it necessary to understand these interactions. At this point, changing ways of seeing everyday life to notice these interactions could be a useful starting point for rethinking who the city is really for. As the understanding of the city as a place of production of limited relations and a controllable closed system causes the city to be understood differently than it is, the importance of this understanding that the city is a complex and open system should be emphasized once more. This understanding stresses thinking about the city with its connections without focusing on any concept and understanding this in the system that is open to recognizing new connections (Braidotti, 2006, p.139). From this perspective, it could be possible to rethink the city as an open and dynamic place where new relationships can always be established by "becoming with" others.

Understanding and developing these connections in cities shows the need to define new directions and develop collaborative methods for multidisciplinary work, especially in urban planning and design. One way to incorporate this approach into urban thinking through urban design is to consider these questions: How can smart city tools help us to think about cities in terms of human and non-human beings? How can urban design practices contribute to the development of collective relations formed by the interaction of human and nonhuman beings in the city? What is the role of designers in rethinking the smart city as an open system through more-than-human participation? These questions indicate that urban designers, who have an important role in shaping the environment and influencing different living forms, should realize what kind of effects their own actions have on cities. In order to understand this responsibility, it could be the first step to reconsidering what the word "empty" means, used to shape and develop "empty" land, which is commonly used for current planning and design practices in terms of non-human beings (Wolch, 1998, p. 119). It means that the designer has an important responsibility for generating an alternative understanding separated from ethical dualism to ensure the participation of non-human beings in the city (Luusua et al., 2017). This perspective considers the designer not as someone who has the authority to control and shape from a human-centered perspective, but as someone who bridges the clarification and development of engagement between humans and non-human beings. Briefly, designers can help create democratic environments in which humans and non-humans interact. However, before any of these role distributions, it is important to critically evaluate existing urban design practices understanding whether projects focusing on more-than-human participation are inclusive. Only from this critical point of view, could it be possible to talk about how we can rethink smart cities with more-than-human participation.

Method

In order to understand how existing urban design practices affect the interaction between humans and nonhuman beings in the city, a multiple case study method was used in this research and animals were referred to as non-human beings in the selected case studies. Living Breakwaters, Living Biobank, 'Hypar-nature' wildlife bridge, and Amphibious Architecture projects, among the design projects that use digital technology systems related to the smart city vision and incorporate the interaction between humans and non-human beings into design approaches, were determined as case studies. The selected case studies were evaluated within the framework of the concepts of more-than-human, anthropocentrism, and closed and open systems.

Case Studies

Living Breakwaters

After New York was severely affected by Hurricane Sandy in 2012, multiple attempts were made to minimize damage. One of these attempts, the Rebuild by Design (RBD) competition, organized to take precautions against climate change and long-term risks, was launched in 2013 by the U.S. Created by the Department of Housing and Urban Development (GOSR website, n.d.). The Living Breakwaters project, proposed by the SCAPE Architecture team, was awarded in the competition. The project suggests bringing oysters to New York harbor in the next 20 years, improving local resilience, and raising awareness of the community (ASLA website, n.d.). The aims of the project, which develops layered and systemic approaches to infrastructure planning, can be summarized as risk reduction, ecological enhancement, and fostering social resilience (GOSR website, n.d.). Furthermore, the project's inclusion of community and stakeholder participation in initiatives encouraged to understand how and where best to conserve fish, lobster, and shellfish creates a link between the ecological and social dimensions of the project (BFI website, n.d.).

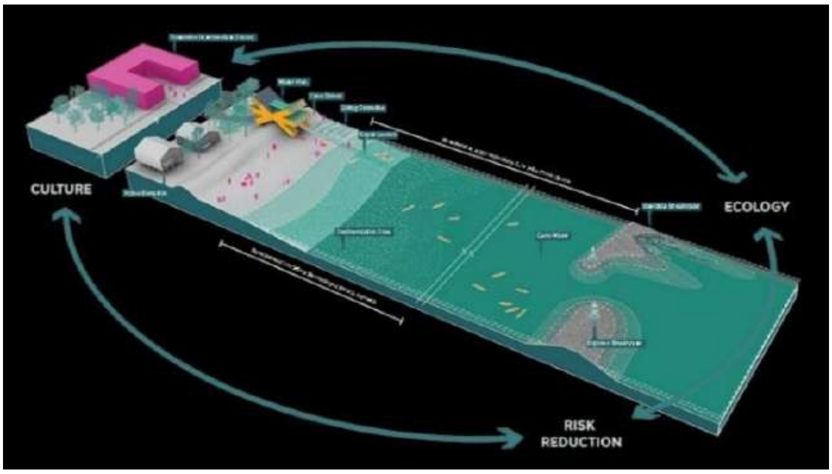

Figure 1 Living Breakwaters *(Source: https://www.scapestudio.com/projects/living-breakwaters-competition/)*

As stated before, it is critical to integrate multiple understandings that do not focus on only one concept in the more-than-human design approach. The fact that the Living Breakwaters project considers the consequences of climate change not from a human-centered perspective, but through the protection of local biodiversity, indicates a comprehensive ecosystem understanding. Furthermore, involving the community in the process encourages interaction between humans and non-humans by allowing for increased social interaction as well as recognition of the local ecosystem. More importantly, aiming at integrating culture, risk reduction and ecology into the project design process (e.g. Figure 1) can be considered as an important step towards blurring the boundaries between nature and culture. Consequently, the fact that the project considers marine life in its own entirety rather than from a human-centered point of view shows where the design stands in the interaction between humans and non-human beings.

Living Coral Biobank

The Living Coral Biobank project, designed by Australian architectural firm Contreras Earl Architecture and developed by engineering and sustainability consultancy, aims to protect the biodiversity of corals threatened by climate change and to provide optimal conditions to keep them for future generations (Melbourne Design Week website, 2021; Reedie, 2021). While the facility aims to create a sustainable environment by controlling energy consumption through mechanical and technological systems, particularly sensors and real-time monitoring, it also aims to provide the opportunity for visitors (e.g. Figure 2) to observe corals (Reid, 2021). The project team states that they thought of corals as users in the design process, and intended to design a facility that would enable human users to best understand the living organisms on display (Reedie, 2021).

Figure 2 Living Coral Biobank *(Source: http://www.contrerasearl.com/the-living-coral-biobank)*

In the project, the relationship established between corals and humans through observation and 'display' raises questions about the role of non-human beings in the design. While the starting point of the project is the loss of biodiversity, the emphasis on biodiversity conservation for future generations creates uncertainty between the project suggestions and the more-than-human approach. The fact that the interaction between humans and nonhuman beings in the project takes place in a closed facility where technological tools are used, can be interpreted as an effort to integrate corals into the human world in a 'controlled' way. At this point, it can be emphasized that, from a more-than-human perspective, it is necessary to evaluate the interaction between humans and nonhumans within the context of collective integrity in which different connections are integrated, rather than a one-sided integration. As Rosi Braidotti (2006, as cited in Ednie-Brown et al., 2020) states, "'a living nexus of multiple inter-connections' and alliances that empower the collective. We are all in this together."

'Hypar-nature' Wildlife Bridge

In the Animal Road Crossing (ARC) International Wildlife Crossing Infrastructure Design Competition, the 'Hyparnature' wildlife bridge, which aims to ensure a connection between the divided habitats, was awarded (Climate ASLA website, n.d.). Hypar-nature, which was developed by MVVA and HNTB, seeks to ensure the transition of species safely (e.g. Figure 3) with multiple habitat corridors consisting of diverse landscape bands (e.g. forest, grassland, and bush) (MVVA website, n.d.). Furthermore, the project that brings together design, ecology, and technology, suggests not only physically connecting a fragmented habitat but also providing a connection between community and wildlife. The 'Hypar-nature' wildlife bridge encourages real-time observation of the bridge and ensures that information about the species and their habitats is accessible by developing a digital observation platform in this regard (Minner, 2011).

Figure 3 'Hypar-nature' Wildlife Bridge *(Source: https://www.archdaily.com/123465/arc-wildlife-crossing-competitionwinner-hntb-michael-van-valkenburgh-associates)*

The road is defined as "an open way for vehicles, people, and animals" (Merriam-Webster Dictionary). However, the fact that some roads that give priority to vehicle transportation turn into borders that cause devastating consequences for wildlife, makes it necessary to rethink this definition in view of non-human beings. Anthropocentric practices, particularly creating boundaries and duality, are prevalent not only on roads but in existing urban planning and design practices. However, focusing on whether it is possible to establish new connections between these boundaries through design can contribute to the development of more holistic design process. The 'Hypar-nature' wildlife bridge project demonstrates that design can create a connection between these boundaries and play a role in bridging the gap. In the project design approach, giving priority to recognizing wildlife in their own habitats and including humans in this recognition process provides an opportunity not only to build a secure physical connection, but also to establish a connection between humans and non-human beings. In point of view, it is necessary to rethink the role of design in creating new boundaries and blurring them.

