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Designing with flood risk in Venice, Italy

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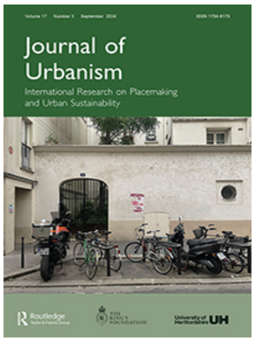

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The Casco concept as an enabler for interdisciplinary design: Designing with flood risk in Venice, Italy

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ABSTRACT
The environmental crisis demands for an interdisciplinary design of urban infrastructure to increase resilience to climate change. Interdisciplinary design is about integration of data, concepts, ambitions and goals by bridging instrumental differences between engineering and spatial design. This paper presents the results of an interdisciplinary design study that deals with persistent flood issues in the Venice lagoon (Italy). The study illustrates how the differences in languages, methods and tools of the disciplines can be overcome by interdisciplinary collaboration directed towards the designing of spatial and technical solutions. Two design proposals are instrumentally described through the lens of the Casco and the Open Building concepts; both advocate the creation of an overarching frame as the basic condition for adaptive design. The paper gives insights on how to cooperate in interdisciplinary design settings in educational environments and builds knowledge on the collaboration between fields that might be relevant also for professional figures.

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Interdisciplinary design; engineering; architecture; landscape; sea level rise; flood defence systems

Introduction

Climate change is one of the most pressing issues that humanity will be facing in the twenty-first century (Portner et al. 2022). Some of the already known manifold and often interrelated symptoms of continuing trend of raising of global mean temperature can be felt and measured. Sea-level rise, extreme weather events like heavy rainfalls and/or in combination with severe dry periods are, increasingly, impacting our daily lives even in urban contexts (Masson-Delmotte et al. 2021). These challenges are furthermore linked to more human centric challenges such as rapid urbanisation, energy and food security and water scarcity (Allan, Arias, and Berger 2021).

The city of Venice is a prominent example in this canon of challenges due to its mix of being very exposed especially to sea-level rise and having an interdependent relationship with the lagoon that surrounds it: a system created by millennial human interventions and non-human forces (Bevilacqua 1998; D'Alpaos 2010). It also suffers from other human-based challenges, such as the overcrowding caused

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by massive tourist flows and overcentralization of functions and infrastructures, most of which are positioned on the main island or further into the hinterland bordering the lagoon (D'Alpaos 2019; Zucconi 2002).

According to Meerow, Newell, and Stults (2016) climate change can only be endured by increasing the resilience of the built environment achieved by a more conscious and integrated design process within the field of urban and infrastructure development. Interdisciplinary design is about integration of data, concepts, ambitions and goals by bridging instrumental differences between engineering and spatial design (Van de Ven, Gehrels, and van Meerten 2009; Hooimeijer, Yoshida, et al. 2022b).

To get more grip on the act of bridging knowledge, the challenges of Venice and its lagoon served as a paradigmatic case for an interdisciplinary design research executed by students supervised by staff of the Delft University of Technology as part of the interdisciplinary research Delta Futures Lab. The aim of the design research is to investigate how scientists, designers, and engineers can consciously integrate spatial visions and technical data in the design process and to understand how both impact the process and the results in terms of technical solutions and spatial measures.

The research resulted in two design proposals that share the ultimate aim of mitigating the impact of sea-level rise in Venice (Buis et al. 2021). Since both the proposals are underpinned by the same methodological approach, the study reveals that it is possible to create different designs while relying on the same engineering evidence and theory. This challenges the engineering assumption – that there is only one good technical solution – and acknowledges that there are numerous possible answers because more elements are weighed when finding for the most appropriate spatial solutions (Hooimeijer, Yoshida, et al. 2022b; Lee and Kothuis 2022).

The designs are, respectively, based on two proven concepts of the Dutch practise and academic tradition that are representative for the design disciplines participating in the study: the (landscape) Casco (Sijmons 1991) and the (architecture) Open Building (Bosma, Hoogstraten, and Vos 2001; Kendall 1999). The Casco Concept has been a proven concept for integrating the technical approach with the spatial design process in delta management in the Room For the River project (Meyer and Nijhuis 2016), the Netherlands. The (architectural) Open Building concept is the equivalent of the (landscape architecture) Casco Concept. Both concepts advocate the creation of a strong conceptual framework, the Casco, as the basic condition for design projects, both technical and spatial. The two concepts offer a new perspective when designing since hydraulic engineering in the Netherland has been always considered the *conditio sine qua non* (van der Woud 1987) for spatial development, separating and even arranging into hierarchy disciplines and specialisms. In this paper, these concepts are instrumentally used to scrutinize how hydraulic engineering impacted the design process and its outcome. This is done on the two design proposals that work with flood defence systems in Venice from two scales: the landscape and the architectural.

The main question of this paper is "what is the impact of the engineering domain in spatial designs for flood risk mitigation when using two different

Casco concepts"? The paper first presents the theoretical frame of design theory, methods and concepts that have been employed and are specific for the interdisciplinary design process on the basis of earlier studies (Hooimeijer, Bricker, et al. 2022a). The Casco and the Open Building concepts are described in combination with a specific design theory highlighting how they can be strengthened when running interdisciplinary design projects at different scales. Secondly, the paradigmatic case study of Venice and its lagoon is introduced in its flood risk challenges; final results of the designs are also briefly described in order to explain and further analyse the design decisions. In the discussion, the role of engineering in this design study is elaborated on the process and outcomes.

