Methods and Methodologies – Methodology of trans- and interdisciplinary processes

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The demand for a more conscientious and integrated design process in urban infrastructure design arises from the realisation that the environmental crisis can only be addressed by enhancing the resilience of the built environment (Amirzadeh, Sobhaninia, and Sharifi, 2022). Resilience can be achieved through a meticulous design process that seamlessly integrates spatial design and engineering in a smart way (Cutter et al., 2008). However, since the era of industrialisation, civil engineering and spatial design have evolved into fields with distinct cultures and languages, characterised by protocols and efficient organisation in multidisciplinary cooperation. Meanwhile, the core of urban infrastructure design remains inherently interdisciplinary (Hadfield-Hill, 2020).

Inter- and transdisciplinary urban infrastructure design should involve a deliberate and coordinated process where disciplines present their ideas within a shared value system formulated for the project. This system serves to articulate the shared ambition before systematically integrating disciplinary ideas (Hooimeijer et al., 2022). The challenges in this context are both personal and cognitive, covering various aspects such as communication, maintaining an openness to perceive and respond, processing and understanding information, retrieving data, making decisions, and generating appropriate responses for co-creation. While having an 'open attitude' is inherently a personal trait, it can be cultivated through understanding its importance, which in turn fosters a willingness to embrace it. This recognition is rooted in the necessity and enhanced quality of re-integrating engineering within the spatial design process.

Collaboration in urban infrastructure design in deltas involves integrating spatial design and spatial engineering. Specific methodologies are essential to facilitate this collaboration and harmonise different approaches, as simply bringing people together in a room does not guarantee effective teamwork. This is particularly true because engineering thinking is oriented towards problem-solving, while design thinking is focused on identifying problems. As argued by Tim Brown in 'Change by Design' (2009), the design thinking process utilises visual representation, which, according to Liedtka and Ogilvie (2011), is considered 'the mother of all design tools' as it plays a crucial role in every stage of a design thinking process.

The significance of these visualisations extends beyond aesthetics; they also contribute significantly to understanding the operational logic of a territory, as demonstrated by the work of James Corner

(1999), a prominent figure in the landscape urbanism discourse. Corner advocates for prioritising the agency of landscape – how it functions and its impact – over its mere appearance. He emphasises the need to blur or transcend boundaries between technology (understanding the natural system and the consequences of interventions) and urban design.

Trans- and interdisciplinary collaboration should commence with a shared understanding of the challenge, acknowledging the specific perspectives of all stakeholders and disciplines involved. This collaboration entails integrating goals, recognising that each discipline holds distinct value in its objectives. The key to success lies in combining knowledge and language by applying shared methods, unified concepts, and integrated scales – a hallmark of trans- and interdisciplinary design.

Mere dialogue is insufficient; dedicated methods are required to achieve goal integration. The DIMI portfolio projects employ various applied methods to address this need. These include the Tohoku Method, Scenario study, SEES, Research by Design, Exploratory research, Voorendt's integrated design approach, and Challenged-Base learning (as referred to in section 2 of this chapter). In this section, these are explained and underpinned.

Tohoku Method

The work in Japan, involving students from hydraulic, transport and geo-engineering, along with water managers, architects, urban designers, landscape architects, and managers in the built environment, led to the development of a methodology named after the region affected by the 2011 Tsunami: Tohoku. This method provides interdisciplinary design conditions and a process design with specific methods to facilitate conscious integration among different disciplines and avoid superficial dialogue (Hooimeijer et al., 2022). The process involves iterative analysis, synthesis, and design phases, as depicted in Figure 4. Fundamental methods during the transition from synthesis to design include the Scoping in a charrette formation. Scoping entails integrating information and ideas by establishing a shared understanding of the problem and the case context. The Charrette format refers to the organisation of dialogue in rounds, allowing disciplines to integrate their knowledge and ideas one-on-one before synthesising them as a group.