Amphibious Architecture

The Amphibious Architecture installation project, developing a dynamic interface by using sensors and light systems to connect the life below and above the water in New York waterways, aims to make invisible relationships visible by attracting people's attention to the water (Coexist Build website, n.d.). The project, which was developed by The Environmental Health Clinic at New York University and the Living Architecture Lab at Columbia University, encourages creating a dynamic environment for dialogue between humans and fish (Chris Woebken website, n.d.). In this context, digital technology systems and underwater sensors (e.g. Figure 4) used in Amphibious Architecture allow humans to send messages to the underwater and create a new language of communication to provide the understanding of environmental information that cannot be detected in the city (Semenov, 2017).

Figure 4 Amphibious Architecture *(Source: https://chriswoebken.com/AMPHIBIOUS-ARCHITECTURE)*

The more-than-human approach emphasizes that many relationships established in the city consist of interactions between humans and non-human beings. However, the invisibility of these relations in everyday life does not allow the development of these relations and the establishment of new interactions. Therefore, it is necessary to define new ways of seeing and communicating in the city for these relations to be visible. The Amphibious Architecture project shows how invisible relationships in the city can be visible with new methods developed through design and technology. In the project, the development of a new communication method to increase human engagement with different life forms shows that design can play an effective role in the interaction between humans and non-human beings. In addition, this interaction encourages new interactions that can be established not only underwater but also with different living forms in the city.

Discussion and Conclusion

The interest in more-than-human approaches and non-human participation in current urban planning and design practices has increased as a result of increasing environmental crises. Within the context of the relevant morethan-human literature and the case studies examined in this research, this participation can be discussed in two ways. The first type of participation allows increasing interaction between humans and non-human beings and contributes to the establishment of symmetrical relations in the city. In the second type of non-human beings' participation, especially aimed at reducing human concerns about environmental crises, causes the maintenance of asymmetrical relations. Urban design practices, which have a significant impact on shaping urban life, play an important role in changing or maintaining these relationships in the city.

Concepts related to anthropocentrism and closed system understandings (e.g. Figure 5) make it difficult to think of the city as an equal and common living space for all species. The relations established by these concepts that support controlled and exploitative relationship types cause asymmetrical relationships between humans and non-human beings. In the Anthropocene epoch, the increase in the dominance of these approaches threatens the lives of humans and non-human beings in a common way, while also showing the necessity of alternative approaches that allow thinking about the city separately from these concepts. This requirement points to an understanding of the concepts that represent the combination of more than human and open system understandings (e.g. Figure 5) that enable thinking of the city as equal and common for all species. The spread of this understanding through urban design practices provides an important opportunity for the interaction of humans and non-human beings in the city to become visible and to encourage the establishment of symmetrical relationships.

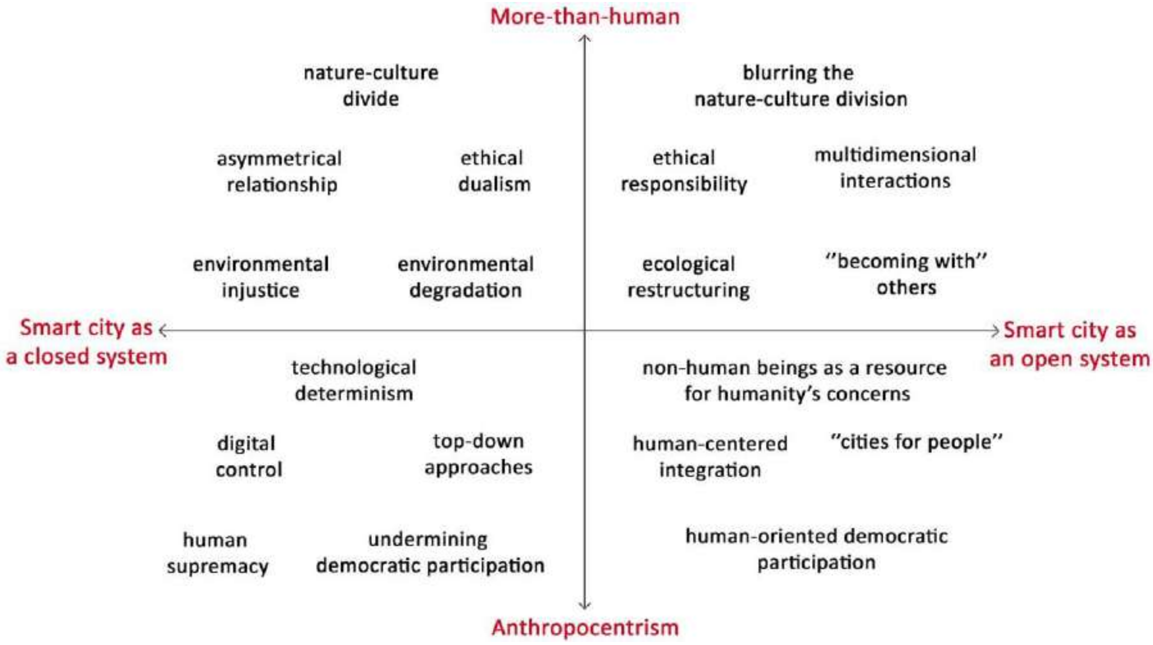

Figure 5 Rethinking smart city along two axes: closed system/open system and more-than-human centered/humancentered (created using relevant literature and selected case studies)

Consequently, it could be said that rethinking the smart city is related to an inclusive design approach that explores and develops new types of interaction with non-human beings, rather than anthropocentrism and closed system design approaches and their related concepts. It is only possible to imagine the city's future as democratic, multidimensional, and multicultural for the whole species when we replace human-centered approaches with more-than-human approaches and disseminate this understanding through new urban design practices and designers who take into account ethical responsibility.

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Industrial Ecology Self-Organization System and Its Adaptation in Chinese Urbanism

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Extended Abstract

Chinese cities, especially in the Pearl River Delta, have seen enormous development under globalization and the consequent ecological, socio-economic, and political changes (Yan, Jia, Li & Weng, 2002). This 'high-speed urbanization' (Ipsen, 2005) results from various factors, e.g., reorganizing the administrative and institutional system and new modes of production, employment, and investment. These processes lead to fundamental transformations in the urban structures with massive growth and potent concentrations of population, infrastructure, and economic and political power. These cities are also characterized by an increasing loss of control and unregulated, informal processes. The complex relations and connections influence the spatial, social, and ecological development in the new-urban areas.

As a result, the rapid industrialization and the lack of a vital supporting infrastructure gave rise to the contamination of the environment from a number of perspectives. It has given rise to a unique characteristic of spatial discontinuity. The establishment of non-agricultural activities, such as trading, transportation, and industry in areas that have previously been mainly agricultural, has directly impacted urbanization. The contaminated sites support lower-income local workers, thereby causing differentiation in society manifested in socially/physically isolated urban settlements.

The application of eco-industrial development has attracted increasing attention globally, leading to various implementation strategies of eco-industrial development, including eco-industrial parks and industrial symbiosis. The success of the Industrial Ecology concept in developed countries in Europe and the States provoked industrialization in third-world countries. Industrial Ecology should be applied in an industrialized urban area of the developing regions as a resolution towards its modern development. Moreover, it will bring genuine programmatic interaction between public entities such as industry, housing, agriculture, public open space, and the potential for mutual benefit to the city. This paper argues for the advantages of the Industrial Ecology concept in an industrialized city in low-mid income regions and the spatial patterns of urban landscapes determined by Industrial Ecology, which is used to devise a sustainable integrated urban development system. Additionally, it stretches an idea that a better human ecological understanding can assure the urban sustainability of the mutual interactions among environmental, economic, political, and cultural factors and careful planning grounded in ecological values.

The latest urban development in China, the Yangtze River Delta (YRD), is one of the most significant urban development projects. The Yangtze River Delta, which hubs around Shanghai, provides international commercial opportunities and is one of the effective mechanisms of China's economy. Chinese marine urbanism developing along the mega water infrastructure has several cases in different regions. In 2010, China's State Council approved a plan to make the Yangtze River Delta region a robust economic center and transform the area into a world-class city cluster by 2030. The "Outline for the Development of Regional Integration in the Yangtze River Delta" was released in 2019, where "dual circulation" economic model planning for YRD was proposed. As the inner city within the hub, Shanghai's economy will play the leading role, with the external cities keeping their financial supplement. As demonstrated in the initiative planning, this inter-connected cooperation between the cities along the YRD aims to bring much competitive development to China.

In the last few decades, Chinese urbanism applied diverse strategic planning across its regions. Reflecting on the development outcomes in the Pearl River Delta, this paper examines the possibilities for new strategic action in the economically important and developing Yangtze River Delta area. Based on positive outcomes from integrating industrial ecology into the planning of new urban developments, this paper argues that applying these ideas to Chinese urbanization could result in shared economic values and sustainable success.

