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Performance-oriented architecture and urban design

Relating information-based design and systems-thinking in architecture

Abstract
This article discusses a performance-oriented approach to architectural and urban design that seeks to intensify the interaction between architectures and their specific settings and environments. The overarching aim is to expand performance-oriented design in architecture to urban design and to integrate architectural, urban design and landscape design into a multi-scalar and multi-domain approach. This effort is currently comprised of three distinct research by design efforts: [i] designs for urban areas with a focus on demographic and environmental aspects, [ii] designs for peripheral areas with a focus on preserving or restoring vital local bio-physical conditions and interrelations, and [iii] designs for rural areas that elaborate an integrative approach towards constructions and correlating land uses. In order to facilitate this approach, computational information-based design is linked with systems-thinking. The portrayed research was undertaken at the Research Centre for Architecture and Tectonics and the Advanced Computational Design Laboratory at the Oslo School of Architecture and Design over a period of five years from 2014 to 2018.

Keywords**:** architecture and environment interactions, performance-oriented architecture, performance-oriented urban design, integrated architecture, urban and landscape design

Introduction

This article describes an approach to the relationship between architecture and performance that is predicated on architectures that are essentially *non-discrete* (Hensel, 2013, 2019; Hensel & Sunguroğlu Hensel, 2019). Such architectures display a deep correlation with their local setting, environment and culturally specific patterns of space and land use, instead of seeking to stand out against their settings as a primary design intent. This approach aims for expanded and intensified context and architecture relations as well as environment and architecture interactions. It is interdisciplinary, multi-scalar and multivariate in character. On an architectural scale, this implies the pursuit of a notion of local condition-specific *design systems* that occupy an intermediate position between universal prototypes and bespoke architectures. Such systems entail adaptable assemblages of parts that are particular to a range of context-specific conditions, instead of fully individual designs or homogenous repetition of a singular specified construction irrespective of context. Furthermore, these systems entail the development of a related computational design method that we have termed *information-based design*. In order to approach the involved complexity in architecture and environment interactions in a broad sense, systems-thinking is employed in the design process. The research is often interdisciplinary and research by design based.

The starting point of this research is a hypothetical position that assumes that urban outward growth and sprawl is suspended. This is done with the aim to facilitate re-orientation and the definition of an alternative approach to architecture and environment relations and linked broad-range sustainability aspects, including cultural, social and environmental sustainability. For this reason, the portrayed approach to architectural and urban scale performance is inherently inclusive, with the aim of encompassing cultural, social and environmental aspects. This aim entails a focus on new collective space and the integration of architectural and urban design with landscape architecture and various forms of culturally specific land use (Hensel, 2012, 2013, 2019).

Primary focus is placed on the correlation between the local bio-physical environment and the spatial and material organization complex that constitutes architecture and the built environment, while at the same time incorporating the cultural and social aspects that are specific to a given context (Hensel, 2013, 2019). This foregrounds local aspects and conditions as drivers in defining the interaction of architectures with their settings as key inputs for generating architectural designs. For this reason, this approach is based on locally specific conditions and circumstances, as well as societal and environmental changes that require architectural responses that invariably go beyond the scope of current practice.

The portrayed approach to performance-oriented architecture seeks to finally resolve the perceived dichotomy between form and function in architectural discourse. It is rooted in Actor Network Theory (Latour, 2005) and ascribes the capacity of agency to nonhuman actants. This chiefly concerns other species, ecosystems, geophysical systems, etc.—in other words, key aspects of the bio-physical environment. These are understood as possessing agency in interacting with and constituting the environment. Employing both a human and nonhuman perspective (Grusin, 2015) in relation to performance-oriented embedded architectures—and, by extension, to performance-oriented urbanism—enables us to consider possible correlations between cultural, social and environmental sustainability by way of significantly extending the involved roster of potential 'stakeholders' (Hensel, 2017, 2019).

Thus far, the research portrayed in this article is comprised of three lines of inquiry:

1. designs for urban areas with a focus on demographic and environmental aspects;
2. designs for peripheral areas with a focus on local bio-physical conditions;
3. designs for rural areas that elaborate an integrative approach towards land uses that are typically seen as mutually exclusive.

The portrayed research is ongoing, and the long-term objective is to correlate the three lines of inquiry and to formulate an integrated approach from these three related lines of inquiry. The need for this research arises from increasingly complex design and sustainability requirements that are insufficiently addressed and resolved in current practice. Due to fast-developing sustainability requirements, there already exists a distinct need for design approaches that enable early stage multi-criteria design specification to meet advanced sustainability criteria. This need entails analysis and synthesis in early design stages, based on an understanding that design can constitute a specific mode of inquiry towards this end. Moreover, this research anticipates that the engaged researchers will acquire the capacity to formulate multi-stakeholder projects for which currently no client exists or no latent potential has been identified prior to the investigation. This requires an understanding of design as a deliberate mode of projective inquiry, as well as a systemic and systems approach to design that can serve to handle the involved complexity.

Research context

The research portrayed in this article took place in the context of the Research Centre for Architecture and Tectonics (RCAT) and the Advanced Computational Design Laboratory (ACDL) at the Oslo School of Architecture and Design. RCAT was founded and inaugurated in 2011 and was in operation until 2018. The centre pursued experimental and practice-oriented research, combining elements of traditional knowledge production with an inter- and transdisciplinary research by design approach. In the context of RCAT, researchers conducted inquiries in a range of subject areas focused on performance-oriented architecture, embedded architectures, locally specific architecture, urbanism and landscape architecture, architecture and environment interactions, informed non-standard architectures and information-based computational design. ACDL was the innovation laboratory of the research centre. It integrates research and teaching on master- and PhD-levels based on the research subjects in RCAT, with specific focus on informed non-standard architecture and information-based computational design. Special focus is placed on the role of data in design, multi-modal data-collection and processing and advanced computational visualization methods, including augmented, virtual and mixed reality.