This paper contributes to interdisciplinary design research in two ways. Firstly, it demonstrates that theories and concepts from spatial design are conducive to the participation of other disciplines. Secondly, it highlights that the utilisation of spatial concepts does not preclude or negate the necessity of engineering knowledge. By showcasing the mutual influences of interdisciplinary design research between spatial design and engineering, the paper underscores the importance of fostering integrated workflows in both educational and professional settings for the development of research and design proposals.

Theory & methods

Interdisciplinary spatial design integrates diverse fields, such as engineering, architecture, landscape design, and urbanism, to address complex issues like climate change and urban resilience. It enables collaboration across disciplines to create solutions that are both technically sound and spatially effective. Interdisciplinary approaches bridge methodological and conceptual gaps, fostering innovation through shared knowledge. Interdisciplinary work not only allows for the integration of diverse perspectives but also creates entirely new frameworks for addressing problems that individual disciplines cannot solve alone. Bringing together different fields allows for more flexible and resilient solutions that can evolve with changing urban and environmental conditions (Brand and Karvonen 2007; Klein 1990). This adaptability is essential in creating sustainable urban environments that can withstand the pressures of climate change, rapid urbanization, and other global challenges. Reflecting these theoretical principles, TU Delft has integrated interdisciplinary design and research into its MSc-level education of the faculties of civil engineering and architecture through the Delta Futures Lab. The Lab provides the necessary interdisciplinary conditions (students, staff and shared cases), process (specific steps that enable integration) and methods (how to actually integrate data, concepts, ambitions and goals). The work in the Lab has been developed over the years with the focus on interdisciplinary methodologies and design for urban infrastructure designs. It resulted in a theoretical framework for interdisciplinary design and in a methodology named the Tohoku method (Hooimeijer, Bricker, et al. 2022a). In this paper, the Tohoku method is aligned and combined with the design theory of van Dooren et al. (2013) in which five elements exemplify the design process.

The method and the theory are further explored by the intertwining with the two Casco (Sijmons 1991) and the Open Building (Bosma, Hoogstraten, and Vos 2001; Kendall 1999) concepts that are used to frame the different approaches of the two design proposals. The concepts discussed in this study operate at a fundamental level distinct from approaches like “building with nature,” “resilience,” or “co-creation” which focus more on the end goal or ambition rather than the practical “how” of design (Bush and Doyon 2019). Unlike these broader concepts, the study does not primarily aim to explore interdisciplinary outcomes in relation to nature, sustainability, and social inclusion. Instead, its primary objective is twofold: first, to assess whether fundamental spatial design concepts, used as a Guiding Theme, can act as catalysts for engaging other design disciplines in the design process; and second, to evaluate the role of engineering knowledge when integrated into these concepts.

Design theory

Even though the act of designing is ambiguous, personal and somewhat intangible, van Dooren, Boshuizen, van Merriënboer, Asselbergs and Van Dorst unravel it into a framework (2013). This framework provides a structured approach to navigating the complexities of the design process, especially in interdisciplinary settings. It helps facilitate collaboration between disciplines by breaking down the design process into clear, manageable stages, allowing diverse fields to contribute meaningfully. Focusing on the qualitative aspects of the process of design, this framework is particularly valuable in interdisciplinary environments as it offers a shared methodology, ensuring that creative, technical, and spatial considerations are integrated into a cohesive outcome. This framework presents five elements involved in the design process: Experimenting, Guiding Theme, Frame of reference, Sketching and modelling and Domains. Experimenting is a process of exploring by means of the formulation of general visions and possible sketches that need to be further deepened and evaluated. The second element is about defining a Guiding Theme: a design idea (or concept) able to interpret into the spatial dimension the ambitions and the goals of the designer leading to decisions that create a coherent result. The Frame of reference (or Library) refers to the fact that all design decisions come consciously or unconsciously from knowledge that already exists. Sketching and modelling describes a setting in which the physical counterpart of the mental process helps to shape and evaluate the design. Finally, the element Domains is the necessary supportive knowledge (data) which is related to the engineering of the built environment.

Tohoku method

The Tohoku Method provides interdisciplinary design conditions, a process design with specific methods to make possible conscious integration between different disciplines and avoid superficial dialogue (Hooimeijer, Bricker, et al. 2022a). The process consists of analysis, synthesis and design phases that are iterative. Important method to guide the synthesis into design is Scoping in a charrette formation. Scoping is the integration of information and ideas by creating a common understanding of the problem and context of the case.

Experimenting, Sketching and the Frame of reference are the first three elements of the design theory of van Dooren et al. (2013). Within the Tohoku method, these are elaborated first according to the single involved discipline to set a series of concepts and measures that all disciplinary groups produce and value on the same parameters using the 4P Traeder (van Dorst and Duijvestein 2004).

The base of the 4P Traeder is the triple bottom line of sustainability: people, planet and prosperity (UN 2002). To make this approach more instrumental for spatial interventions, Van Dorst and Duijvenstein added a fourth P in the 4P tetrahedron theory, which represents both Project and Process (see Figure 1). Project stands for the physical results and represents the spatial quality, relations through scales, (bio)diversity, robustness and aesthetics of the design. Process regards the interaction between stakeholders, their skills and the institutional context that is needed to support a feasible design (van Dorst and Duijvestein 2004).

The making of the scopes (Scoping) enables the involved disciplines to value their individual concept according to a shared value system with the other disciplines. Aligning the proposals – according to this value system – enables the integration of ideas because the disciplines can integrate values. This is brought together in the charrette, meeting each other one by one in rounds and ending up together as a group.