Keywords: Sustainable city, urbanism, industrial ecology

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Mind The Space: Using Meteorological Architecture to Define the Life of Public Spaces

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Abstract

During the days people live in digital and conditioned worlds of isolation, people's relation to their physical surroundings became limited and their engagements with the social spaces grew into be constrained. Impacted by the pandemics and air pollution as a result of rapid urbanization, urban lives are now threatening people's well-being and forcing space-oriented studies to focus on proposing new ways of designing. This paper aims to look into applications of meteorological architecture that form an ephemeral relationship between body and environment. As the logic goes to link anthropogenic drivers of climate change by their impact on social lives in urban spaces, designers now have the tools to establish a robust design language that can increase the use of outdoor spaces by informing the design by atmospheric data. By recognizing particles, waves, chemical interactions of energy that continually surrounds us as 'new materials 'instead of just 'air'; Jade Eco Park designed by Philippe Rahm Architects and Urban Sun by Studio Roosegaarde are analyzed to indicate that meteorological architecture has the capacity to build spaces by energy like heat, humidity, and light that can organize the public life responsively.

Through this paper, Jade Eco Park Masterplan and Urban Sun will be reviewed in the ways they form a lively and healthy public life in and around these gradients of energies and question what qualifies architectural space and how the relationship of the human body with these spaces change when moving through the gradients of energy nested within their environment.

Keywords: Meteorological architecture, energy, sustainability, social life of public spaces.

Minding the Space

Considering the human history is constructed around the cultural reception of climate change, it is becoming critical to understand how meteorological realities are impacting global decisions about social identity and expectation in an ever-changing environment. Although the temperature of the world observed to be changing since the beginning of time, humanity is nearing a critical threshold for the livelihood of the planet earth for humanity. During the Neolithic period, these changes were due to the natural causes that allowed people to start farming which eventually caused the cultural and social lives of the cities to start. However today, the activities of excessive farming and rapid urbanization are causing the extinction of wildlife and increasing the air pollution that is forming the ground for global warming and turning our planet into an unlivable space.

Getting ultimately exposed to pollution, heat and now viruses, urban lives are growing into being constrained, becoming indoor and leading to the isolation that is ending the social lives in cities or any kind of life as we know of it. This relationship between people, buildings, and the earth seems to leave its place to symbolic and political opinions of nature that are not capable of responding anymore. The conditioned urbanization process constantly makes people ignore the real relationship with the matter which causes people difficulty in comprehending the real impacts of climate change all over the world. As 'Junkspace 'points out to this global world of concrete and aircon people ended up having, meteorological architecture as a method tries to avoid constructing a singular approach towards the desired present by focusing on the micro-scale of conditions that affect users. As it has been extensively discussed, the concept of science doesn't allow people to evaluate cases in a vacuum without understanding the impact of the context (Laudan, 1984). All atmospheric events now are influenced by global warming since all weather now develops in a different atmosphere than before.

Described by Philippe Rahm as a method to design spaces in a more 'sensual' and 'atmospheric 'way, meteorological architecture design to create exchange between the body and its surrounding that is impacted by humidity, light, and temperature (Rahm, 2021). Architecture's investment in stability and longevity that comes with groundedness, is eventually a resilient trait. While architecture necessarily engage with flows such as dealing with movements of people, fluctuations of air and fluidness of water as well as entropic tendencies of matter, design became a stationary discipline (Cairns et al., 2012). Although the city mentioned by Castells as 'space of flow' that includes flows of people, ideas and information, his concept described globalization that is overtaken by visual flows. Pointing to an ambiguous architectural style that is homogenizing and dislocating the planet, he called upon an architecture that 'root itself in culture and place'. As the climate events turn from 'matter of facts ' to 'matter of concern', the need to 'root' the flows themselves while organizing thermal comfort in outdoor spaces becomes necessary (Latour, 2004).

This relationship between human beings, the epidemic, and thermal discomforts, like the relationship between human beings and meteorology, is a fundamental issue to be considered in architectural design and urban planning. It is conceivable that due to climate change, a major migration of people and goods will likely occur towards the global north capitals, prompting people to use new geospatial spaces. Visible with the relocation of super large data centers like Facebook, Amazon, and other companies from California, United States to cut costs of the use of energy to cool the servers, global warming has huge impacts in all parts of life. As a foreseeable result culmination of great numbers of people in city centers puts space-oriented designers to establish a dynamic urban life around thermal comfort.

Visible in the mentioned two examples, building with the new set of material energies formed by particles, waves, chemical interactions of energy that is found in the the 'air' (Lally, 2014). design can be responsive to its immediate surrounding that is in constant change. By using 'meteorological design 'that employs light, temperature, humidity, and pressure to inform spatial and experiential qualities to produce healthy and sensorial social spaces, Jade Eco Park (designed in 2011) and Urban Sun (designed in 2021) form the ground for meteorological architecture to indicate the capacity of design that can alter and decrease the impacts of climate change in the urban environments.

Although projects date back to different times and settings of the world we live in, by benefiting from this seemingly 'empty space 'to create healthy public spaces both projects success to meet the biological and physiological needs of the human body and reestablish this heavily damaged relationship with the nature.

Defining the Boundaries

As the urge to define the space with ephemeral needs emerge, the ultimate tasks of space-oriented designers of constructing the spatial boundaries that organize and accommodate specified activities within them requires a rethinking. The behavioral properties of materials used to define the boundaries not only impact the physical characteristics of the space but also determines how the people sense those boundaries change, which eventually informs the behaviors and movements of the people using those spaces. With the change in techniques or use of different materials, architects have continually tested these boundaries, and impacted social trends have emerged over the centuries. It seems to be that when energy has been controlled and deployed as 'a 'boundary which can be either physical or within the form of gradual gradients, the human body can detect and re-organize its activities that take place in these spaces (Banham, 1969). and a new pastoral space emerge. The elusive nature of meteorological factors impacts daily life on infinitely larger scales today. As the materiality of energy can influence and inform the design of public spaces, architecture can use these pressures to build and re-inform people's assumptions about physical boundaries, spatial organizations, lifestyle, and aesthetics of everyday life. By contrasting material energies with atmospheric effects and climate control, meteorological architecture can define and control boundaries of outdoor comfort and produce various spaces for different activities (Lehanneur, 2009). Intensified pockets of energy essentially become a new method for organizing the uses and events that occur in public spaces and inform social interactions of people within these spaces (Lally, 2009).

Amplifying the Nature's Ways in the Digital Age

With the advancement in energy research and representations, it is now possible to visualize the material aspect of these energies and design low energy consuming and responsive public spaces. By studying natural physical

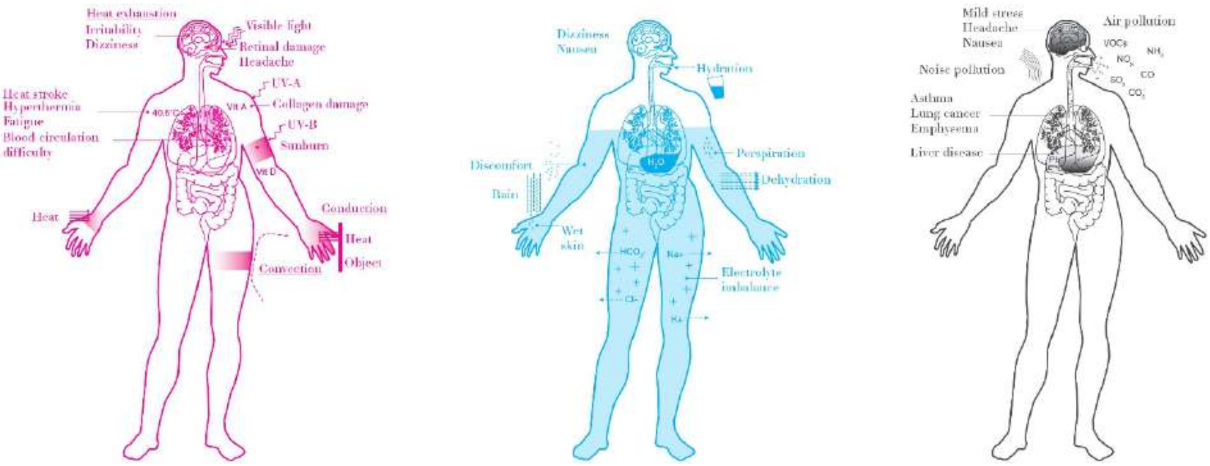

Figure 1. Body Agency (https://landscapetheory1.wordpress.com/tag/leopold-lambert/)

characteristics of materials like emissivity, light gradient, Philippe Rahm Architects benefited from a cultural heritage that is developed throughout the years by people that lived differently in different places to create microclimate environments by controlling heat, humidity, and pollution (Rahm, 2009).

Figure 2. Jade Eco Park (http://www.philipperahm.com/data/projects/taiwan/index.html)

Inspired by the original concept of "park" that was built to avoid the summer and the spread of infectious diseases such as Victoria Park in London during the 19th century, Philippe Rahm Architects designed the Jade Eco-park project by taking into account the environmental factors of global warming and tropical weather that is constant throughout the year in Taichung, Taiwan.

Centering the concept around a response to the nature of the context with now observed by advanced computing techniques, Rahm Architects have designed the park by simply adapting laws of physics that reflects as 'convection', 'conduction', 'evaporation', 'digestion', 'pressure 'and 'radiation'.