Research methods

The key research method deployed in the work discussed in this paper is research by design, which utilizes design as a projective method of inquiry. Research by design is frequently utilized in architecture, urban and landscape design with largely shared traits and strategies. Our approach shares the main characteristics of research by design in landscape architecture as outlined by Lenholzer, Duchart and van den Brink (2017) as research through design. Their approach entails a distinction between four modes including (post)positivism, constructivism, transformative and pragmatism, each with its own particular type of questions, aims for new design knowledge, research methods and research evaluation criteria. While the research portrayed in this article displays aspects of all four modes, it is most noticeably placed within both the (post)positivist and the pragmatist modes. The former is characterised by aiming for deductible knowledge and verified theory/design guidelines via design hypothesis testing, and design experiments based on site-specific surveys; the latter mixes research methods depending on the specific research questions with the aim to derive new practice-oriented knowledge that includes new design knowledge (Lenholzer et al., 2017). Furthermore, Lenholzer et al. (2017) stipulate that developments in computation regarding handling of large amounts of data; advanced visualisation methods (augmented reality, virtual reality, etc.); and linked computational design, simulation and analysis methods will have a strong impact on the development and use of research by design outcomes.

This view is shared by the research portrayed in this article, which is based on a set of linked computational methods including multi-modal data collection, multi-scalar associative modelling and a series of computer-aided analysis methods in conjunction with advanced visualization methods, including virtual, augmented and mixed reality visualizations (Hensel & Sørensen, 2014; Sørensen, 2006). We term the combination of these methods *computational information-based design*. Site-specific data is collected and, by way of inquiry, structured into information (Sunguroğlu Hensel & Vincent, 2015). The latter is at the base of knowledge production via generalisation in principle and specification through research by design. Utility is accomplished by linking research by design efforts with the development of the principal working method, namely *information-based design*. The goal is to work towards a research and design method along the paradigm outlined by Pim Martins (2006), who stated that

> …a new research paradigm is needed that is better able to reflect the complexity and the multi-dimensional character of sustainable development. The new paradigm, referred to as sustainability science, must be able to encompass different magnitudes of scale (of time, space and function), multiple balances (dynamics), multiple actors (interests) and multiple failures (systemic faults). (p. 38)

In addition to the methods described above, we approached the criteria laid out by Martin (2006) by way of coupling a systems-thinking approach with a design-thinking approach. In order to handle a considerable number of design criteria related to architecture and environment interactions, both from a human and non-human perspective, we commonly deploy tools such as mind-maps and other related methods of mapping complex correlations. This is done with the aim of keeping track of key design criteria and their interactions and to set out suitable design methods. This approach does not seek to be all-inclusive, but to circumvent unjustifiable reductionism in the formulation and pursuit of design intentions.

We based our approach to systems-thinking, on the one hand, on systems-oriented design as developed by Birger Sevaldson (2013) and others, and more specifically on the work of Arnold and Wade (2015). The latter posited that

> …systems-thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects. These skills work together as a system. (Arnold & Wade, 2015, p. 675)

They proposed a systems-thinking systemigram that combines elements proposed by other researchers (Hopper & Stave, 2008; Plate & Monroe, 2014; Sweeney & Sterman, 2000) with elements of their own. This systemigram consists essentially of nine elements:

1. Recognizing Interconnections
2. Identifying and Understanding Feedback
3. Understanding System Structure
4. Differentiating [Resources], Flows and Variables
5. Identifying and Understanding Non-Linear Relations
6. Understanding Dynamic Behaviour
7. Reducing Complexity by Modelling Systems Conceptually
8. Understanding Systems at Different Scales
9. Undertaking a Systems Test (Arnold & Wade, 2015, pp. 676–677)

Several of these characteristics also apply to a method that Sevaldson (2017) termed giga-mapping. We utilized this method in earlier stages of the research. The various projects portrayed in this article deployed elements of the systemigram with different weighing and in different iterative configurations in the mapping and design process stages, depending on the way projects are informed in the pre-design and early design stages.

Overall, this entails that the research portrayed in this paper is based on research by design rooted in linked design and systems-thinking, facilitated by computational information-based design. Each of these three key aspects comprises a select range of methods and tools that are configured according to specific research and project needs along an interdisciplinary and practice-oriented trajectory.

Urbanism from within: Embedded architectures in urban contexts

Our research on the relationship between architecture and urbanization in an urban context focused on Oslo as a laboratory. This included current driving factors of urban transformation, such as demographic change, urban diversification and the problem of accelerating commodification that makes urban living increasingly unaffordable for a growing range of citizens. Likewise, urban climate transformation and ecological impact makes life for other non-human stakeholders increasingly difficult from an ecosystems perspective. We explored this theme in a series of master-level studio courses that investigated architecture and society relations through the theme of *24-hour Oslo – Architecture and Demographic Change*. Students selected sites, then undertook a broad range of analyses, data collection and computational simulations to pinpoint specific local problems and opportunities for intervention. Based on the insights gained through this process, the students subsequently identified probable stakeholders for possible projects and formulated possible responses starting from the design brief to the detailed design of projects. In this context, research is not limited to investigations leading up to the project brief. Instead, the design project is understood as a forward-looking speculative inquiry that can be strategized and analysed in its own right to help inform decision-makers about possibilities that otherwise may remain unnoticed. In order to examine whether this form of projective research was recognisable to possible stakeholders, we submitted one project to the Oslo Research Award committee in 2017. This award is typically given to researchers in different disciplines to award research advances on topics such as demographic change, but design is not typically utilised as a form of inquiry. In 2017, Matteo Lomaglio's *Oslo Convergence* project received an Oslo Research Award. In the process, he was invited to present the work to the award committee, which included a range of representatives of the city planning department, as well as the educational and research environments.