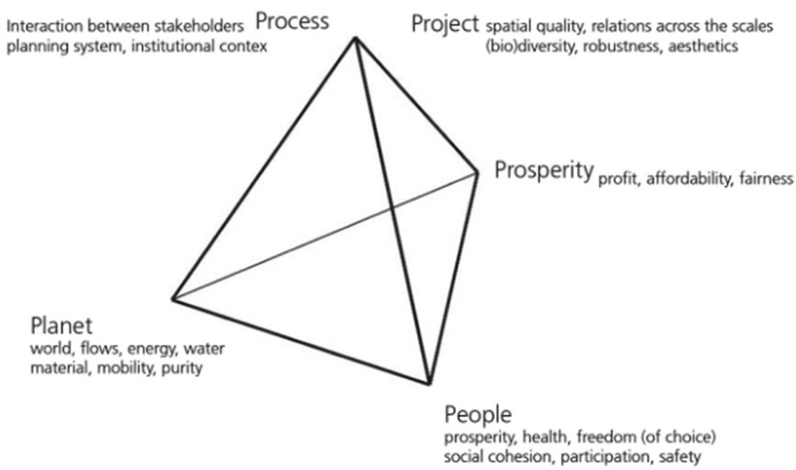

Figure 1. The tetrahedron of sustainable construction (van Dorst and Duijvestein 2004).

Guiding themes

Since the study aimed to contribute to interdisciplinary design research by testing the Guiding Theme as a catalyst, it was essential that the theme align with both the participating design disciplines (architecture and landscape architecture) and the specific challenges of the study.

The choice was made for two proven concepts that can be considered part of the same type of "design thinking:" one originated from the field of landscape architecture – the Casco Concept (Sijmons 1991) and one originated from the field of architecture – the Open Building Concept (Bosma, Hoogstraten, and Vos 2001; Kendall 1999).

Both landscape and architecture concepts originated in the Netherlands and are design and zoning strategies related to spatial and temporal dynamics, and, as stated in the introduction, especially the Casco Concept has a proven impact on delta management. These concepts give insight and tactics on how to make a decision in what is fundamental to the design (the casco) to guarantee the desired result. Both are attempts to reconcile fast and slowly developing processes in the city and in the environment. The landscape concept aims at this goal concentrating on the ecological values of natural areas, while the architecture concept is aimed at strengthening the agency of adaptive urban systems.

The casco concept (Landscape design)

The Casco Concept was developed in the late 1980s and early 1990s as a planning tool for landscape governance. It is inspired by the so-called "Plan Ooievaar" (de Bruin et al. 1987) which proposed a strategic spatial disconnection of natural and agricultural areas in the Dutch river delta in order to reactivate and prioritise the biodiversity processes of the riverine landscape (see Figure 2). This idea is based on the observation that the abiotic and biotic layers of the natural environment develop much slower than the built one: urban layers are much more subject to human led economic and societal trends, as well as a higher degree of uncertainty. In order to give both, the slowly developing processes for vegetation, frost, groundwater reservoirs and the fast-developing ones for farmland, industrial settlements and cities, sufficient space, and time and to prevent one process from taking over the other, a spatial separation is proposed by the means of the "framework" and the "user space." The framework is meant to provide a stable chunk of the environment where natural processes can unfold and develop over a long-time frame. It provides base conditions as well as sufficient land to support the overall ecological dynamisms of a given landscape. The user space is separated from the framework as much as possible in order to let its functions develop independently and flexibly without impacting the framework. Depending on landscape typology and local conditions, framework and user space can take on different shapes and sizes characterized by specific elements based on regional climate and ecology or local building traditions and economies.

Figure 2. Plan ooievaar (de Bruin et al. 1987).

Plan Ooievaar and its founding proponents played a crucial role in applying the Casco Concept to the Room for the River project in the Netherlands (2007–2015). This initiative allowed rivers more space to flow and manage higher water levels during floods, aiming to reduce flood risks, enhance ecosystem services, and support sustainable development (Meyer and Nijhuis 2016).

Open Building Concept (Architecture)

The Open Building Concept (*Open bouwen*) was developed by John Habraken as criticism of the Dutch and European reconstruction policies after the Second World War (Bosma, Hoogstraten, and Vos 2001). Habraken questions specifically the construction of prefab buildings which prohibited the users from exercising influence over their own living environment. This developed into the idea to separate the shell (or casco) of the building from its interior fittings, not only to facilitate the agency of its users, but also to allow the structure of the building to absorb changes in use without structural modifications.

This concept was developed on a bigger scale that sees the separation of the slower development of buildings and structures of the urban fabric, the "casco," and its faster changing (inner) program and possible customization by individuals (see Figure 3). The approach was attributed with a clear working method that organises connections between the various scales: land use, urban tissue, support, and installation. The different levels require the input of different parties involved (professionals and non-professionals) and different methods and techniques for design, realisation, and management. Each level has a different lifespan, which can be predicted and determined. At the urban scale, the concept of "Open Cities" is developed as a flexible, resilient, and collective framework that provides ample space and infrastructure, allowing for individual design interventions and short-term investments. The Open Cities theme is designed to accommodate changing investment patterns, new legislation, asset management strategies, and tax regimes, incorporating policies and planning tools to support adaptable urban development (Open Building 2024).