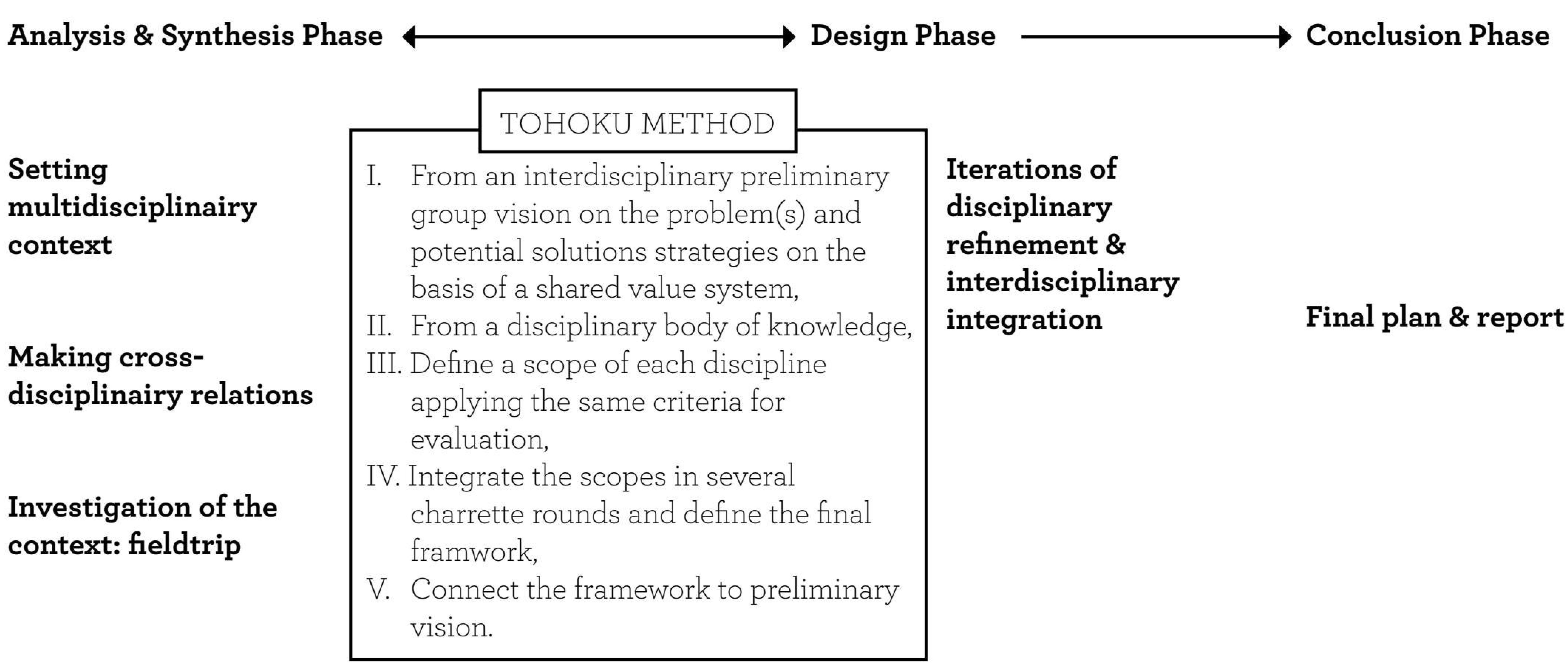

Figure 4: Interdisciplinary design process

Although the design process is ambiguous, personal, and somewhat intangible, Van Dooren et al. (2013) have organised it into a clear framework. This framework identifies five generic elements involved in designing: Experimenting, Guiding Theme, Frame of Reference, Sketching and Modelling, and Domains.

- Experimenting: This involves exploring ideas and sketches, which are then further evaluated.
- Guiding Theme: This element focuses on defining a guiding theme, which encompasses concepts, ambitions, and goals. This theme ensures that all decisions contribute to a coherent and consistent outcome.
- Frame of Reference (or Library): All design decisions, whether made consciously or unconsciously, draw from existing knowledge. This element underlines the importance of having a frame of reference or a library of knowledge.
- Sketching and Modelling: This element describes a setting in which the physical counterpart of the mental process helps shape the design.
- Domains: Domains encompass the essential supportive knowledge (data) related to the engineering of the built environment.

This framework provides a structured approach to understanding and navigating the complexities of the design process.