Oslo Convergence was based on detailed multi-modal and multi-objective computational analyses that shed new light on how to obtain a more detailed understanding of urban demographic change and use of the city by its diversifying population. The analyses focused on seasonal and 24-hour circulation and activity patterns in the city context around the site; they took into consideration the different patterns of activities in relation to different groups of citizens, especially the younger generation and their respective needs (Figure 1). Consequently, the analyses informed a speculative design project that addressed the programmatic needs of a changing urban demography and proposed a mixed and multiple use building that combines institutional and public functions in a dynamic and adaptive manner over 24 hours of the day, thus catering to the needs of different parts of society, with an emphasis on a multicultural youth. In so doing, the project addressed population growth and change, and treated the multicultural community as an opportunity for the city's economic, social, cultural and environmental development; culture and architecture as driving forces in the city development; and innovation, value-creation and the city's ability and willingness to attract and manage talents and knowledge communities. In this way, design was used as a mode of speculative and projective research that produces tangible results that can deliver a basis for dialogue between stakeholders.

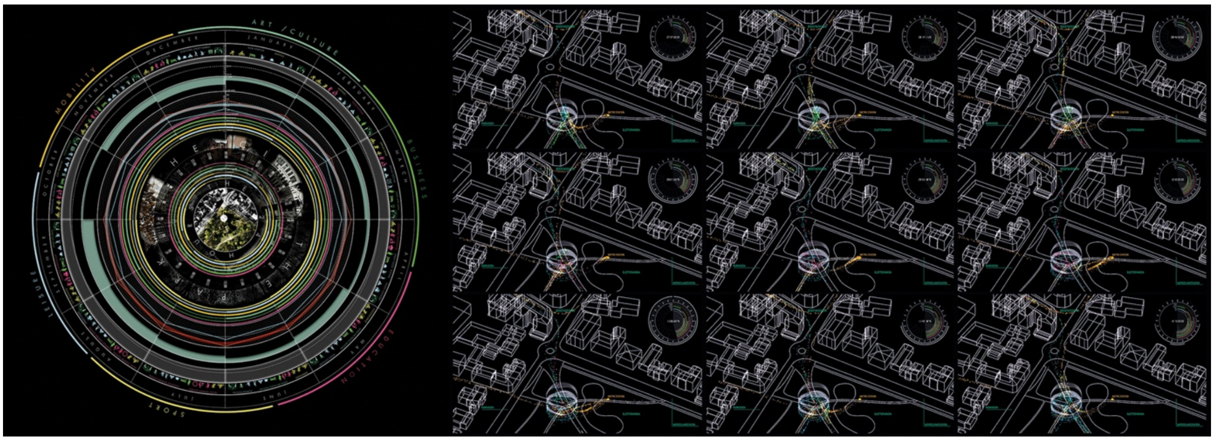

Figure 1. *Oslo Convergence*: analysis of seasonal and 24-hour cycles of programs and activities on-site and in an urban context (left); analysis and simulation of pedestrian, cyclist and vehicular circulation pattern on and around the site (right).

The project was developed through an associative computational model (Figure 2) that was presented as an immersive experience through advanced virtual reality visualization. In so doing, the project could be adapted through dialogue with the stakeholders in further development stages. As such, this approach demonstrated how the development of the contemporary city could not only respond to urban change, but also involve the agents of change and the various stakeholders in a transparent and participatory process. In this way, the designer can become an orchestrator of dialogue, while offering an urban and societal vision that is co-developed with the citizens of the contemporary city on its route to increased diversity.

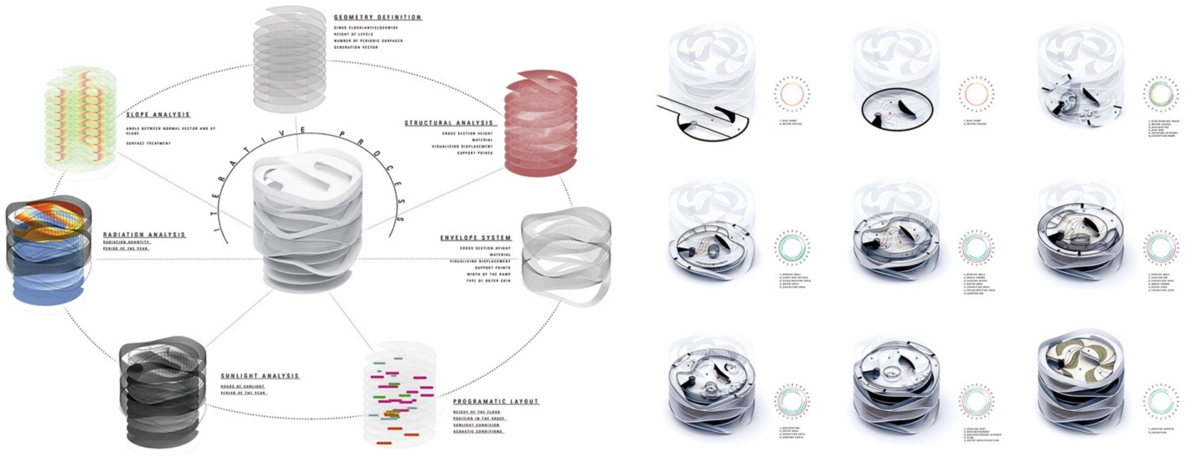

Figure 2. *Oslo Convergence*: associative computational model and computer-aided analyses (left); axonometric views of the computational model cut at different heights to show the continuous surface and placement of main activities of the project.

Oslo Convergence was a proposal for a 24-hour multifunctional building at the northeast corner of the Palace Park in Oslo above the subway line (Figure 3). The project is located at the edge of the Park at a busy car, bicycle and pedestrian route. The continuous and spiralling surface of the project taps into this flow, while distributing public programs and activities. The activities are correlated with a multiple envelope strategy, which provides fully enclosed, transitional and exterior spaces. The transitional and exterior spaces of the building offer the opportunity for the integration of local flora and fauna, to reinitiate and support ecosystems in an urban environment, benefitting from and linking with the surrounding Palace Park.