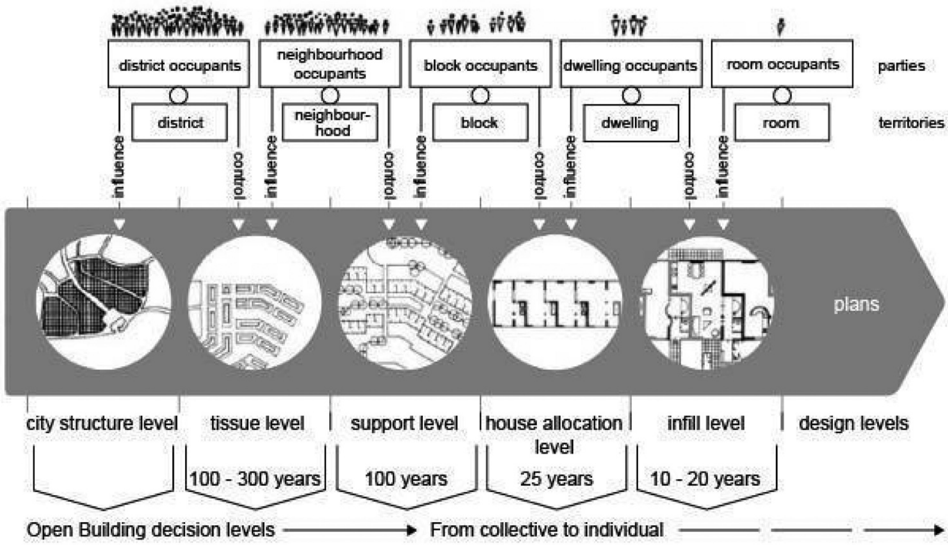

Figure 3. Levels of decision making (Habraken 1961).

As it is for the landscape Casco, also in this case the methodology foresees flexibility to adapt to the site-specific conditions and external boundaries of a given urban context (van der Werf 1993).

Venice and the lagoon

Venice was established as an island settlement by Roman citizens seeking refuge from the invasion of Germanic tribes on the Italian peninsula (Bevilacqua 1998; Bosio 1987; Canal 1995; Distefano and Paladini 1997). The shallow water of the lagoon granted safety as it was hard to reach and easy to defend. Centuries later its position along the Adriatic Sea aided Venice in becoming a dominant trade route in the Mediterranean and one of the most prosperous European cities within the Renaissance period (Longworth 1974). This ongoing habitation and economic exploitation, however, necessitated measures to preserve the fragile balance of the lagoon landscape. In the beginning of the 15th century, natural forces – mostly sediments' accumulation towards the mainland and erosion towards the seaside – were jeopardising the survival of the lagoon. A series of interventions at multiple scales (like river diversions, channelling of water flows, wooden barriers, reclamation) started with the aim of preserving its ecological and strategic functioning (Bevilacqua 1998; Cessi 1941; Cosgrove 1990; D'Alpaos 2009, 2010; Iuorio 2022).

Four centuries later, in the wake of industrialisation, the hard found balance of the lagoon changed. Modern infrastructural projects (railway, bridges, port, industrial areas, airport) came into being, tipping the scale of the ecosystem of the lagoon (Miozzi 1969; Scano 1985; Zucconi 2002). During the 1900, the inlets were dredged to allow passing of bigger ships causing ongoing sediment loss, underground water pumping to sustain the industrial demand amplified subsidence progress, wetlands were reclaimed to support fast urbanisation and the development of agricultural areas (D'Alpaos 2019; Madricardo et al. 2019; Mencini 2002; Pisenti and Rosa Salva 1972).

In the latest decades, also due to the increasing sea-level rise, Venice started to flood more frequently (Cavaleri et al. 2020). As a countermeasure, plans for a movable storm surge barrier, the MOSE, were drawn up in the 1980s (Allan, Arias, and Berger 2021; 1984). It became operational only in 2020. Umgiesser (2020) forecasted that with a sea-level rise of 50 centimetres, the barriers will be closed nearly once per day. Since the operations to move the dams can require up to 8 hours to be completed, it means that in the near future the lagoon will be more closed than open to the sea, drastically changing its ecological characteristics (Iuorio and de Marchi 2022).

In the light of the inability of the MOSE to protect Venice over a long span of time (D'Alpaos 2019), the interdisciplinary design project has been executed to study the lagoon and bring forward possible spatial visions for its survival.

The project is done by a group of nine students coming from hydraulic engineering, architecture, and landscape design in the masters of TU Delft. They performed interdisciplinary research resulting in two design proposals, both built on the principle that "Venice is the lagoon, and the lagoon is Venice" (Bevilacqua 1998). The assumption of the design study is that if we want to save Venice, we must save the lagoon; only a healthy lagoon can reverse or mitigate the processes that have negatively impacted the city over the past decades such as erosion, ground subsidence and sea-level rise. The following descriptions of the two proposals are abstracts of the full research report done by all students (Buis et al. 2021).

Design proposal: the perfect lagoon

The Perfect Lagoon is an ambitious spatial vision aimed at mitigating the negative impacts of anthropogenic development across various scales through landscape design. Its title refers to the general aim of reclaiming the ecological function of lagoon as it was envisioned during the 16th century. Today, to achieve this goal, it has been developed a strategy that sees natural processes as instrumental to overcome all the environmental negative externalities that the infrastructural interventions have created in the 20th century. The vision embodies a paradigm shift from a world where humans try to limit the dynamics of non-human systems, to one where natural systems take precedence over our current needs to extend human practices over a longer time frame.

Following the slogan "we must change to preserve" (subtitle of this design proposal), the embodied ecological processes of the lagoon are studied and re-adapted for contemporary and future challenges. The goal is to create a lagoon that is more resilient to sea-level rise by the means of the so-called green infrastructures.