The Tohoku method consists of five steps:

I. The initial step involves creating a preliminary group vision or deciding on a 'Guiding Theme' to align the disciplines under a common vision. This is most effective when established before introducing disciplinary concepts and measures. Alongside the vision or guiding theme, the group develops a shared value system using the 4P tetrahedron by Van Dorst and Duijvestein (2004), as illustrated in Figure 5. It's foundation is the triple bottom line of sustainability: people, planet, and prosperity (United Nations, 2002). To make this approach more applicable for spatial intervention, Van Dorst and Duijvestein added a fourth P to make the 4P tetrahedron theory, representing both 'Project' and 'Process'. 'Project' refers to the physical outcomes, covering aspects such as spatial quality, relationships through scales, (bio)diversity, robustness, and aesthetics. 'Process' focuses on the dynamics among stakeholders, their skills, and the institutional context in achieving a balanced design (Van Dorst and Duijvestein, 2004).

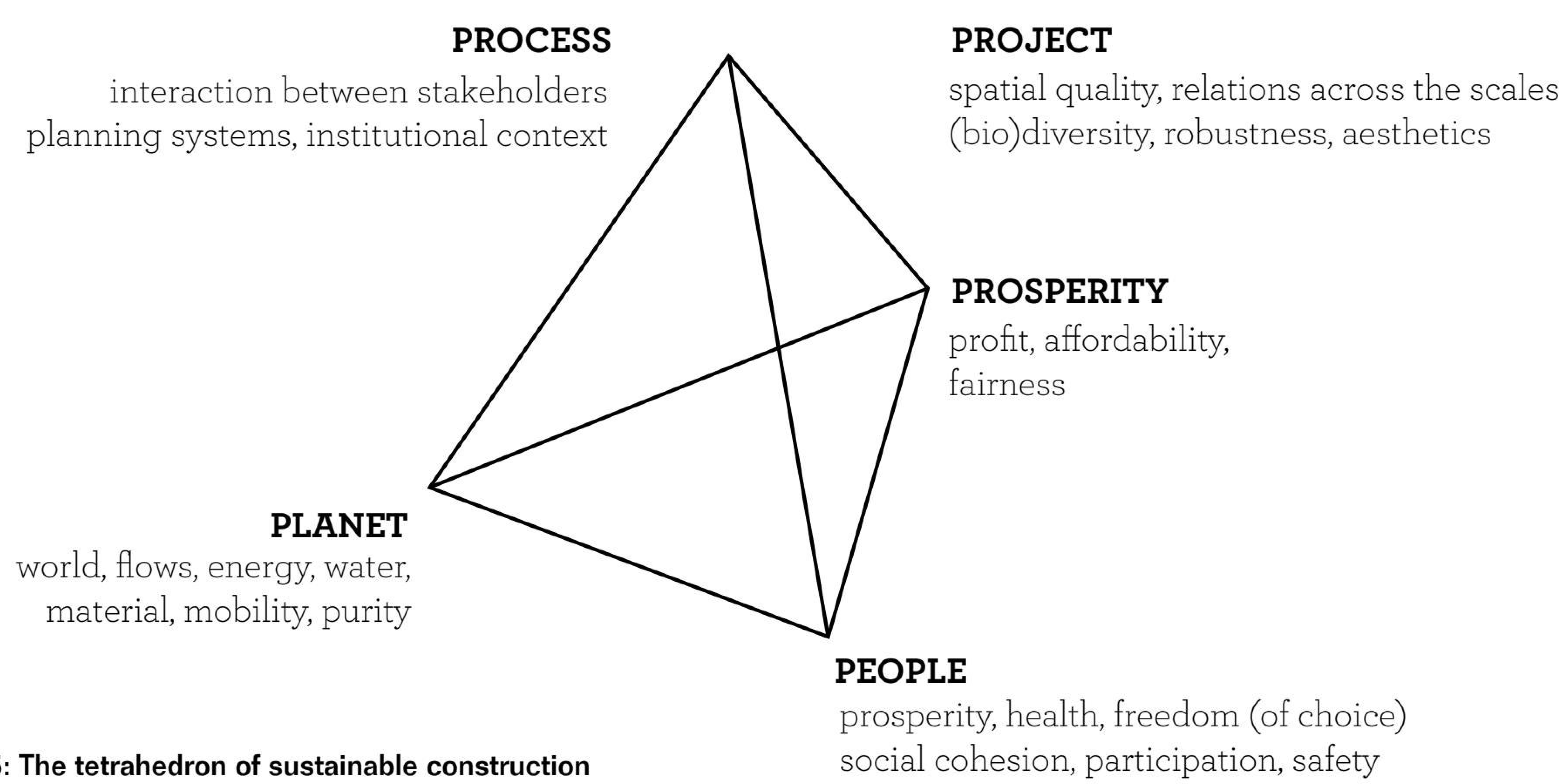

Figure 5: The tetrahedron of sustainable construction (van Dorst and Duijvestein, 2004).