The integrated associative model served to ensure that the open interior space without subdivision would make suitable provisions for its intended public and collective activities and set out a vision for architecture driven by demographic changes and the diversifying needs of Oslo's citizens. Along the continuous path of the project, there is a succession of activities that are selected based on a detailed site analysis. These elements include walk-by kiosks, displays and other items, located along the path from the proposed new underground train stop to the ground floor, thus collecting and attracting different flows of movement. Farther along, a publicly accessible cooking school and an extension of the nearby music school are located together with a succession of exterior spaces to extend activities during the warm season. Located at the top of the building is a public garden. There are numerous choices of paths and experiences up and down the building that make it interesting to visit the project multiple times during the day as activities and their relations change over 24 hours. In this way, the project pursued an innovative approach towards attracting and managing talents and knowledge communities by way of 24-hour activities that emphasized a strong element of learning and exchange within a public setting. This approach made it possible for typically more removed and controlled access activities to be exposed and more open to participation, distributing knowledge through experiences to a wider and more diverse public. At the same time, the different levels of spectating and engagement are free of charge, except for the most central activities, such as specific direct participation in the cooking and music school events.

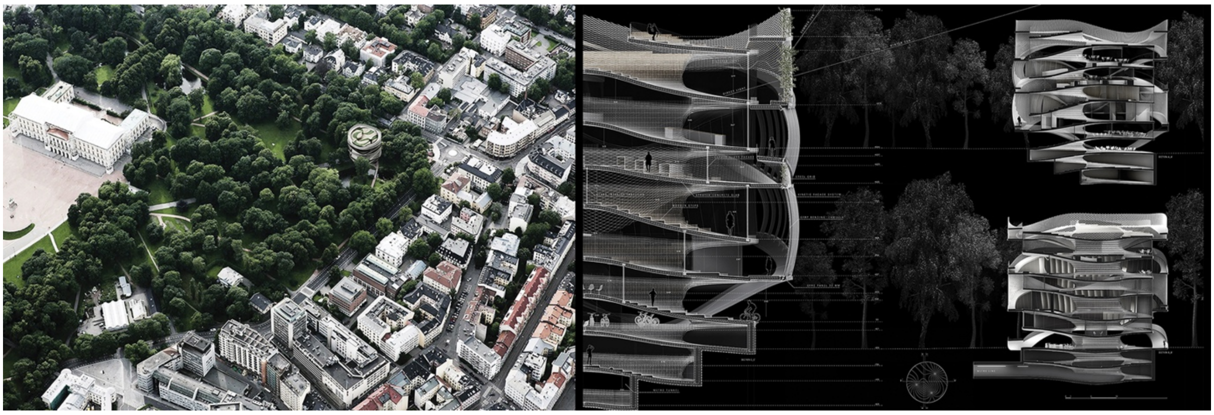

Figure 3. *Oslo Convergence*: aerial view of the project in context (left); detailed sections showing the continuous public surface as an extension of the public landscape into and through the architecture.

Tor Anders Sudmeyer's project *Makeriet* was based on a similar premise and analyses as the *Oslo Convergence* project. *Makeriet* was proposed as a large maker-space and a cultural meeting and production place at Vipetangen at Oslo's waterfront, a semi-industrial setting with an industrial history. The project establishes an alternative take on how to re-invigorate an urban waterfront, compared with the existing master-plan of the city that mainly projects high-end cultural institutions, touristic consumption and accelerated commodification of Oslo's waterfront. The potential human stakeholders in this project include all age groups who are interested in making or restoring items, whether related to the waterfront or not. Such a provision can help foster start-ups and also provide a substantial place for restoring or repairing of wooden boats, etc. The scheme projects an urban landscape in the form of a roof-scape and an interior landscape for production. The roof-scape, alongside a number of related design interventions in the vicinity, seeks to transform the perception of discomfort due to accelerated coastal winds into a varied experience of outdoor climate while also providing areas of improved outdoor comfort. Continuing along the quay, the project sought to secure public access to the water surface. The extended exterior surface can furthermore be planted with local flora to link the waterfront with the green area of the adjacent forest, thus providing an extended area for reinitiating and supporting a local ecosystem.

What is common to the above-described and other similar projects produced in the context of this research group is that design is utilized as a mode of forward-looking speculative inquiry; this inquiry also highlights the possibility of architects mobilizing towards unsolicited projects as a way of enriching urban transformation with proposals and interventions that otherwise can have no point of origin in current developer-driven urbanization and commodification. Furthermore, a related shared characteristic of these projects is that the public urban surface is continued in a landscaped manner through the proposed designs, and activities are projected based on a nuanced analysis of which provisions and programs exist and which might be introduced to the urban context, in response to demographic dynamics and change or ecological needs or opportunities. The range of activities typically includes some that allow free participation, to counterbalance activities that require payment for participation.

As such, these projects do not initially have an assumed client or brief, but evolve from an understanding of what might be missing and who might be the different stakeholders for a specific proposal. At the same time, all schemes are considered in terms of spatial progression and transitional spaces that enable a shared ground between exterior and interior. Given the climate, particularly during the cold season, this approach offers a new type of landscaped collective space with an extended interface between different activities, stakeholders and the city as a complex and dense assemblage of objects and systems.

Perimeters: Architecture, terrain and climate as a link between the urban and the natural
This part of the research on correlating and integrating architecture and the bio-physical environment focuses on the urban perimeter, where terrain, habitats and microclimates are either still intact or require urgent action due to pronounced disturbance. We utilize Oslo and its wider region along the Oslo Fjord as a laboratory for design-based inquiry. Focus is placed on developing the brief and designs for low-rise and high-density architectures on sites that are normally considered difficult, for instance, due to steeply sloping terrain, etc. The aim is to circumvent typical interventions such as levelling the site or interrupting the water regime, and instead seeking to provide or protect green corridors, reserve areas for natural habitat, and so on. We explored this theme in a series of master-level studio courses that investigated this issue through research by design and practice-based research. In terms of the former, students selected sites, collected data, and undertook a broad range of analyses and computational simulations to pinpoint specific local problems and opportunities for intervention. Based on the insights gained through this process, the students subsequently identified possible stakeholders for projects and formulated possible responses, from the design brief to the detailed design of projects. In this context, research was not limited to the investigations leading up to the project brief; instead, the design project was treated as a forward-looking speculative inquiry that could be analysed in its own right to help inform decision-makers about possibilities that otherwise may have remained overlooked.