As explained by the design team, the project consists of the three maps that indicate the heat, humidity, and pollution intake of the site and identifies three microclimatic zones that are 'coolia', 'dryia', and 'clearia 'which refers back to cool, dry and clean-aired areas that are assigned activities accordingly. By proposing 2.2km long paths that connect these same specific zones, Rahm Architects also proposed a dehumidifying/cooling planting palette and specific programs that attract the users to spend more time outdoors.

By understanding the context of lower-carbon means of human activities, the project essentially creates public spaces that are cooler in summer and hot during the winter (Rahm, 2009). By employing computational fluid dynamics simulation (CFD) throughout the design process, the project team was able to identify the coldest, driest, cleanest areas of the park. By increasing the climatic qualities of the context by various devices and trees, the design achieves to cool, dry, to clean the air for people to enjoy the public space (Picon, 2017).

The project looks at climate change as a physical entity by re-assembling, reworking, and re-inscribing the data sets to be worked in reverse to decrease socioeconomic and environmental impacts of the thermal discomfort (Cairns et al., 2012).

Figure 3. Urban Sun (https://www.studioroosegaarde.net/project/urban-sun)

A similar mindset is visible in another project called Urban Sun designed by Studio Roosegaarde. Designed in 2021 as a response to the impact of Covid 19 in public space use, Urban Sun employs a traditional 254nm UVC light which is harmful but uses it with far-UVC light with a wavelength of 222 nanometers that can purify the air and define the boundaries of safe public space (Roosegaarde, 2021). Inspired by the movement properties of the sun, the project can combat the negative impacts of the pandemic by allowing people to gather safely again. By visualizing the boundaries of the safe space with urban furniture like catenary light, the project makes the experience visible to help users associate with it. Proposing a social and technological innovation, this project also employs energy as a building material to form a safe space that aims to increase the relationship with the body and its surrounding.

This amplification is a strategy that intensifies and builds upon the existing properties of a known condition, accentuating them until the condition becomes something other then itself. Producing architecture through amplification involves strengthening the energies associated with exterior microclimates until they become a material to build with.

Figure 4. Urban Sun (https://www.studioroosegaarde.net/project/urban-sun)

As seen in these two projects, it is critical to recognize that atmosphere is in a position to inform global decision making, technological change, and humanitarian reform. Meteorological architecture in this sense can design with fluid and mobile urban life.

"The Architecture of Leap"

As asserted by Mark Wigley that "all architecture is a form of radiation" (Wigley, 2004), these new amplifications of data nested within the environment allow architects to explore new territories of design, aesthetic and social interactions. By comparing and contrasting the two examples, it becomes clear that architecture formed through this amplification engages the existing energy systems within our immediate environment, intensifies them to become architectural materials that can increase participation in public life. As an architecture that is at the limit of visibility, meteorological architecture can define the spaces by ephemeral means. New spaces can emerge that are defined by ʽorganic entities ʼinstead of fixed enclosures.

As the world nears a deadline defined by the Intergovernmental Panel on Climate Change (IPCC) as 2030 to decarbonize the infrastructures of life in cities before self-amplifying effects of climate change become irreversible, adapting a design language that benefits from ʽnew modes of calculating ʼand ʽnew forms of network ʼto associate with the substances interact with the environment and atmosphere becomes necessary.

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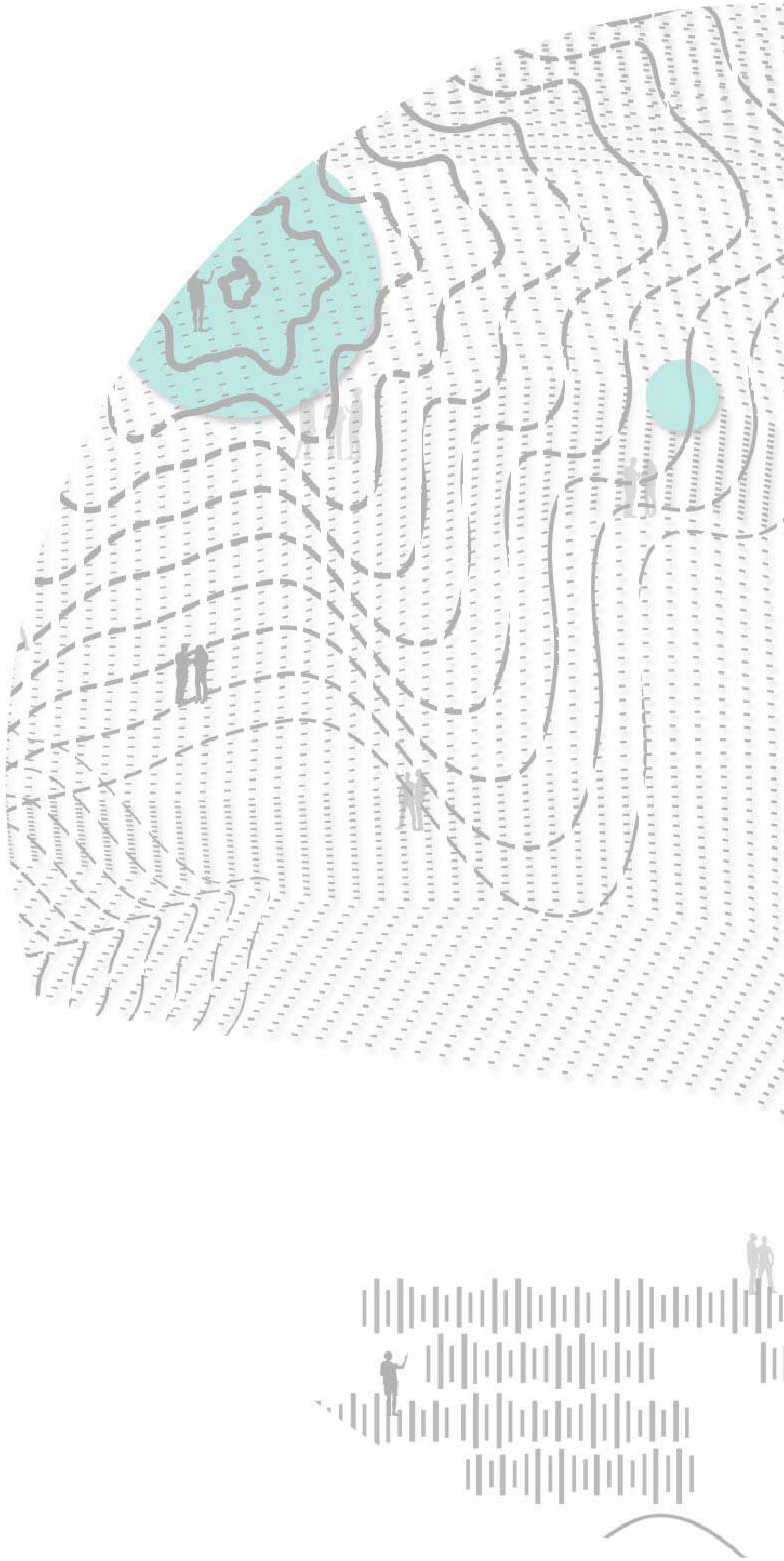