Creating scopes allows the disciplines involved to evaluate their concepts in Step II according to a value system that is shared with the other disciplines.

II. In the second step of the Tohoku methodology, the individual disciplines delve into the first three elements: Experimenting, Sketching, and the Frame of Reference. This step involves the development of a series of disciplinary concepts and measures.

III. Each discipline then evaluates its concepts and measures against the value system established by the group in step I.

IV. The concepts and measures from individual disciplines are aligned in rounds, known as the charrette. This one-on-one process facilitates the incremental integration of ideas. The shared value system ensures clear communication about the importance each discipline attributes to its measures. This charrette formation culminates in the entire group coming together, resulting in a set of shared guidelines.

V. Finally, the integrated set of concepts and measures is validated against the initial vision or guiding theme, with adjustments made where needed.

The entire process is demanding and time-consuming; however, feedback indicates that participants engage in thorough and organised discussions. Unlike approaches that immediately target solutions to problems, this methodology compels groups to progress from initial concepts to more refined ideas. Integration occurs while ideas are still in their formative stages, allowing for the comprehensive blending of diverse ideas. The ultimate outcome is a spatial vision, strategy, and design where the essential principles have been meticulously developed. A tangible example of this process can be observed in the ***'Japan Tsunami Reconstruction in Yuriage & Otsuchi'*** (P 92) project detailed in Chapter 3.

Scenario Study

The separation of disciplines and the tendency towards sectorial research stem from an inherited deterministic and mechanistic worldview. However, there is an evolving shift towards complex dynamic systems theory and non-linear systems theory (Liening, 2013). This philosophical shift has implications for virtually every discipline involved in shaping the world. The concepts of non-linear and open systems prompt a re-evaluation of the roles and interconnections among engineering, technology, design culture, critical thinking, and visualisations. Given that the societal and ecological challenges we face are intertwined with how we transform the land (Rockström and Klum, 2015), synthesising knowledge and action requires a reintegration of the arts, humanities, and sciences. This integration will foster a new transdisciplinary perspective guiding collaboration and research.

The Scenario Study instrument serves as a valuable tool for consolidating information, concepts, and perspectives from various stakeholders. Salewski's (2012) research offers insights into understanding scenario studies in the Netherlands. In his exploration of Dutch planning practice from 1970 to 2000, Salewski distinguishes scenarios from other future-oriented concepts such as visions, trends, utopias, or dystopias.

According to Salewski, visions of the future, as seen in Structural Vision and Environmental Vision, presuppose a comprehensive and supported perspective on the future. In contrast, depictions of a flooded Netherlands in 2300 can be categorised as dystopias, serving as warnings about impending developments. Trends, as exemplified by projects like Op Water basis from Sweco, BoschSlabbers, and Deltares (2021), are utilised to project forward, understand current practices, or test new strategies. Notably, significant trends in subsurface development, such as densification, subsidence, and saline seepage, have been systematically delineated for the entire Netherlands across different time periods.

Scenario studies utilise these tools to explore uncertain futures by creating a sequence of possible events, culminating in a specific vision of the future. There are two fundamental methods at the base of working with scenarios:

- Method of forecasting: This approach is numerical, arithmetic, or factual, used to extrapolate future trends.

- Method of foresight: This method can be linguistic, visual, analytical, and creatively generate various futures for a specific challenge.

In a workshop setting, forecasting involves identifying trends or conditions to test across various potential futures, known as foresight. For instance, this setup for a workshop with students focused on addressing challenges in extreme landscapes, where the dynamic between humans and nature is a central investigation. See Figure 6.

Another example is the scenario used in the 'Spatial Exploration (2023)' by the Dutch Environmental Agency (PBL). PBL has developed four scenarios for the spatial order of the Netherlands in 2050: 'Globally Entrepreneurial' (a future scenario in which large companies lead), 'Fast World' (increased digitalisation makes distances disappear), 'Green Land' (providing ample space for nature), and 'Regionally Rooted' (where citizens take the initiative in their own living environment). For each scenario, detailed maps of the associated Netherlands in 2050 have been created based on spatial modelling and design research. These scenario maps illustrate the consequences of different choices.