Eskil Landet's project focused on developing a design system for a low-rise high-density settlement for the *Oslo East Fjord Project* (Figure 4). The steep slope, thin layer of substrate on bedrock, related above-ground water run-off and sensitive areas of vegetation on the site, as well as the path inclination analysis for circulation, were key parameters for the project and related associative model. Surface water run-off maintains existing trajectories and preservation spots for vegetation and listed buildings, and the lowest-inclination pedestrian circulation paths in the existing terrain were maintained and implemented as raised walkways. In this way, the scheme entailed a minimized impact on the natural terrain, water-regime and ecosystem. The dense low-rise residential fabric was interspersed with green corridors, communal spaces and provisions, such as shared greenhouses and office spaces for hot-desking to avoid extensive commuting, as well as some commercial and necessary shared social spaces. In the conception of this project, a new extensive public surface emerged both as a landscape above the built volume and as a social communication and circulation space. The units that constituted this fabric could be used individually or combined according to need. Each unit was further evaluated in terms of accessibility, daylight and thermal exposure. In this way, the design could unfold top-down from the settlement pattern to the individual units, and bottom-up from the individual units to the settlement pattern. Evolutionary algorithmic methods were deployed to evolve different arrangements that were analysed and rated. This could be done either for the overall settlement or, alternatively, for portions of phased development so as to accommodate change over time. As such, the projects aimed to cater to the multi-generational living of different income groups that could configure their specific number of units according to need and financial capacity. At the same time, multi-generational living could facilitate the various social and collective activities and spaces with 'caretakers' who have spare time and wish to engage in this mixed community instead of living in a segregated one.

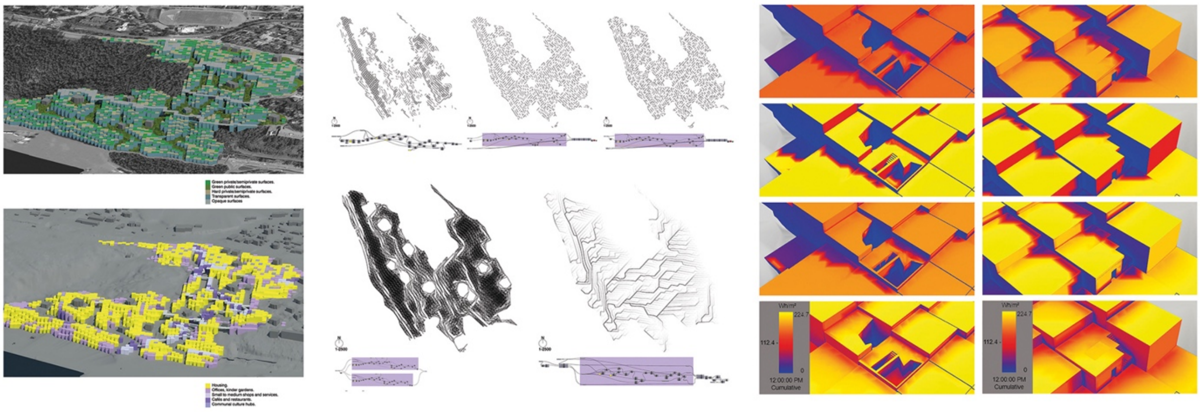

Figure 4. *Oslo East Fjord Project*: low-rise high density mass distribution with green corridors and maintaining the existing steep terrain (left top); dwelling units for different income groups and mixed-use collective spaces (left bottom); slope analysis and rainwater run-off analyses serve to design for the existing terrain (centre); daylight analysis of individual dwellings and collective spaces.

Kristoffer Sekkelsten's project CERO proposes a new *East Fjord Environmental Research Centre* for Oslo (Figure 5), located between the nature reserve of Ekeberg and the Oslo Fjord. The aim of this project was to overcome the problem of the automotive infrastructure that transects and divides the site, by way of a layered landform building that provides an extensive ecological surface that can be claimed by the local flora, fauna and ecosystem. Furthermore, the aim was to utilize tidal changes in staging varied interactions between the built and the natural environment, allowing part of the surfaces and infrastructure to be flooded and transformed over time. This constitutes a radical shift from the predominant approach towards minimizing the impact of both the physical and biological environment in architecture and suggesting a different way of thinking about sustainability, with a focus on staging and managing processes between the man-made and the natural.

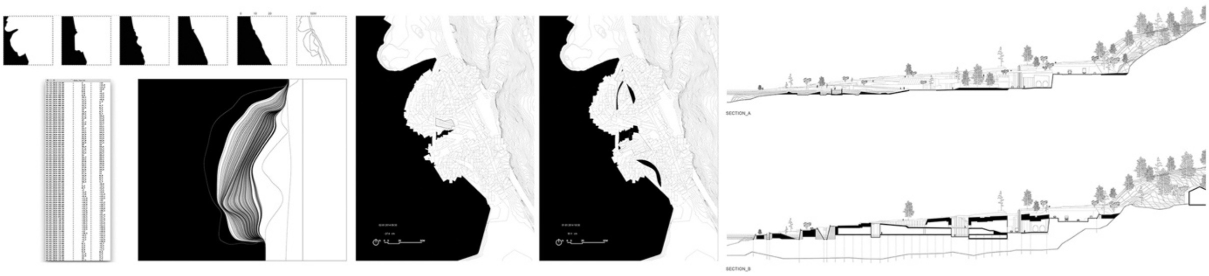

Figure 5. East Fjord Environmental Research Centre: Tidal change animation (left); different stages of flooding of the site (centre); landform arrangement of the architectural massing scheme with integrated extensions of the local water regime and ecosystem (right).