The main strategy is to divide the lagoon in three parts by a green dike system (see Figure 4). This system protects the central, urban part of the lagoon from sea-level rise, while leaving the largely un-urbanized northern and southern part of the lagoon exposed to the sea. This division is necessary to preserve and enhance the characteristic landscape of the lagoon – *barene* (islands periodically submerged by high tide) and salt marshes, and harness its potential for flood mitigation, nature development and water cleaning (see Figure 5). It is made possible by the ability of the *barene* to trap sediment and essentially

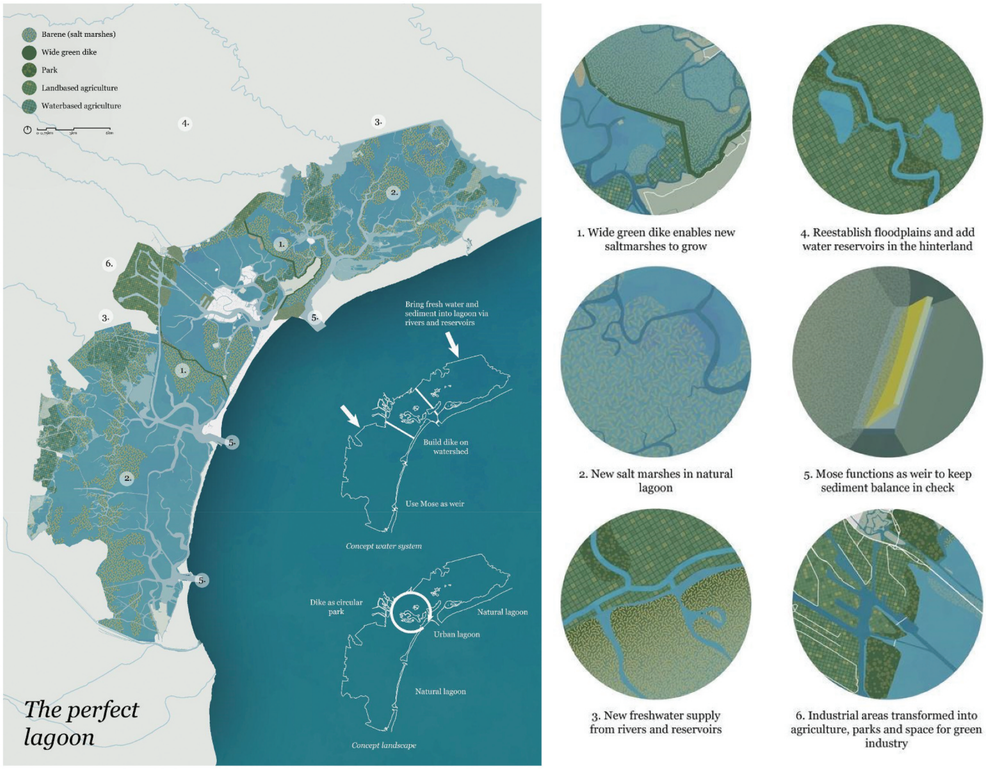

Figure 4. The perfect lagoon design proposal. General vision and main interventions (Buis et al. 2021).

grow with sea-level rise (van Loon-Steensma 2015). Furthermore, by reconnecting the Brenta and Piave rivers, respectively, to the southern and northern lagoon, sediments, and freshwater – needed for the regrowth of the *barene* – are brought into the body of water.

Figure 5. The perfect lagoon design proposal. View from the green dike onto lagoon with water-based agriculture (Buis et al. 2021).

This green dike system aids as a catalysator for this salt marsh development, as well as a central space for recreation and agriculture within the lagoon. On the outer perimeter, a gentle slope and planting with salt-resistant plants enable sediment trapping and with that *barene* development. A foot and cycling path on top of the dike connects the mainland and the Lido and allows citizens and tourists to experience the lagoon without heavily interfering in it. Within the perimeter of the dike a system of natural reserves is developed, as well as a water cleaning mechanism for the central lagoon. Old industrial sites and islands are redeveloped into agricultural land.

To minimise interference with the ecological lagoon processes, the dike is positioned across two tidal watersheds. The Lido becomes an essential part of the dike system and is fortified at its lowest point at the back of the island. With these interventions the city of Venice is protected by the dike and occasional flooding is allowed in the lagoon. This means that the MOSE can be repurposed as a submerged weir that aids in controlling sediment flow.

Design proposal: the Symbiotic System

The Symbiotic System envisions for Venice a metropolitan lagoon in which new connecting infrastructure and mobility systems are proposed; these are instrumentally used and designed to reduce the impact of human activities on the natural system of the lagoon while preventing extreme flood events. The main strategy is to introduce a new circular dam that works also as a mobility network (see Figure 6). This ring divides the city of Venice and its main surrounding islands from the rest of the lagoon to mitigate the negative externalities of the urban activities and enable the ecosystem of the lagoon to gradually restore itself, finding a new possible ecological balance. The infrastructure controls the water level inside the Venice system, increases accessibility by providing a new public transport network and connecting the main islands and introduces more public urban programs and amenities. The proposal aims to increase the development of connectivity and infrastructure in a scenario of growth in which mobility infrastructure will be strategic especially to distribute the impacts of tourism; also, local citizens will benefit from the design of the new ring because of the reduction of flood risk and the public program related to the infrastructure.

Figure 6. The symbiotic system design proposal. General plan of the dam-ring and development of the new islands (in red) through time (Buis et al. 2021).

Figure 7. The symbiotic system design proposal. View impression of new developments and integration of the dam-ring into the current urban tissue of Venice (Buis et al. 2021).

Connection between the island is performed by bridges that are designed for boats to pass, avoiding the interruption of the existing internal water transport routes and the traditional way of moving goods and people. Shipping locks are located in specific locations of the ring for bigger boats to go through when necessary. In addition, a metro lane is envisaged: it runs above the gates on extended bridges.

In the vision, as proposed by D'Alpaos (2009), 2019) the waterway that connects Padua to the lagoon (PD-VE waterway) is completed; it can be used for fluvial ships to move goods between the two industrial areas in order to reduce the crowding on the hinterland roads. In addition, the waterway can be used to control sediments and freshwater inputs that help with erosion and salinity problems of the lagoon.