During the development of the High-Speed Line in the south of the Netherlands, the transport project team used scenario analysis to overview alternative developments relevant to the transport contract and to support decision-making. The experience showed that this approach improved awareness of the threats and opportunities and was helpful in managing the complex environment. Their experience suggested that reality tended to be a mixture of distinctive scenarios (Hertogh, Westerveld, 2010).

FORESIGHT	**No Humans** This is part of a retreat strategy over a longer time (total shrinkage). Who leaves first?	**Nature first** In the redesign of the city, nature is put central as part of a 'de-growth/shrinkage/give back to nature' strategy.	**No technology** In this scenario there is growth and densification; in the design of the city, natural solutions are preferred over technological solutions, but the technology is still there, it implies 'deep ecology' – so designing nature/re-nature process.
FORECASTING What does it mean for:			
Resources			
Environmental risk			
Eco life			
Demographics			
Economy			

Figure 6: Example of three futures. One where all humans have left; one where nature is first and the last where thechnology is reduced.

In conclusion, scenario studies are a powerful and flexible tool for navigating uncertainties, testing strategies, and fostering a more holistic perspective on future challenges and opportunities. Their application across disciplines and contexts makes them invaluable in shaping informed decisions and strategies.

The DIMI portfolio includes several examples using this method. ***'The Rhine River Mouth as an Estuary'*** (P 72) explores a foresight for a more natural future of the Waterweg; design studies like ***'Highway & City'***, (P 118) the ***'Zaan Corridor'*** (P 128) and ***'City of the Future'*** (P 174) , as well as ***'Intelligent Subsurface Quality'*** (P 184) also work with a sustainable future as the goal for design.

System Exploration of Environment and Subsurface (SEES)

The System Exploration of Environment and Subsurface (SEES) methodology was developed during the project 'Design with the Subsurface,' involving Deltares, TNO, TU Delft, and the Municipality of Rotterdam, see figure 7. The objective was to integrate subsurface data from urban development into the design process. SEES was initiated to bridge the gap between engineers with their subsurface data and urban designers creating development plans. This methodology facilitates a creative design process that integrates engineers' data early in the urban planning process, which is crucial for adapting to climate change and fostering closer collaboration with the natural system.

The key questions SEES addresses are identifying climate change and environmental crisis issues that can be tackled using the natural system and determining which aspects still require technical solutions. By integrating the ecosystem, climate, and dynamics of soil and subsoil into urban redevelopment, a more resilient design can be achieved. The System Exploration of Space and Subsurface methodology is not fundamentally new but promotes common sense and open communication, emphasising direct exchange and constructive outcomes. In this regard, it aligns well with the 'lean' thinking prevalent in the international construction industry, or possibly scrum. The methodology leverages existing insights and investigations of the surface and subsurface, simplifying and clarifying them in a system overview for professionals.

The system overview divides the Y-axis into layers corresponding to the Layer Approach: occupation, networks, and subsurface layer (De Bruin et al., 1987). Originally a strategic policy model, this new division of layers now serves to describe and analyse the physical domain. The layers include the subsurface, networks, public space, buildings, flows (the 'software' such as water, energy, waste, etc., not the 'hardware' like the sewer system), and the top layer, representing people. Each layer exhibits different dynamics and requires distinct knowledge and expertise. This classification not only aids in spatial analysis but also supports 'knowledge brokerage,' illustrating different domains of knowledge and actor groups and enabling them to position themselves relative to each other.

The substrate layer is expanded upon the X-axis of the system overview, acknowledging that there is no singular 'subsurface expert.' This layer includes subsurface qualities categorised into water, soil, civil construction, and energy. While this classification deviates from the usual categorisation employed by soil scientists, it frames the subsurface's regulating, producing, informing, and supporting functions. Importantly, this classification aligns more coherently with the language and concepts of spatial planning, making water, energy, civil structures, and soil logical and understandable categories within urban tasks.