These types of peripheral projects constitute a crucial link between inner urban locations with their specific set of circumstances and dynamics and the architectures with landscape characteristics. As such, this approach indicates how inner urban projects could construct landscapes that integrate natural systems to improve a number of aspects of inner urban environments. These projects can be further informed by landscape and agricultural land uses that are specific to the wider region, while taking local bio-physical conditions into close consideration. From these projects, continuous networks of green spaces can gradually evolve, starting from the areas surrounding the perimeter and eventually moving to the cores of cities. Existing studies of the value and contribution of green urban infrastructure can further inform such approaches (Gill, Handley, Ennos, & Pauleit, 2007; Pauleit, Liu, Ahern, & Kazmierczak, 2011), but can be extended by different overlapping land use.

As in the previous research strand, a related and shared characteristic of these projects is that the shared public surface is articulated in a landscaped manner that is continuous throughout the schemes; additionally, activities and relationships to natural systems are projected based on a nuanced analysis of which conditions and latent provisions exist and which might be introduced into a dense setting of overlapping land uses that integrates the man-made with the natural.

Further potential in developing such projects arises from culturally specific practices related to public access to ground. In Scandinavia, regulations for the public access to ground can be located in the so-called *everyman's right*, which governs the public's right to access privately owned land for recreation and exercise. Here, the right evolved through what might be called *cultural practice* over centuries. In Norway, the everyman's right is an old customary law, laid out in the Outdoor Recreation Act (Ministry of Climate and Environment, 1957), which protects the natural basis for outdoor recreation and the public right of access to the countryside. Understanding the historical motivations and customary and common-sense-based implementation, as well as the contemporary version of such provisions and practices, could be of use for delivering access not only to the countryside, but also to peripheral and urban areas; this understanding could also help to formulate regulations for individual and collective rights to ground for various purposes, and to deliver specific requirements for the design of architectures that incorporate such use. This eventuality would serve to extend governing public access to the natural landscape outside of cities into a framework for culturally specific public use of constructed landscapes in inner cities (Hensel, 2018).

Urbanism from without – Embedded architectures and integrated land use in rural contexts

Today, the vast amount of architectural effort is focused on urban or peripheral environments, and relatively little attention is given to rural areas that have been cultivated for generations in a sustainable manner. As the latter are falling into disrepair or are rapidly replaced by industrial agriculture, invaluable resources, insights and valuable (land) knowledge is lost. Much can be learned from the way such landscapes are traditionally articulated, so as to yield crops in quality and quantity that are otherwise not possible. Often, such productive landscapes are shaped and facilitated by constructions, such as, for instance, terraced landscapes. In such cases, constructions and productive landscapes are not in contradiction but correlated instead. Such cases suggests that models for integrating architectures and productive land use are not in necessarily in contradiction, and that new approaches can be formulated based on analysing such examples. For this reason, this part of the research focuses on the question of how architectures and productive landscapes can be integrated with the goal of overcoming perceived contradictions in land use. This objective involves as a long-term perspective the development of novel ways in which ecosystems and agricultural use may be integrated in urban contexts. As such, this research addresses questions of environment, economy, productive landscapes and the related role of architectural design and architectures within the context of an expanded sustainability approach to human-dominated environments. It does so by focusing on diffuse heritage, which entails historically long-practiced means of altering landscapes for improved agricultural production.

We have focused our research initially on Italian historical terraced landscapes that utilize dry-stone walls for improving climatic conditions for agricultural production, especially in higher altitude locations with unfavourable diurnal temperature ranges. This research and the collected data are expected to provide some insight into this question, and to shed light on why the dry wall constructions that facilitate the terraced landscapes are deteriorating. The latter question is of major significance, since terraced landscapes are ubiquitous in Italy and have fallen into disrepair. Terraces in a state of disrepair accelerate soil erosion, landslides and seasonal flooding. Well-maintained terraces prevent these issues and provide favourable local climate modulation that enables enhanced growing of produce, e.g., red grapes for wine production, at altitudes at which it is not normally possible. Terraces, in conjunction with different pruning strategies, orient plants in a favourable way towards the sun for increased photosynthesis. This effect believed to be further enhanced by the thermal performance of the dry-stone walls that are assumed to extend the temperature ranges for effective photosynthesis by up to two hours in the late afternoon, when temperatures begin to rapidly fall at higher altitudes. Since reliable data on the costs for maintaining dry-stone walls and their climatic performance is missing, detailed policies have not been established to help maintain terraced landscapes and to support the small-scale agricultural production often associated with it. If required data could be made available, maintenance efforts and costs could be established and made part of national policies that help develop viable business models for small-scale farmers that rely on terraced landscapes. When we realized that data-collection and analyses could help solve several interrelated problems, we configured an interdisciplinary team to pursue this task. We collaborated with the Department of Agricultural, Food and Forestry Systems and the Civil and Environmental Engineering Department, both at the University of Florence, Italy. As part of the site documentation, our team collaborated with the Laboratory of Geomatics for Conservation and Communication of Cultural Heritage at the University of Florence, as well as the Geographical Institute of the Italian Military. A drone and advanced scanning technology were used to document diffuse heritage in an interdisciplinary research effort.

In September 2016, the RCAT/ACDL studio installed a network of measure-stations on the site of the terraced Grospoli vineyard. This vineyard was reconstructed by the proprietor Paolo Socci in Lamole, Tuscany. The aim was to collect data for a period of two years in order to obtain micro-climatic data that could facilitate a more nuanced understanding of the terrace and environment interaction, which in turn would facilitate the production of red wine at altitudes of 600 meters and above. In our research by design approach, we then set out master-level studio courses to develop speculative projects for a research facility for the site. The requirement was that any architectural intervention on the site of the terraced Grospoli vineyard should not to alter the micro-climate that results from the terraced landscape and that the agricultural use and productivity of the site was therefore not altered. This was done with the intention of developing an information-based approach to architectural design that is finely attuned with its specific setting and thus sustainable above and beyond any established sustainable measures that are currently practiced or projected. Moreover, this principle points towards an approach to designing architectures that are finely attuned to required and decidedly specific local conditions. With the speculative design projects, it was possible to undertake succinct research by design effort geared towards this purpose.