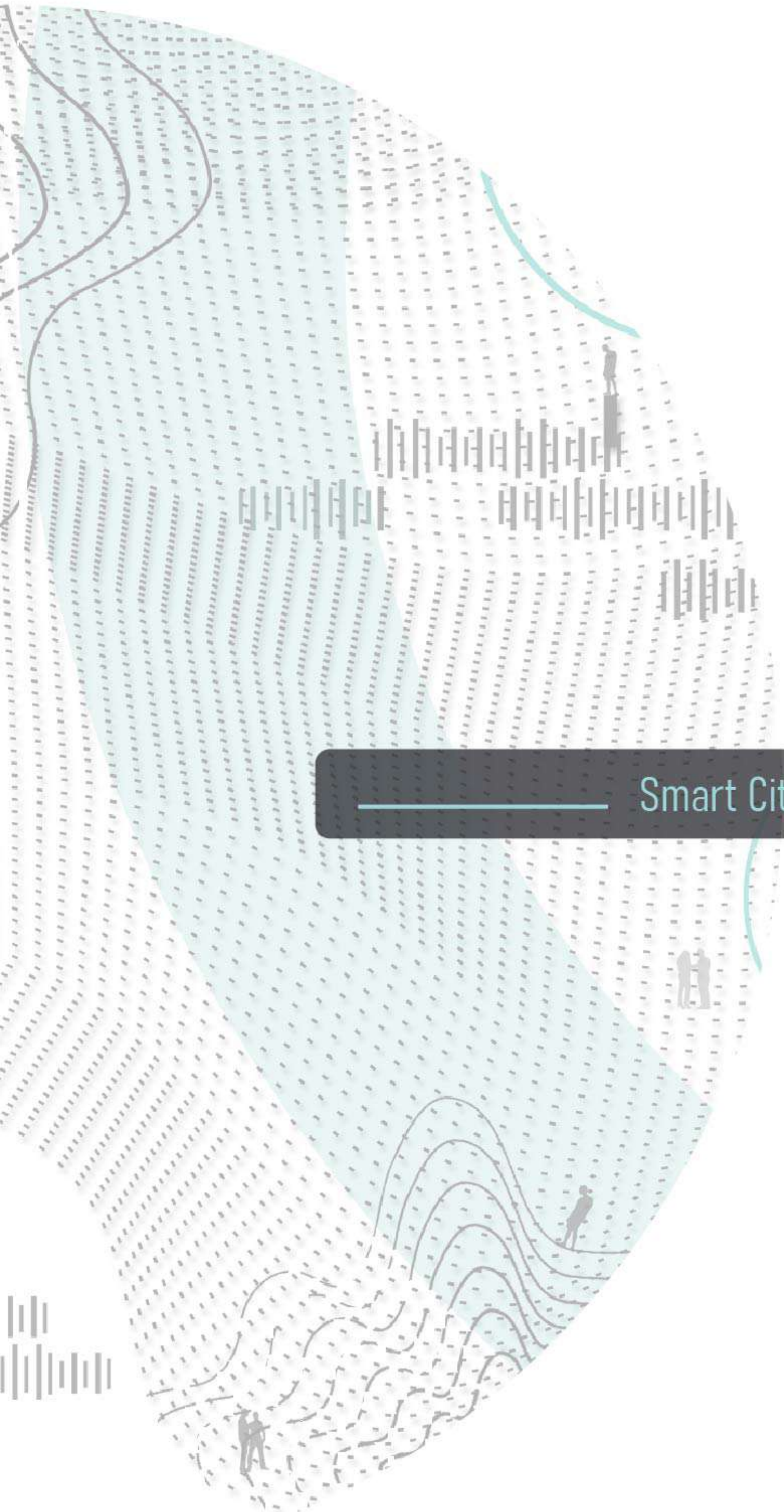

Smart Cities & Urban Ecologies

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Evaluation of Optimal Solar Façade Performance in Office Building with the Use of Machine Learning
Mohammad Mehdi Akhavan Saraf, Mina Movahedi, Yaser Shahbazi and Farhad Ahmadnejad

The Role of Light Shelf and Window Size on Daylight Performance of an Architecture Studio
Aybüke Taşer, Tuğçe Kazanasmaz

Comparison of Different Data-Driven Models on Prediction of Useful Daylight Illuminance (UDI)
İlkim Canlı, Orçun Koral İşeri, İpek Gürsel Dino

Evaluation of Optimal Solar Façade Performance in Office Building with the Use of Machine Learning

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Abstract

This study tries to shed light on the evaluation of the optimal solar façade performance in office buildings in cold and mountain climate during the cool season by the assessments which were done using Design Builder. This goal was achievedby using this softare to simulate thermal load and energy consumption in the above-mentioned climate with the implantation of machine learning. The outcome demonstrated how an ML algorithm can be welltrained to detect patterns inside the environmental analytical data to make an efficient design possible, and how this trained ML framework can help the architects toward an optimal design that not only assists the energy-efficacy but at the same time, its results will benefit the environment by reducing carbon footprint. The present study also provides insights for further future research perspectives.

Keywords: Solar façade, BIPV/T-DSF, machine learning.

Introduction

It has been decades since humans have learned the usage of solar power, this knowledge has caused buildings to face southward in many cities around the world to facilitate the efficient utilization of this endless power in solar-wise architecture all year round. Nowadays, the implantation of solar design in the architectural design process has changed wide and rapidly which may be due to widespread technological advances and development in industrial production not only in manufacturing but also in control and analysis (Rousse 2012).

The outer shell of a building is one of the most crucial and the main parametric architectural pieces in a building. Ascribed to being faced toward the sun, its design and manufacturing process should be taken into account, which will directly lead to an improvement in the design performance in terms of thermal comfort, natural ventilation, thermal insulation, electricity generation, and day-light usage. In recent studies, application of Building Integrated Photovoltaic (BIPV), which are photovoltaic (PV) modules integrated into the building envelope and hence also replacing traditional parts of the building envelope, e.g. the roofing (Jelle, Breivik, and Drolsum Røkenes 2012), and thermal double skin façade (T-DSF), which is a building typology consisting of two skins (a glazed outer layer and either a glazed or mixed inner layer) placed in such a way that air flows in the intermediate cavity(Parra et al. 2015), caused the building shells' performance in indoor thermal comfort and its energy efficiency is simulated and evaluated in different studies[4]– (Yang et al. 2021).

On the other hand, it should not be forgotten that buildings are a major producer of greenhouse gases. As Buildings & Climate Change: A Summary for Decision-makers report (Anon n.d.) claims 40% of the Global Greenhouse gases are emitted from the Architectural, Engineering, and construction industry (AEC). The carbon footprint is "Carbon footprint, amount of carbon dioxide (CO2) emissions associated with all the activities of a person or other entity (e.g., building, corporation, country, etc.). It includes direct emissions, such as those that result from fossil-fuel combustion in manufacturing, heating, and transportation, as well as emissions required to produce the electricity associated with goods and services consumed (Selin 2020).

BIPV/T-DSF has lots of benefits. Firstly, it is semi-transparent as a result daily sunlight can be used in the building effectively. Secondly, it provides natural ventilation, thermal comfort, and high air quality. Finally, its aesthetic values should not be forgotten, besides it provides visual contact with the outdoor environment. The arrival of the computer, other technological office-based appliances, the need to use artificial light, and heating devices with high electrical consumption has significantly increased electricity usage within office buildings, especially in cold seasons in cold climates. On the other hand, façade geometry modifications and cavity ventilation to achieve efficient thermal performance become more difficult and intense in cold seasons. As BIPV/T-DSF reduces energy consumption, while on the other hand generates energy as a sustainable source, provide natural ventilation in high-rise buildings, and help adjust the indoor microclimate of new buildings this technological development should be taken more seriously in todays' modern parametric architecture (Anon n.d.; Hou, Li, and Wang 2021). In this article, we try to seek help from Machine Learnings (ML) to assist architects to design an optimal solar façade . The design is done using Design Builder which is used to simulate building energy usage. Two steps were taken as demonstrated in (Fig.1): during the first two steps Design Builder software was used to calculate the energy analysis of the generated examples and to calculate the thermal load of different options of design for a building, in the second step the accumulated data were exported to an ML framework and the training process happened based on the input which was provided in the first step. As a result of the training, extensive datasets were created describing the façade geometry, cavity, the degree of BIPV, and the resulting environmental performance of the façade .

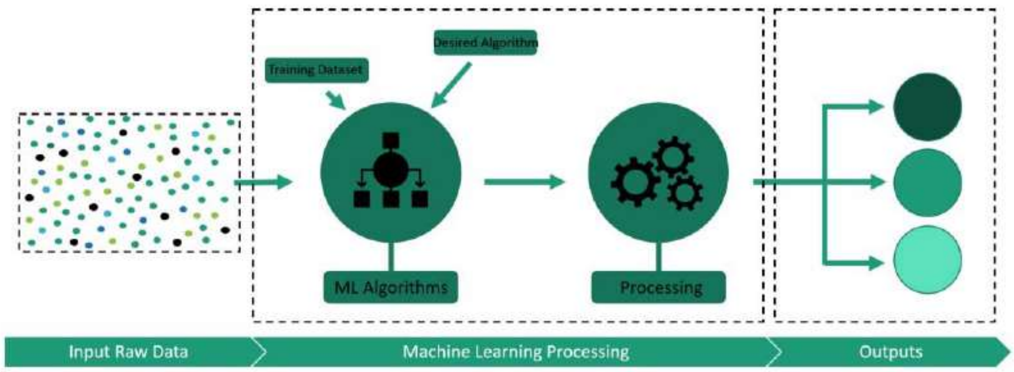


Figure 1. An overview of the research process

In order to reduce greenhouse gas emissions, considerable changes in human behaviour in terms of energy consumption, production of more environmentally friendly products, and understanding and mitigating the source of these harmful gases are required. The first step in reducing building energy consumption is to quantify it using a building energy assessment technique, which is an educational tool that provides decision makers with a comparative energy performance index. Engineering calculations, simulation model based benchmarking, statistical modelling, and machine learning (ML) are the four primary types of building energy evaluation . First, it appears that a quick introduction to the reason for and requirement of utilizing machine learning in the building energy field is required. In most countries, Zero Energy Building (ZEB) has garnered a lot of attention in the previous decade and has been recognized as the key architectural idea for future buildings (Marszal et al. 2011). Building energy efficiency retrofit (BEER) of existing stock, on the other hand, is the primary energy reduction component. Data-driven models can be used for more than just BEER and ZEB design; they can also be used to optimize Energy Management Systems (EMS) and Heating, Ventilating, and Air Conditioning (HVAC) systems, and they can even be a better alternative to traditional building energy benchmarking and rating schemes.(Deb et al. 2016; Gao and Malkawi 2014).