Within the substrate layer, further division is based on depths. The shallow subsurface, water layer, and deep subsurface domains each serve distinct purposes and fall under different jurisdictions. The deep subsurface is regulated by the Mining Act and, consequently, the Ministry of Economic Affairs. The water layer is managed by provinces and water boards, while the shallow subsurface is primarily overseen by provincial and municipal practices. This division according to

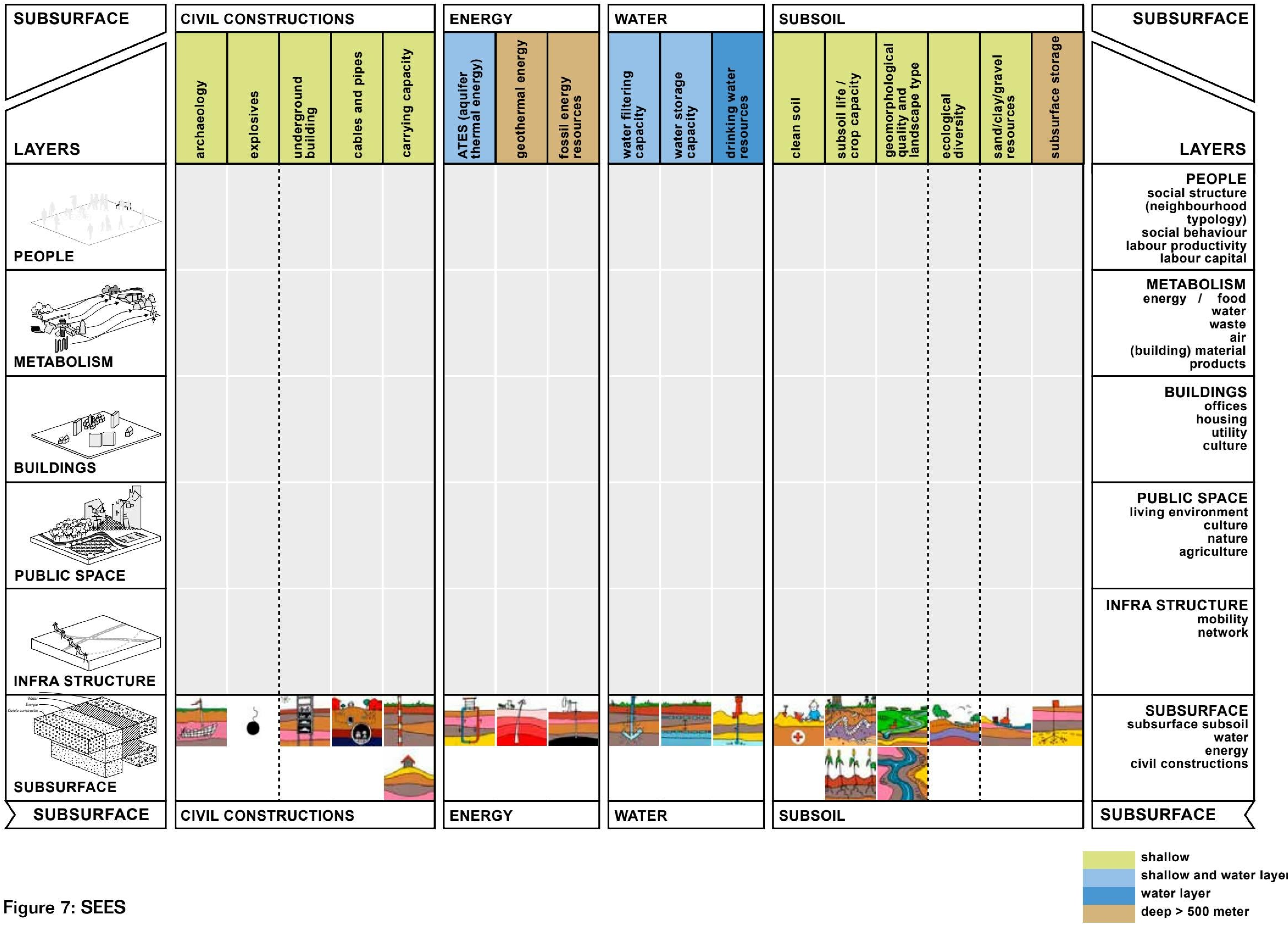

Figure 7: SEES

fields of knowledge and competence proves highly functional.