In these projects, we correlated climate data obtained from the local meteorological station in Lamole with thermographic analysis of the terraced Grospoli vineyard provided by the Geomatics for Conservation and Communication of Cultural Heritage laboratory at the University of Florence; this information was also correlated with industrial grade and purpose-made measure-stations provided by the RCAT/ACDL studio. Additionally, we utilized computational simulation tools for local and micro-climate analyses and correlated the outcomes with the measured data. The climatic conditions required for the wine cultivation were established in collaboration with the proprietor, Paolo Socci, and Prof. Preti's team at the Department of Agricultural, Food and Forestry Systems Department at the University of Florence. For the indoor climate, we utilized established comfort charts for the specific building programs.

Master-level students Maria Lagging and Joar Tjetland pursued a design approach that located all required spaces for the *Grospoli Research Centre* and accommodation for six researchers in one building with most spaces located underground (Figure 6 and 7). The central space for the research laboratory opens upwards toward the sky and is marked by a larger canopy, a landscaped entrance and a main space for collective use. The spaces for accommodation are located underground adjacent to the dry-stone walls, with large openings that permit physical access, daylight and ventilation. Various environmental/micro-climatic analyses (shading, solar radiation, etc.) for the exterior space adjacent to the projected building were conducted during the different design stages to ensure that the resulting conditions were within the permissible limits for growing wine. Concurrently, various interior climate analyses were carried out to assess the interior climate conditions during the different design stages to inform the spatial and material organisation of the scheme.

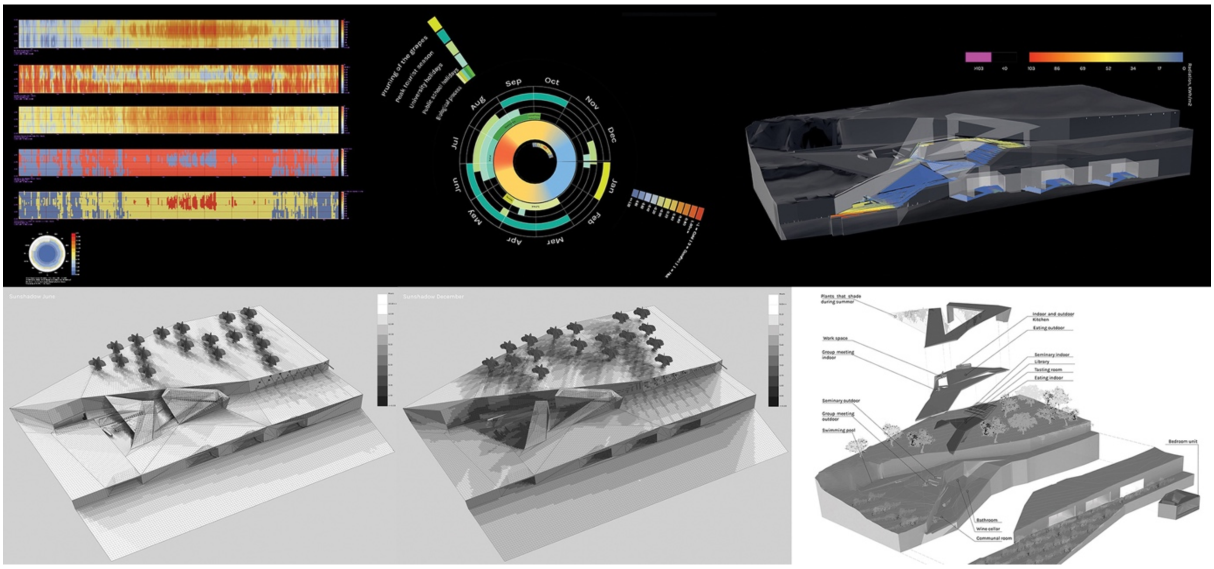

Figure 6. *Grospoli Research Centre*: local climate data (top left); seasonal and daily activity distribution on site in relation to local climate conditions (top centre); analysis of indoor climate conditions of a design instance (top right); shading analysis (bottom left and centre); exploded axonometric showing the program distribution of the scheme (bottom right).

Figure 7. *Grospoli Research Centre*: night view of the project (left); section showing the architecture and terrain relation (right).

Two projects pursued a different strategy for minimizing the micro-climatic impact of the proposed scheme. Master-level students Andra Nicolescu and Kristian Taaksalu (Figure 8), as well as Julia Anna Maria Eriksson, had projects that entailed a series of small buildings distributed along the historical downhill water drainage canal and pools of the terraced Grospoli vineyard. The distributed small spaces served for wine production, storage, tasting and related research, interspersed with follies that offered atmospheric experiences related to the production of wine, including water, sunlight, gardens and specific landscape views and experiences. The specific quality of these two distributed projects arose from their combination of local dry-stone wall construction, spatial organisation and atmospheric conditioning of the individual architectures and the series of experiences.