Due to the significant increase in the quantity of valid and achievable dataset of structures, there is a lot of interest in using Artificial Intelligence (AI) technologies, notably machine learning (ML), in the construction industry. A computer algorithm that learns from existing data is referred to as machine learning (ML). For the learning process, these algorithms generally employ a large quantity of data and a small number of input characteristics. In the building industry, a number of machine learning algorithms have been developed for estimating heating and cooling loads, energy consumption, and performance under varied conditions.

Case Study

The case study was carried out in an office building (as shown in Table.1) which is located in Tabriz, Iran. As demonstrated in Fig.2, Tabriz is classified as a cold climate.

Table1. Case study specification

	The Building Specifications	
1	Climate	**Cold and Mountainous, Tabriz, Iran**
2	Activity	**Office Building**
3	Plan	**Pilot = 18m x 17m / Floors = 20m x 20m**
4	3Floor + Pilot	**Number of Floor**
5	The Height of Each Floor	**4 Meters**
6	Schedule to Occupancy	**Saturday to Wednesday = 7 – 19** **Thursday = 7 – 14** **Friday = Off**
7	Occupancy Density	**0.11 people/m^2**
8	Metabolic Factor	**0.9**
9	Clothing	**Winter Clothing = 1,00 clo** **Summer Clothing = 0,50 clo**

Table 1. The Building Specification

Table.2 DSF specification as demonstrated in

	DSF Specifications	
1	Height	**The Height of 3 Floors Is 12m + 1m Extra = 13m**
2	Width	**The Width of The Façade Is 20 Meters and It Has Been Checked in 3 Cases** **First Case: 20 Meters** **Second Case: 4 Parts x 5 Meters** **Third: 8 Parts x 2.5 Meters**
3	Depth	**It Has Been Checked in 3 Cases** **First Case: 0.90 Meters** **Second Case: 1.2 Meters** **Third: 1.5 Meters**
4	Type of Interior Glazing	**Dbl Clr 6mm / 6mm Air**
5	Type of Exterior Glazing	**Sgl Clr 6mm**
6	Internal Shading	**Micro Louvre**
7	External Shading	**No**

Method

ML models use data to find the relationship between various input variables and output objectives (e.g. energy efficiency). When ML models are sufficiently trained with adequate data, they may be used to forecast targets for unknown samples, but the relationship between the features and the targets is unknown. In the field of machine learning, this is referred to as supervised learning. In the field of building energy analysis, the second type of machine learning, known as unsupervised learning, has gained a lot of attention. Unsupervised learning, also known as unsupervised classification, is used to cluster unlabelled data based on hidden patterns and similarities in characteristics. Clustering for such purpose includes four distinct steps: 1) data collection 2) feature identification and selection 3) adaptation of appropriate clustering algorithm and 4) benchmarking the building within classified groups.

This approach is particularly useful in the context of energy benchmarking, in which establishing a baseline building is essential for assessing the energy performance of similar situations. As a result, in comparison to the old strategy, which relies mostly on building utilization type, clustering algorithms gives more precise tools for categorizing diverse buildings.

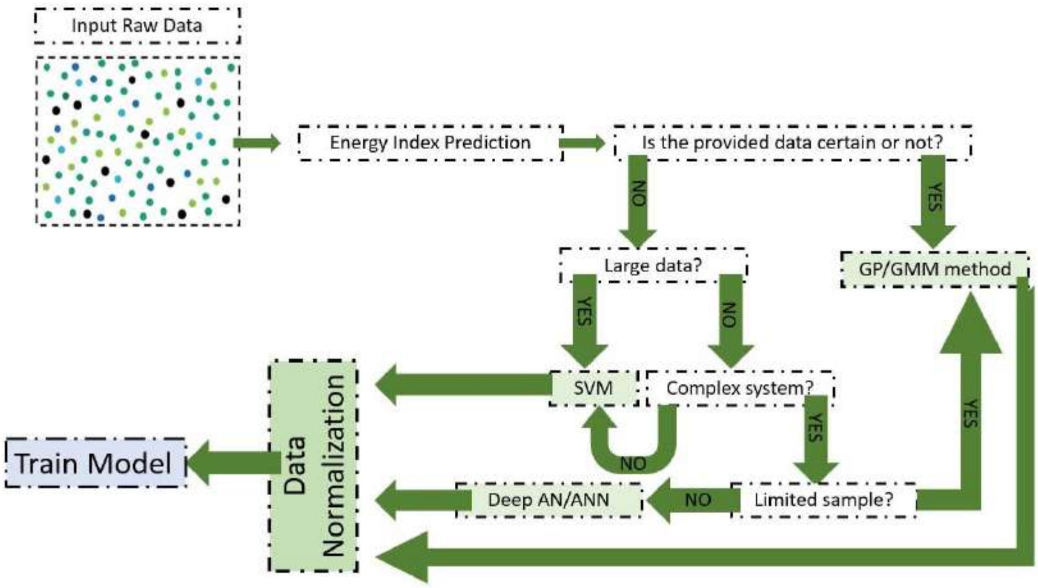


Figure 2. Proposed method of selecting ML for building energy data

In the first step, which is data collection, a seprate corridor space was created on each floor,and the openings were also placed on the facede. At this stage of modeling and simulation, only the space between the two corridor façade shells is examined. The space between the two shells acts like an airflow corridor. The openings are placed in the bottom of the second faced level and close to floors . Air vents are created at the highest level of the second façade and close to the ceiling (both 5.1 meterswide and 21 meters high). During the modeling and simulation stages of the selected sample (two-shell corridor view has been used to divide the space into smaller parts. This goal was achieved by evaluating the parameters of velocity, temperature and flow distribution in the middle space. The middle space of the two-shell façade of the corridor is 21 meters long with no division, once divided into 5 parts with a depth of 2.1 meters and a length of 5 meters, and on another try it was divided into 8 parts with a depth of 2.1 meters and a length of 5.2 meters. In both cases, the openings are designed in the same way that was used in the non-split mode which measn they were at the bottom and the top of the façade to allow air to enter the space. For air outlet, an area of 5.1 x 5 square meters was created for the first case and 5.1 x 5.2 square meters for the second case.

According to the simulations, the flow pattern in the space between the two shells was very regular and it is convenient, but there is not much change in the flow velocity due to the lack of space for upward movement. By dividing the middle space of the two-shell corridor façade , it was found that the velocity of air flow in the middle space, which is divided into 5 meters in length is more (0.41 s / m) and in case its length is 2.5 meter it is less (0.31 m/s) compared to the case without division (0.34 s / m). Distribution pattern of the flow in the middle space is almost the same in all cases.

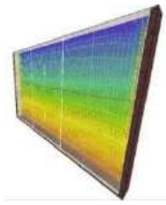
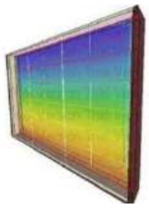
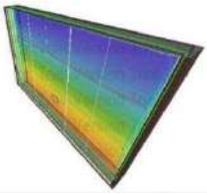
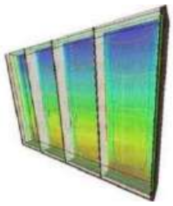
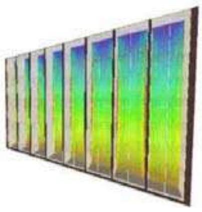
Step 2: In this step, in addition to the openings between the two shells, openings in the common wall between the interior of the building and the middle space were created. Two openings, one at the top of the wall to allow air to escape from the inside into the space between the two shells and one at the bottom. Location and dimensions of the middle space and the size of the openings in the two-skin view of the corridor are according to Table 2.

The simulation results showed:
In the first step: the velocity of the incoming air flow from the opening to the middle space without division is about 0.26 m / s and when entering the building it reaches to about 0.40 m / s. The velocity of air flow in different floors is almost the same when it enters inlet openings and when it leaves the outlet openings with a maximum speed (0.58 m / s). Air flow with a speed of 0.37 m / s and temperature 25.32 ° C enters the interior space from the middle space and gradually it leaves the building in the opposite direction. It should be considered that the speed and temperature of the air is reduced when it leaves the building.

In the second step: In the middle space option with a length of 5 meters, the air flow speed is the same in all partitions of the middle space and is about 0.37 m / s while the temperature is 25.60 C °. It can be seen that in the middle space of the three floors, the air flow distribution is quite similar. The air flow inside the building penetrates to the middle space with the appropriate speed and temperature, and as it moves in the opposite direction (east), the speed and temperature decreases.