The workshop process that incorporates all disciplines involved in an urban development project consists of the following seven steps:

1. The panel chairman introduces the SEES (10 mins).
2. Each participant introduces themselves and identifies their specific domain within the system (15 mins).
3. The project leader of the urban development provides an overview of the area's characteristics, socio-economic ambitions, and plans (15 mins).
4. Data for each category, along with the associated subsurface qualities, is systematically presented, considering natural and technical boundary conditions:
   a. Civil Construction: Involves archaeologists, specialists on explosives (when expected), and experts on cables, pipes, and geotechnical aspects related to subsurface building and carrying capacity.
   b. Energy: Includes ATES and geothermal energy specialists.
   c. Water: Features geohydrological and water management specialists.
   d. Soil: Comprises soil experts and ecologists.

5. Discuss the opportunities, challenges, considerations, and requirements for boundary conditions.
6. Establish connections: Record the main findings in the system exploration scheme, clearly noting the relationships.
7. Once all subsurface qualities have been discussed, evaluate them against each aboveground layer to identify conflicts and synergies within each domain.

The outcome of this process is a comprehensive overview of opportunities, challenges, considerations, and boundary conditions in the area. This facilitates the possibility of more cost-effective, climate-resilient, and sustainable development. Gathering the necessary stakeholders and specialists into a workshop saves valuable time by fostering a dialogue where both aboveground and subsurface specialists can understand each other's perspectives.

Importantly, the methodology deliberately avoids incorporating spatial objects or types in the system overview to prevent oversimplification. For instance, the question of 'where does water belong?' often arises during discussions about the data. Treating water solely as surface water simplifies a more complex reality. Water is a system that traverses the entire cityscape, necessitating a broader consideration. Hence, the methodology promotes a systematic approach that does not categorise systems merely based on their spatial appearances. For instance, a river is considered a part of the groundwater system that happens to be visible.

This methodology effectively consolidates content and encourages systematic thinking, as explored in projects such as 'Intelligent Subsurface' (P 184) and technical sessions of ***'Spatial Design starts with a Cross Section'*** (P 194). Using this methodology, opportunities and challenges in plans are identified early on. This supports a creative process where involved parties, both above and below ground, can fully grasp each other's perspectives. Based on this collaborative understanding, an urban designer can create a Subsurface Potential Map, illustrating the impact of the subsurface on the topsoil, which can be utilised in spatial design.

Research by Design

Design serves as both the subject of investigation and the means through which the study is conducted (Glanville, 1999). The former is referred to as 'design research,' which involves examining designs and the knowledge production process inherent in the act of designing (Biggs, 2002; Laurel, 2003; Fallman, 2007; Koskinen et al., 2001). This investigation employs specific methodologies, encompassing strategies, procedures, methods, routes, tactics, schemes, and modes that contribute to the creation of the designs. Design itself encompasses observation, testing of ideas, materials, and technologies, innovative conceptual development, and the generation of alternatives – all within the cultural, social, economic, aesthetic, and ethical framework.

De Jong (2005) explored various relationships between research and design, contingent on context and object (Figure 8). De Jong delineates four categories: 'design research,' 'typological research,' 'design study,' and 'study by design.' Design research may focus on specific objects within defined contexts, but designs inherently differ, and the context is subject to variation and change. Consequently, other forms of design-related studies may vary in terms of the object (design study), the context (typological research), or even both.

Typological research involves examining context-independent types of design concepts, while a design study utilises design as a means of inquiry to investigate a specific context. The design study addresses a set of related problems within the context, taking into account the desirability and probabilities of stakeholders and specialists to formulate a concept.

Study by design is characterised by generating knowledge and understanding through the active and systematic variation of both design objects and their context. This approach allows for a comprehensive exploration of the effects resulting from these variations. In addition to these categories, research in (art and) design can be further classified into three types: research into (or about) design, research through (or by) design, and research for design. The first involves investigating the canons in design (the science of design), the second entails practical experiments (design science), and the third focuses on development work (scientific design) (Roggema, 2016).

Research by design, described as a strategy by Hauberg, explores the interconnectedness of design and research when new knowledge is produced through the act of designing. This methodology aims to generate desirable and possibly unexpected urban perspectives, contrasting with probable but less desirable urban developments (Hauberg, 2011).

Engaging in the act of designing leads to the emergence of research questions. By focusing on specific goals for a new future, insights into quality and potential are gained through testing the context. Provocative or explorative designs, which break or bend boundaries, possess the power to investigate transformative futures significantly different from the status quo. These designs contribute to a repertoire of plans essential for shaping and organising our shared space.