The dam is not the only water barrier in the designed network: the Lido Island also acts as a part of the flood defence system as the height of its shoreline allows for that. The existing MOSE structure is used as a secondary storm surge barrier for the next 100 years. This way, during extreme storm surges combined with the effect of sea-level rise, MOSE is able to protect the primary coastal defence, preventing possible overflow/failure from happening.

The dam-ring also creates new soil for the city of Venice to grow. The strategy is to gradually expand the land and create new islands using the dredged materials. The process of expansion is done in three steps over the span of 75 years. The first expansion is done simultaneously with the building of the dam, using the ground that is removed for building it. The second stage begins after 25 years when enough sand is collected from dredging the inner core of the system. Last stage, of creating new islands, starts in another 25 years, making use of the traditional Venetian building on piles technique. New housing, offices, alleys, and public parks and amenities are developed together with the dam-ring. In this way, the dam is an infrastructure to connect people and protect from flood risk systematically designed as a continuation of the city (see Figure 7).

Design process

The two design results were worked out in a design process over several months after the intense workshop in Venice using the Tohoku method. This method consisted of encompassed scoping in charette form, as well as a first sketch design (see Figure 8). The individual disciplines were tasked to prepare references of cities facing flood risk (*frame of reference*), as well as first concepts and design experiments that show how flood mitigation could look like in Venice (*Experimenting and Sketching*). In the process of Scoping they evaluated this information according to the 4P tetraeder of sustainability (Van Dorst and Duijvestein 2004), first individually and then in groups of two. What became quickly evident during this process were two values or ideas that were shared by all participants of the workshop: the need to save the historic islands of Venice itself from flooding, as well as the desire to preserve the unique cultural landscape of the *barene*. Aside from the one-on-one discussions, the participants revealed two diverging interests or focal points: one part of the participants (with the landscape architect) was more concerned with the landscape development of the lagoon, while the other group (with the architect) placed greater emphasis on the urban future of Venice in terms of its economic, socio-cultural, and spatial potential. According to these diverging values, two groups were formed, which worked on two separate design proposals. During the remaining workshop in Venice a first preliminary design was worked out. This was done with a guiding theme – the casco approach – as the foundation of the design and discussion process. Each time defined where their casco would be situated in the lagoon, which functions it would fulfil and which spaces it would divide. Afterwards, each discipline went back into the analysis phase researching specific challenges that came up during the initial design phase. In subsequent meetings, these findings were synthesised, and a more detailed design was worked out by each discipline individually, as well as together.

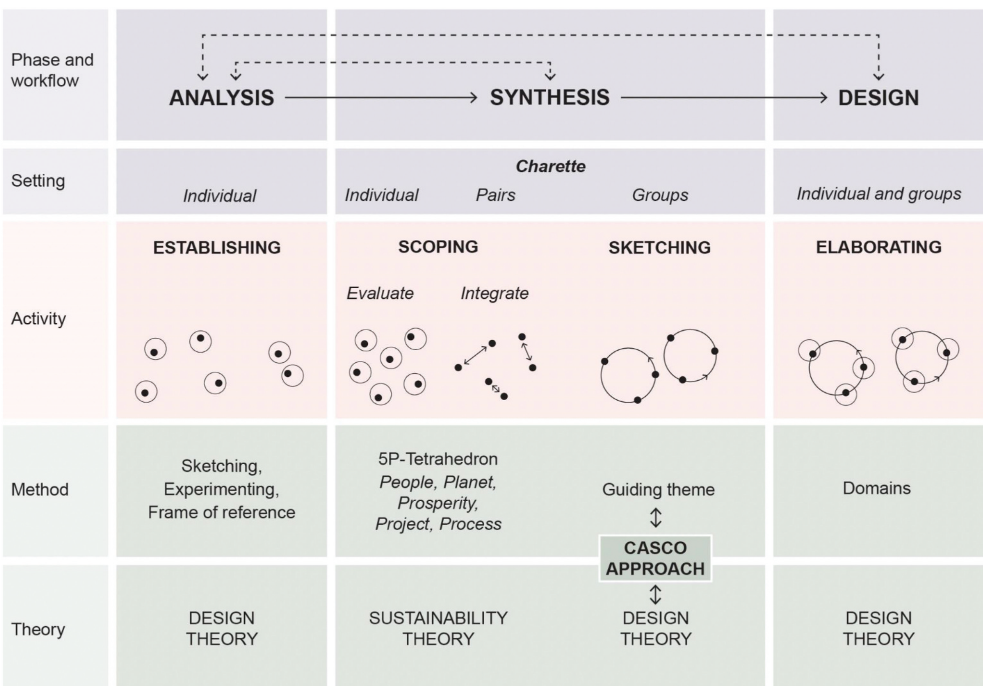

Figure 8. Visualisation of the interdisciplinary design process. Diagram made by Hartmeyer, Kaletkina, Iuorio, Hooimeijer, 2024.

The impact of engineering in the design process

The design proposals for The Perfect Lagoon and the Symbiotic System are both interdisciplinary, where data, concepts, ambitions, and goals are deliberately integrated throughout the design process. They both illustrate how the design of a flood defence system is also a spatial design that impacts the urban landscape. Both the design projects started with the same goal and engineering theories and evidence as a basis, but resulted to be very divergent as each of them used different underlying spatial, social approaches, and ideal future perspectives connected to the design discipline present in the team.

The two interdisciplinary designs showcase how the implemented engineering theories and concepts are integrated and influencing decisions in spatial design. The overview in Table 1 presents the shared starting points and primary interventions of the two design proposals, and how these bring together the spatial designs and engineering ambitions, goals, data, and concepts.