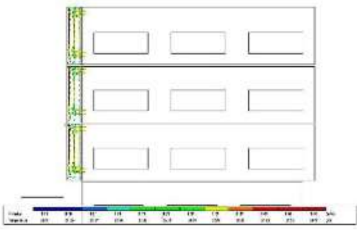
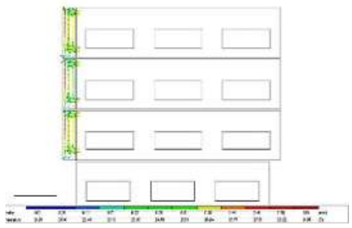
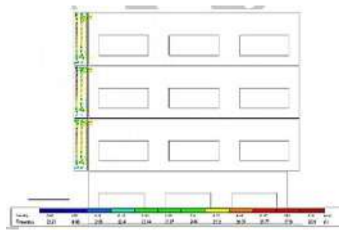
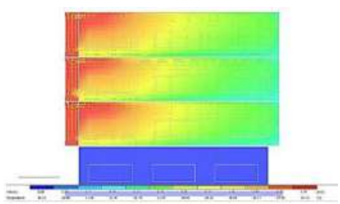
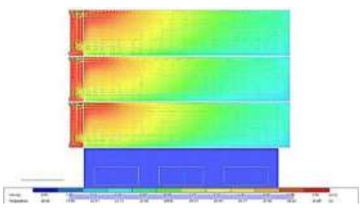
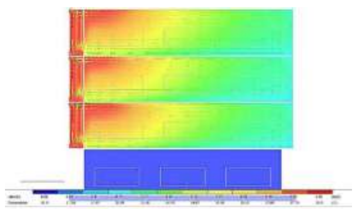
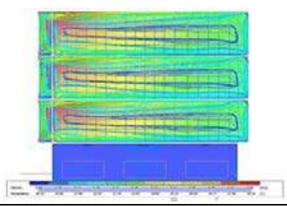
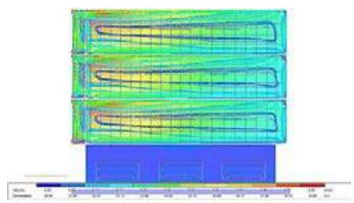
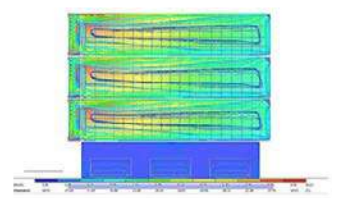
In the third step: the middle space was divided to 2.5 meters length, the average speed and temperature of the incoming air flow in the middle space is around 0.38 m / s and 26.64 ° C and is not much different from the previous two modes.

Table 2: Simulation of double skin façade

Components Obtained from the Analysis	Physical Specifications of the BIPV-DSF		Different simulation modes
Velocity: 0.00 to 0.27 m/s Temperature: 11.18 to 15.58 C° Pressure: -0.88 to 1.15 Pa		Height: 13 m Wide: 20 m Depth: 0.9 m	1st mode
Velocity: 0.00 to 0.34 m/s Temperature: 11.22 to 16.598 C° Pressure: -0.85 to 1.12 Pa		Height: 13 m Wide: 20 m Depth: 1.2 m	2nd mode
Velocity: 0.00 to 0.3 m/s Temperature: 10.76 to 16.98 C° Pressure: -0.82 to 1.10 Pa		Height: 13 m Wide: 20 m Depth: 1.5 m	3rd mode
Velocity: 0.00 to 0.41 m/s Temperature: 12.06 to 18.98 C° Pressure: -0.72 to 1.16 Pa		Height: 13 m Wide: 4x5 m Depth: 1.2 m	4th mode
Velocity: 0.00 to 0.31 m/s Temperature: 13.03 to 18.68 C° Pressure: -0.56 to 0.79 Pa		Height: 13 m Wide: 8x2.5 m Depth: 1.2 m	5th mode

Outlet air flow rate is 0.58 m/s maximum and the maximum temperature is 25.81 C. The distribution of air flow in all three floors is the same. At this stage, the flow distribution pattern along with the appropriate speed and temperature in the interior of the building was examined. Considering the speed and temperature of the incoming and outgoing air flow into the building space and its distribution in the interior space, it was found that the two-shell corridor façade is a suitable option for natural ventilation of the building and if the middle space is divided into smaller lengths (5 meters), the flow velocity is improved. Therefore, in addition to the middle space, the interior space of the optimal sample was divided into smaller parts.

Table 3. Seceond step simulation

<table>
<tr><td colspan="7">Investigation of Velocity, Temperature and Airflow Distribution Pattern in Indoor (Natural Ventilation)</td></tr>
<tr><td colspan="2">3rd mode</td><td colspan="2">2nd mode</td><td colspan="2">1st mode</td><td rowspan="3"></td></tr>
<tr><td colspan="2">Wide 8x2.5 m and Depth 1.2m</td><td colspan="2">Wide 4x5 m and Depth 1.2m</td><td colspan="2">Wide 20m and Depth 1.2m</td></tr>
<tr><td>Max of Temperature 25.51 C°</td><td>Max of Velocity 0.58 m/s</td><td>Max of Temperature 28.95 C°</td><td>Max of Velocity 0.60 m/s</td><td>Max of Temperature 28.23 C°</td><td>Max of Velocity 0.58 m/s</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>Airflow in the Middle Space of the BIPV-DSF</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>Airflow in the Middle Space of the BIPV-DSF</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>Flow Distribution Pattern</td></tr>
</table>

Results

The researchers provide a framework for selecting the correct approach for building energy prediction and benchmarking, as illustrated in Figure 1, based on findings from seminal publications and proposed approaches for diverse applications, as well as some ML parameters.

An option that was deemed appropriate in reviewing the results of the previous step (in which middle space was divided to 5 m length parts), was chosen to have an impact on the smaller interior space , in order to see how the flow is distributed and also check the rate of the speed and temperature increase or decrease of the arflow entering the building. The internal space, which is the two-shell corridor view was divided into the middle space of 5 x 1.2 square meters with a height of 4.08 meters and the interior space with dimensions of 5 x 20 meters square was divided with a height of 4.08 meters.

As previously depicted, the air flow moves properly in the space between the two shells and enters the building through the openings of the shared wall between the two shells and the interior space, as can be seen. The inlet air flows to the end of the space and then leans towards the ceiling and enters the space from the opening of the shared wall outlet. The simulations show that the speed of 0.63 m/s and the temperature of 28.51 C of the air flow also increased.

Conclusion

In the last decade the global warning has been a huge issue of today's world. Considering this issue and the undeniable need of movement toward buildings using less energy and being more efficient the issue of double skin façade was considered for this article. The researchers here tried to evaluate a building using the Design Builder software, later an algorithm was proposed to facilitate decision making for designers. The ML algorithm used here sets an optimal framework for selecting the correct approach for building energy prediction.

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The Role of Light Shelf and Window Size on Daylight Performance of an Architecture Studio

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Extended Abstract

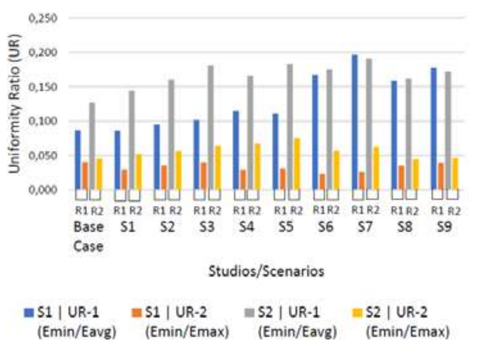
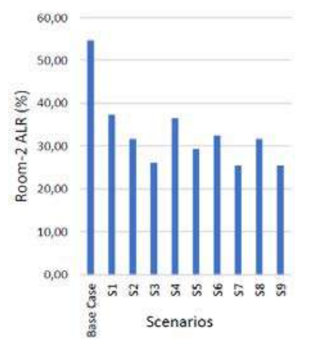
Daylight and its homogenous distribution are significant for human health in a space (Alhagla, Mansour & Elbassuoni, 2019). Recently, glazed surfaces started to be used more frequently. Thus, this has resulted in thermal and visual comfort issues and energy problems with insufficient daylight performance because of not using any solar control element (Day, Futrell, Cox, & Ruiz, 2019). Therefore, in designing stage, strategies for the homogenous and proper distribution of daylight need to be studied. Some research show that daylight performance can be highly influenced by the integration of solar control systems and window-based parameters (Cesari, Valdiserri, Coccagna, & Mazzacane, 2018). Window sizes and light shelves are significant in this sense. One study in a Greek classroom aims the homogenous distribution of daylight. Results show that light shelves can retrofit uniformity of daylight especially when they are used with semi-transparent external blinds (Meresi, 2016). Another study notes that thermal and lighting loads significantly decrease and daylight uniformity is importantly improved when window size is optimized (Alhagla, Mansour & Elbassuoni, 2019). In these studies, it is shown that high illuminance discrepancies between near-window zones and back parts of the room can be balanced with shade components. The window-to-wall ratio (wwr) also has an impact on how well the light is distributed. The goal of this research is to determine the impact and potential of various window sizes and light shelf positions on optimal daylight distribution and visual comfort for an architecture studio on the İzmir Institute of Technology (IZTECH) Campus.