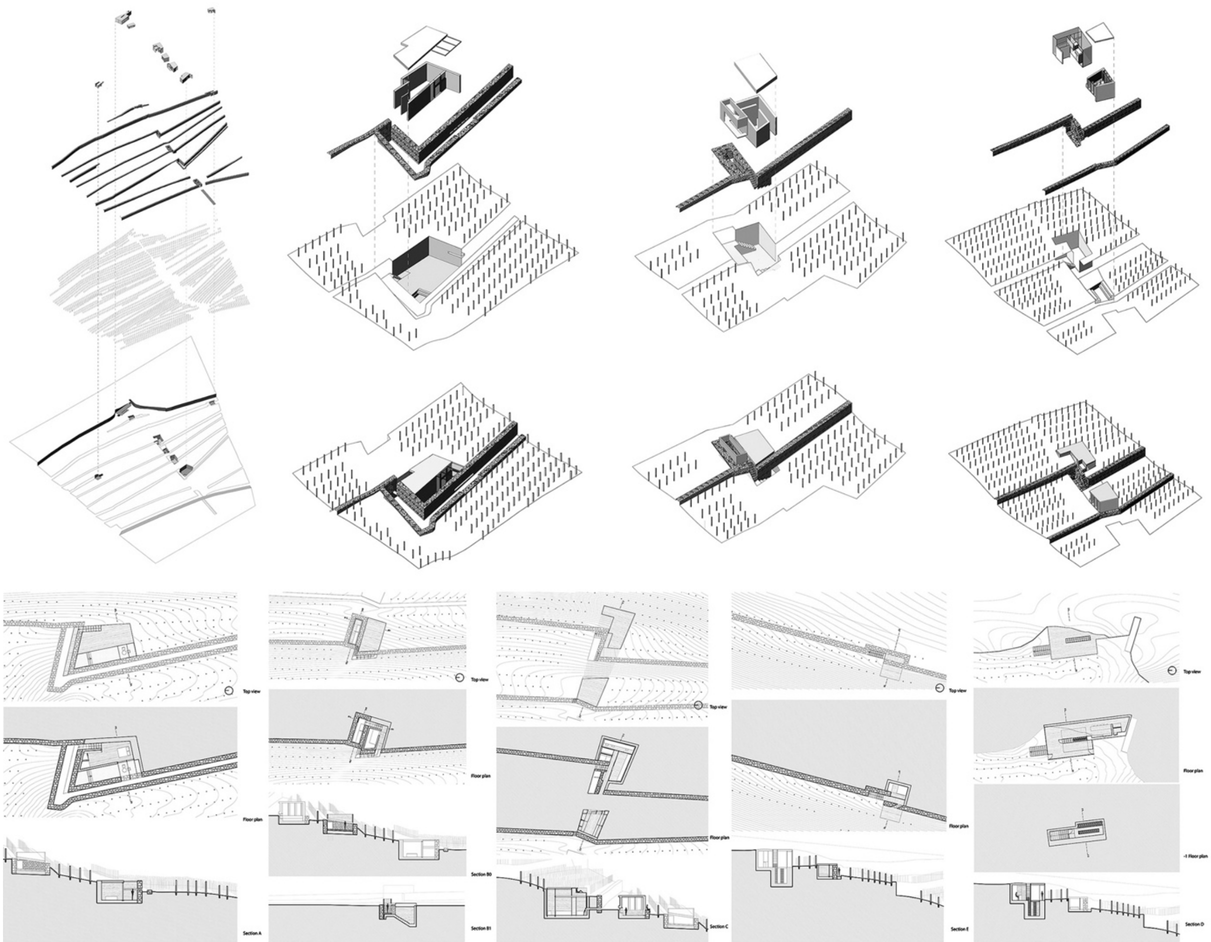

Figure 8. *Grospoli Landscape Centre*: Exploded axonometric showing the landscape systems and constructions and the integration landscape and architectures (top left); exploded axonometic views of individual locations that show the interlacing of architectures and dry-stone walls (top centre and right); plans and sections of five individual locations that show the integration of the architecture into the articulated terrain of the terraces (bottom left to right).

This type of research points towards an approach to the design of architectures that are finely attuned to local conditions above and beyond what is currently practiced or projected. With the addition of the speculative design projects, we were able to mobilize a succinct and projective research programme with design effort geared towards this purpose. The lessons learned can be applied not only to other rural settings and similar cultural landscapes or diffuse heritage performance analysis; this knowledge can also be applied to peripheral and urban settings in which architecture and landscape elements, geophysical situations and ecosystems can coexist (Hensel, 2018). However, these applications entail a variety of combined criteria that require an extensive systems-thinking based approach and will likely result in new architectural arrangements, with focus material and spatial organization related to environmental performances that are the outcome of negotiated requirements of new combinations of land use. The contours of this interdisciplinary undertaking are gradually taking shape as numerous academic research efforts and land-related grant programmes indicate. As such, this line of research is still in its infancy but can be said to already show how the combination of systems-thinking and design-thinking can affect and facilitate the way forward.

Discussion and Conclusion

As discussed above, the need for the research portrayed in this article arises from increasingly complex design and sustainability requirements that are insufficiently addressed and resolved. This seems to be due to an inadequate underlying research and design approach, organized in sequential manner that can be characterized as post-design optimization. We seek to address this issue with an early design stage-integrated research by design approach. Three distinct lines of research, and more specifically research by design, are pursued with the goal of configuring an integrative performance-based approach to architecture and urban design and the integration of cultural, social and environmental sustainability:

1. designs for urban areas with a focus on demographic and environmental aspects;
2. designs for peripheral areas with a focus on local bio-physical conditions;
3. designs for rural areas that elaborate an integrative approach towards land uses that are typically seen as mutually exclusive.

This research is ongoing, and the long-term objective is to correlate and integrate the three lines of inquiry. Key to the three lines of inquiry and their eventual correlation is interdisciplinary early stage multi-criteria design specification, as well as analysis and synthesis in early design stages. While the work discussed above has made some progress in this direction, much remains to be done. From a method perspective, we aim for what we term computational information-based design. This concept entails multi-modal collection of data; the upgrading of data to information through data-structuring and related methods, such as computational ontologies (Sunguroğlu Hensel, 2008; Sunguroğlu Hensel & Vincent, 2015); integrative computational modelling and analyses and advanced computational visualization. The goal of working towards an interdisciplinary data and information-based approach to design is currently hampered by the lack of a multivariate approach that would be based on correlation between different conceptual approaches to models and that would extend to the integration of methods and tools. Due to this problem, current approaches remain frequently unconnected, and the cumulative effect of architecture and environment interaction often remains insufficiently understood. Besides further improvement of integrating systems- and design-thinking approaches, it is necessary to invest significant effort into pre- and early stage design interdisciplinary collaboration. Frequently, this entails starting from discussing basics, clarifying terminology and conceptual approaches before integrative methods can be set out with the aim of formulating and linking integrated approaches to sustainability. This, then, is the context for current and further research efforts and questions *en route* to embedded performance-oriented architecture and urban design by way of information-based design.

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