Discussion on the role of engineering in the Casco concept

The Casco Concept, as a way to centre natural dynamics, is a catalyst to bring landscape design and engineering perspectives together. In the Perfect Lagoon proposal, the

Table 1. Overview of integration of spatial design and engineering (based on project material in Buis et al. 2021).

Primary interventions and designs	Spatial design - ambitions and goals	Spatial design - contribution (data and concepts)	Engineering - ambition and goals	Engineering - contribution (data and concepts)
Shared on a strategic level	- Mitigate the impact of floods in the city of Venice - Implement accessibility between islands - Safeguard the ecological balance of the lagoon	- Mix functions and programs (industrial, commercial, residential and touristic) for Venice and the lagoon	- Mitigate extreme events caused by sea level rise - Enhance the implementation of nature-based solutions	- Storm surges - Tidal prism - Erosion and sediment supply - Water and sediment movement - Stakeholder analysis
Green dikes/ Perfect Lagoon	- Preserve the ecosystem of the lagoon - Find new forms of production compatible with the environment - Reduce the impacts of over tourism - Mitigate the floods in the urban context	- Separate the lagoon according to function and impacts on the ecosystem - Reconfigure the dike profile as a buffer zone - Mix and integrate functions (recreational, agriculture, remediation) into the landscape	- Mitigate the impacts of sea level rise by nature-based solutions (wide green dike, marshlands) - Integrate the MOSE into new flood defence system	- Define dimensions of the green dikes and auxiliary structures - Evaluate operability of the flood defence system
Urban dam-ring /Symbiotic System	- Enhance accessibility to and between the islands - Design new developments (housing and public spaces) preserving the heritage of Venice - Protect the city from floods	- Delimitate the urban context through the dam-ring - Expand the urban tissue (technology, dimensions, materials) - Analyse and design in a systemic perspective (mobility, flood protection, urban development)	- Balance sediments transportation and salinity in the lagoon - Protect Venice and its heritage from sea level rise	- Define dimension of the dam-ring - Study materiality and construction techniques in-situ (single leaf, shipping lock gate, spillways)

northern and southern part of the lagoon constitute the "framework" of the Casco Concept as a way to give time and space, without disturbance, to the slow ecological process of *barene* formation. The urban lagoon around Venice, on the other hand, constitutes an amalgamation of functions (agriculture, recreation, urban development) typical of the "user space" of the Casco Concept. The green dike becomes a transitory zone where human and natural realm meet in the form of sustainable agricultural and slow tourist activities.

This spatial setup was actually informed by engineering insights from early on. During the scoping process innovative engineering projects were analysed; those interventions proved that marshlands can be exposed to changing sea levels, being able to imbed natural and recreational areas into the set up. The technical knowledge on riverine dynamics and sediment budget cemented the feasibility of creating a framework of salt marshes around the urban lagoon; it also helped to establish the spatial location of the dike on the tidal watersheds. The layout of the overall plan can be described as a co-creation of spatial and technical design and knowledge that would have not been possible without the other discipline.

The protection of the city of Venice with a dike as a rather traditional and proven flood defence hard infrastructure also accurately reflects the notion within the flood risk approach to protect the most valued and vulnerable assets both in relation to human life and monetary assets (Brody, Lee, and Kothuis 2022). Ideas of landscape architects and engineers were diverging with the engineers more heavily focussing on a traditional risk approach and safety measures and the landscape architects highlighting the potential of the dike as a multifunctional and biodiverse zone (van Loon-Steensma and Schelfhout 2017; van Loon-Steensma and Vellinga 2019). By designing in dialogue these different vantage points were however brought together: eventually the detailing of the dike as a wide green dike supports the emphasis also on ecological restoration and development.

Discussion on the role of engineering in the Open Building Concept

The strategy of the Symbiotic System interdisciplinary design is representative of the Open Building Concept. The separation between the two major elements of the proposal – human on one side and nature on the other – creating the main barrier in the form of a dam-ring: the structure shapes the external urban layout but is open to other inner functional programs and uses. The design allows the ecological process to run its course limiting the negative impact human interventions (infrastructures for transportation, flood defence projects, urban developments) may have; anthropic activity indeed is meant to be included mostly within the dam-ring.

The integration of engineering and architectural design is of major importance for this proposal: technical data are integrated into the design to support its multifunctionality. Flood protection infrastructure, mobility network, and urban-scale development are designed at the same time in a systemic approach. This has been possible only showing the "spatial potentialities" that engineering infrastructure have, when combined with other ambitions or goals since the first stages of the design.

Specifically, the riverine engineering principles help in understanding how the PD-VE waterway can assist, not only in developing a physical connection between the two industrial areas of Venice and Padua, but also a new balance in sediment volumes and salinity levels that are necessary to maintain the biotic layer of the lagoon. Coastal engineering allows for specific insights on the flood defence systems, its layers and the needed heights and positions of barriers that largely influence the spatial aspects of the design starting from the existing characteristics (orography and structures) of the Lido. Hydraulic engineering concepts are applied majorly on the structure of the dam in order to ensure its feasibility and to identify dimensions and materialisation of the architectural and spatial qualities of the intervention.

Learning from the two proposals and evaluation

The set-up of the design study with interdisciplinary conditions, process and methodology created integration of the engineering work with the spatial design process as formulated by van Dooren et al. (2013). The disciplinary work of Frame of reference, Sketching and modelling and Domains (collection of data) were brought together in Experimenting and synthesised with the use of the two Casco concepts in the Guiding Themes. Especially, engineering data, system knowledge (on sediments, rivers, and hydraulic structures) provided inspiration and insights into the feasibility and workability of certain design concepts. Their initial understanding of the design assignment furthermore provided ground for discussion with the spatial engineers allowing each party to not only widen their understanding but also for the landscape designers and architects to sharpen their concept, which led to a design in dialogue. All the disciplines were influencing each other in shaping ideas and designs (see Figure 9). Important was the creation of the shared value system early on in the Tohoku workshop and the clear concept in the approach of the design elaboration.