The reference building is a three-story structure with a height of 4 meters. Two architecture studios are chosen for the research. The first studio has over-lit parts around window zones and exposes south-east and south-west, whereas the second studio views south-west and north-west and lacks daylight. Simulation models in Relux software are used to test nine scenarios. Each simulation is run at 10:00 a.m. on the 21st of June and the 21st of December under clear sky with sun conditions. The length, height, inclination angle, material, and reflectance ratio of the shade elements, as well as the window size/location, are the parameters in the study. Window sizes are increased by 50, 100, and 150 cm in the first three situations, and overhangs are added to windows. Within next two scenarios, the elevation and inclination of overhangs are altered. The height of the overhang is reduced by 70 cm, and the incline angle is set to 20 degrees. Interior light shelves are then installed in both studios. Finally, the material of the light shelves as well as the reflectance ratio are studied. The outcomes of the simulation are assessed in terms of daylight uniformity ratio (UR), studio artificial light requirement (ALR), and sun patch illuminance values (SPIV). If the illuminance value is less than 300 lx, educational buildings may need artificial lighting. (Yamur & Düzgün, 2019).

In the worst-case scenario, the first studio (S1) featured extremely bright surfaces and sun patch regions on June 21st. There also obtained many measuring points exceeding 10.000 lx and defined as SPIV. Uniformity ratios are calculated lower than necessary. The other studio (S2) lacked adequate daylight. For the 21st of December, similar results are found. On the other hand, S1 eliminated most of the sun patch areas. The artificial light requirement in the second studio is increased and uniformity ratios are estimated less. In Scenarios 1, 2 and 3 windows are expended and overhangs are implemented to all. So far in each scenario, the implementations significantly increased the illuminance values for each studio. In each case and scenario, this resulted in a lower artificial light need for S2. However, as previously stated, window expansion significantly raised Emax. As a result, there could obtain only a modest increase in uniformity ratios. In these cases, a significant retrofitting in SPIVs could not achieve due to high illumination. In Scenarios 4 and 5, it is found that light shelf height and incline angle have the ability to

diminish sun patch areas. They may, however, increase the artificial light requirements of rooms due to the decrease in illuminance levels. They moderately improved some of the uniformity rates. These variables' major potential is to reduce high illuminance values by preventing excessive sunlight. In Scenarios 6 and 7, interior light shelves are implemented. Interior light shelves greatly decreased high illuminance levels in near-window areas. They also reduced sun patch areas and SPIVs in S1 for each date. In S2, implementations improved proper daylight distribution for June 21st. As a result, there found some retrofitting in the studio's dimly lit areas. In Scenarios 8 and 9, shading elements' reflectance ratio and material are changed. For the 21st of June, it is noticed that greater shade element reflection brightens the back parts of the space by distributing daylight more uniformly. Sun patch areas and uniformity ratios are also developed. Illuminance values for the S1 are increased on December 21st, and uniformity ratios are improved. Variables had little effect on uniformity ratios in S2.

In this paper, different scenarios are examined and interpreted in detail. As a summary, it is found that window size and shading elements have a significant ability to achieve a proper daylight performance of buildings.

<table>
<tr><th>Date</th><th>Uniformity Ratio (UR)</th><th>Artificial Light Requirement (ALR)</th></tr>
<tr><td>June, 21st</td><td>
</td><td>
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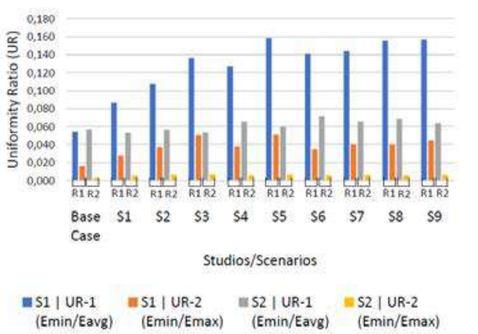
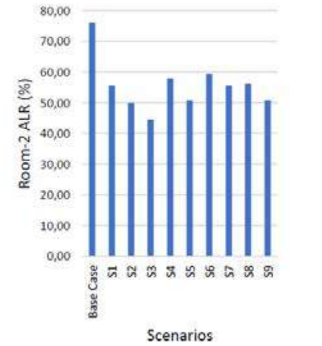
<tr><td>December, 21st</td><td>
</td><td>
</td></tr>
</table>

Figure 1. Uniformity and artificial light requirement result of studios for 21st of June and December

Keywords: Daylight performance, light shelf, visual comfort, window size

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Comparison of Different Data-Driven Models on Prediction of Useful Daylight Illuminance (UDI)

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Extended Abstract

Urban building stock is responsible for approximately 40% of the total energy used in cities (USDOE, 2019). One of the most critical factors in building energy efficiency is lighting energy use, reaching up to 15% of the total building energy consumption (Ryckaert et al., 2010). Buildings' lighting energy demand can be drastically reduced by effective indoor daylighting, increasing building occupants' well-being and visual comfort. Recently, many studies focused on the relationship between daylight illumination metrics and building design parameters. The effect of building design parameters on daylight metrics is analyzed and estimated using statistical learning techniques (Lee et al., 2019). Indoor daylighting is estimated by comparing different machine learning techniques (Ngarambe et al., 2020). The daylight-based performance of buildings is evaluated using sensitivity analysis, metamodels, and Pareto front methods(Maltais & Gosselin, 2017). Despite many studies on the evaluation of daylight metrics in specific buildings, few studies examine daylighting in an urban context by considering parameters related to the building itself and its urban morphology.

Daylight illumination inside buildings is difficult to predict on an urban scale as the surrounding buildings act as context shading and block sunlight from reaching the interior spaces. Although current simulation tools can accurately calculate daylight illumination using actual solar illumination datasets, simulation modeling is quite laborious and computationally costly. Surrogate models based on machine learning approaches have the potential to predict outcomes and reduce the environmental impact of buildings (Ayoub, 2020).

Figure 1. The studied area

This study aims to develop a prediction model with different machine learning models to evaluate daylight illuminance in the urban context. As a case study, several machine learning models are explored, such as Multiple Linear Regression, Artificial Neural Network, Random Forest. The developed models are tested in a small region of a dense urban neighborhood in Ankara, Turkey (Figure 1). Performances of prediction models are compared according to the different performance metrics. Figure 2 shows the flow of the process. In the first step, a 3D model is developed. Then, the simulation model is prepared by investigating design variables and their ranges in the Grasshopper, Honeybee plug-in. The daylighting performance metric is selected based on the literature view (Dogan & Park, 2019; Rogers & Goldman, 2006; Ayoub, 2019; Nabil & Mardaljevic, 2006; Yu & Su, 2015). Useful Daylight Illuminance (UDI) is chosen as a performance metric as it provides knowledge for different conditions by dividing the annual illuminance distribution into three bins (Nabil & Mardaljevic, 2006). Building design parameters are classified into three main categories: 'Building Properties' (material reflectance, room orientation), 'Glazing Properties' (glazing dimensions, transmittance value of the glazing), and 'Urban Form Properties' (context building reflectance, context surface reflectance, tree reflectance). The UDI value of each zone is calculated by using these selected parameters. After deciding building design parameters and their distributions, simulation results are taken. Data preprocessing (converting categorical variables to numerical ones) is applied to the simulation models' inputs and output for machine learning models. Three different machine learning algorithms are trained with the same inputs and output. Models' results are compared based on four performance evaluation metrics (Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and Coefficient of Determination (R2). This study showed that although the learning of machine learning algorithms differs, these algorithms give very realistic results much faster than simulations in estimating the amount of daylight illuminance in buildings at the urban scale.

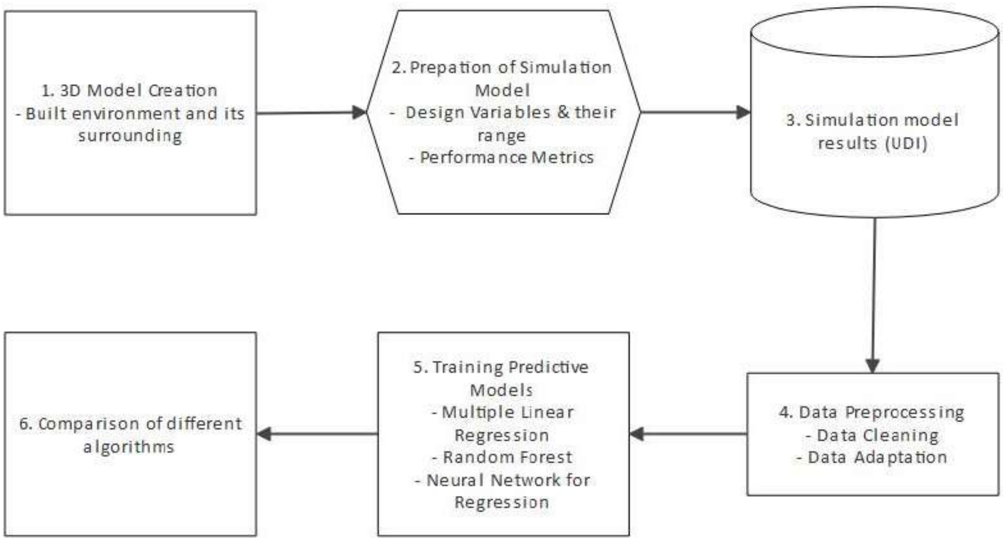

Figure 2. The flow of the process

Keywords: Daylighting, Daylighting Metrics, Machine Learning, Prediction Models

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