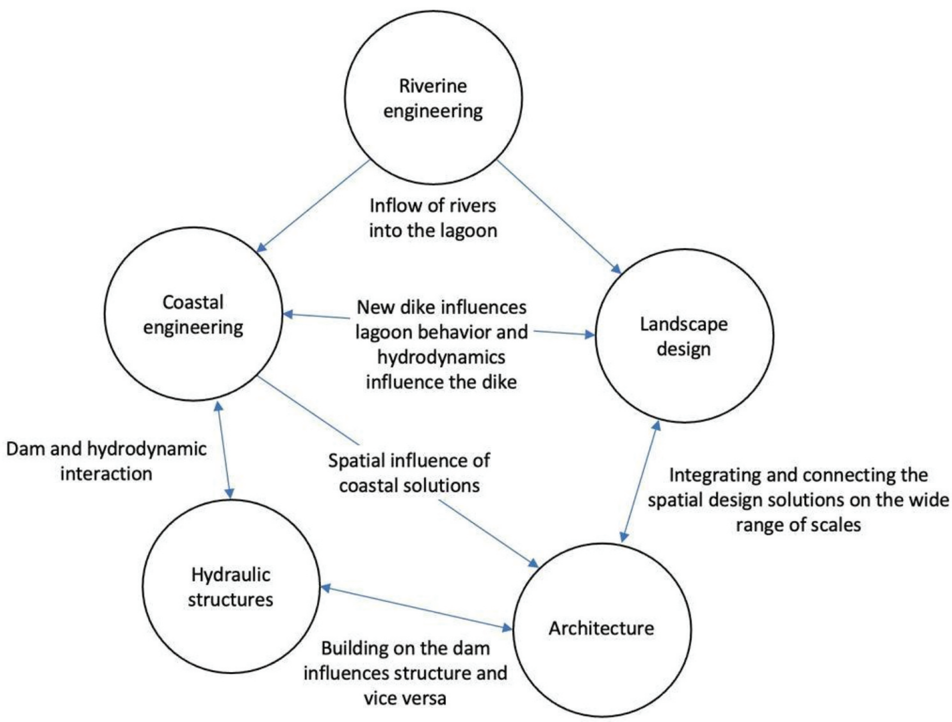

Figure 9. Interaction between scopes. Diagram made by the authors.

The most valuable result of the design is related to the investigation on how flood risk management can take into account the larger scale of flood protection infrastructure. By letting spatial designers and engineers work together from an early stage of the project implications, it is not only possible to integrate flood defence systems into natural landscape or urban areas, it is also possible to use innovative ideas or concepts (Guiding Themes) that are anyway highly grounded in their feasible technical designs and implementation.

The spatial designers (from architecture and landscape design) focused on addressing the spatial implications of the concepts, while the engineers ensured the technical feasibility within the constraints of the context. Both groups collaborated under a shared Guiding Theme that directed their joint decision-making process.

The collaboration within the frame of the design theory of Van Doren helped in structuring the work during the design study; also the implementation of the two Casco concepts have been instrumental to define the responsibilities of the disciplines in the development of the interdisciplinary designs.

Conclusion

This paper has demonstrated how engineers, within the spatial design process, contribute their Frame of Reference and Domain knowledge to the Guiding Theme by experimenting and contextualizing spatial design interventions. Following this process, the collaboration across disciplines expands the scope of experimentation, enhancing the study's success when multiple fields are involved. Engineers go beyond focusing solely on technical aspects and feasibility, while spatial designers are able to explore conceptual ideas with a clearer understanding of the practical limitations that come into play when transforming spatial visions into concrete realities.

It has also been discussed how collaboration between engineers and spatial designers can strengthen specific ideas or concepts (Guiding Themes), leading to mutual inspiration and the seamless integration of ideas. The conceptualization of design is a crucial step, as abstraction in the early stages creates an open environment between disciplines, fostering innovative and integrated designs. This leads to the conclusion that collaboration needs to be directed by defined methodological steps, where iterative process of exchanges and feedback (loops) play an important role. Collaboration is successful and turns into a proper scientific cooperation among disciplines only when it is set at the very early stages, avoiding the hierarchical and only-linear interaction.

Furthermore, in the case presented in this paper, engineers played a pivotal role in implementing design solutions within the frame of both the Casco concepts. Often, when dealing with the technical design of infrastructures, the boundaries between the natural and anthropic realms are not easy to define. Engineering can help to elaborate and understand the spaces where low and high dynamics can develop independently, and where the two can overlap, even integrate. Defining the primary characteristics of different spaces, as suggested by both Casco concepts, can be critical, particularly in cases where space is scarce and highly valuable.

Despite the collaboration between disciplines is becoming more and more necessary to deal with the spatial implications of climate change, these are often implemented in education within specific and limited academic realms. Cooperation between engineers and spatial designers, in the educational set up, is mostly driven by specific methodology and tools, both handled by specialists with academic and pedagogical objectives. In practice, collaboration is often informed and limited by a single specific disciplinary field; open communication and good design tools are thus essential. Process as described in the paper, the use of the design methodology of Van Dooren and the alignment with the Casco concepts, in the architecture and landscape design fields in collaboration with engineering, seem to be a promising perspective to be further developed and improved, also into non-academic environments.

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