Several examples of Research by Design can be found in the DIMI projects, notably in the projects 'The City of the Future' (2019) and 'Design from the Section' (2022). Design research has been utilised as a means by which multidisciplinary teams from various organisations collaboratively interact with stakeholders in a 'low-policy' environment. Even in the earliest stages, the design process starts with the required disciplines and stakeholders, thereby gaining better insights into the challenges, systemic knowledge of the location, technical constraints, and opportunities for sustainability. The intention is to create designs for the future and then, through 'backtracking', to examine what can be done now. It is noteworthy that in addition to the substantive plans, many teams in such studies also explicitly address how to interact and arrive at designs during this phase: 'the process of arriving at.' For instance, the team for the Utrecht study ('City of the Future') compiled a glossary to clarify the various terms. In Oostende ('Designing from the Cross-Section'), the design team devised an extensive toolbox to realise circular development. One prominent component was a matrix consisting of 30 design actions. Each design action included action cards with design principles, serving as instruments for 'interdisciplinary co-creation'. These studies can take place at various scales, ranging from neighbourhood and city to regional levels.

Exploratory Research

Another societal trend worth noting is the shift towards purpose as a key element of prosperity, extending beyond material concerns to encompass the quality of life, relationships, family health and happiness, work satisfaction, and shared meaning in communities (Jackson, 2010). This societal challenge calls for creating

Types of design-related study

CONTEXT		
Determined	Design Research	Design Study
Variable	Typological Research	Study by Design
	Determined	**Variable**
	OBJECT	**OBJECT**

Figure 8: Types of design and research (De Jong, 2005)

conditions that foster such holistic prosperity in society and in academic institutions.

In response to these trends, a new research perspective emerges-one that is inclusive of history, nature, and purpose. Deltas, given their vulnerable and fertile nature, are particularly suited to embracing these trends in the development of methodologies and methods. A research approach that aligns with this trend is exploratory research. Exploratory research focuses on generating hypotheses rather than testing them and often relies on qualitative data from brainstorming sessions, expert interviews, or short surveys on social networking websites.

The project 'Intelligent Subsurface' was particularly exploratory due to the lack of fundamental knowledge on better integrating the subsurface into surface developments when designing urban constructions. This led to an overview of innovative technologies and their impact on urban management and spatial design.

Voorendt's Integrated Design Approach

Since the 1970s, the engineering and spatial design approaches have diverged in academia and practice. This separation has led to a sub-optimal design process where hydraulic structures are engineered first, and then efforts are made to enhance the spatial quality, or vice versa. Voorendt (2017) sought to develop a transdisciplinary design approach that integrates the systematic approach of engineering with the creative and learning characteristics of spatial design (Figure 9).

The integrated design approach proposed in his dissertation is cyclic and highly iterative. It fosters creativity, experimenting, and learning from developing concepts and provides a framework to organise the process within a multidisciplinary team. It considers landscape, nature, and cultural values, includes stakeholder participation, and involves multiple disciplines in the design process, ensuring that feasible and functional results are achieved.

The approach outlines seven main steps (Figure 10). that can be repeated across multiple design loops, starting with an overall conceptual design, and culminating in a final design that includes construction drawings:

1. Exploration of the problem,
2. Development of concepts,
3. Drawing up a programme of requirements, evaluation criteria and boundary conditions,
4. Verification of the developed concepts,
5. Evaluation of the verified alternatives and selection of the best solution,

Engineering design	Spatial design
Linear, sequential process	Cyclic, iterative process
Prescriptive	Descriptive
Problem is well-defined	Problem is ill-defined
Problem is decomposable into parts	Problem is not decomposable
Analytical character	Experimental, learning character
Normal abduction	Design abduction

Figure 9: Comparison of the engineering and spatial design methods with their supposed differences (Voorendt, 2017)

6. Validation of the result,
7. Decision to proceed with the validated result to a more detailed design loop or to commence construction.

The proposed approach is documented in the DIMI portfolio under the 'Bio Bridge' project and has been tested by student design teams. It proved intuitive and creative while ensuring that all necessary design activities were included. If attention is given to several aspects of the application of the proposed method, an integrated design is guaranteed. The approach is most suitable for conceptual functional design loops. For detailing loops, such as the design of reinforced concrete elements, the added value of working in multidisciplinary teams is limited.

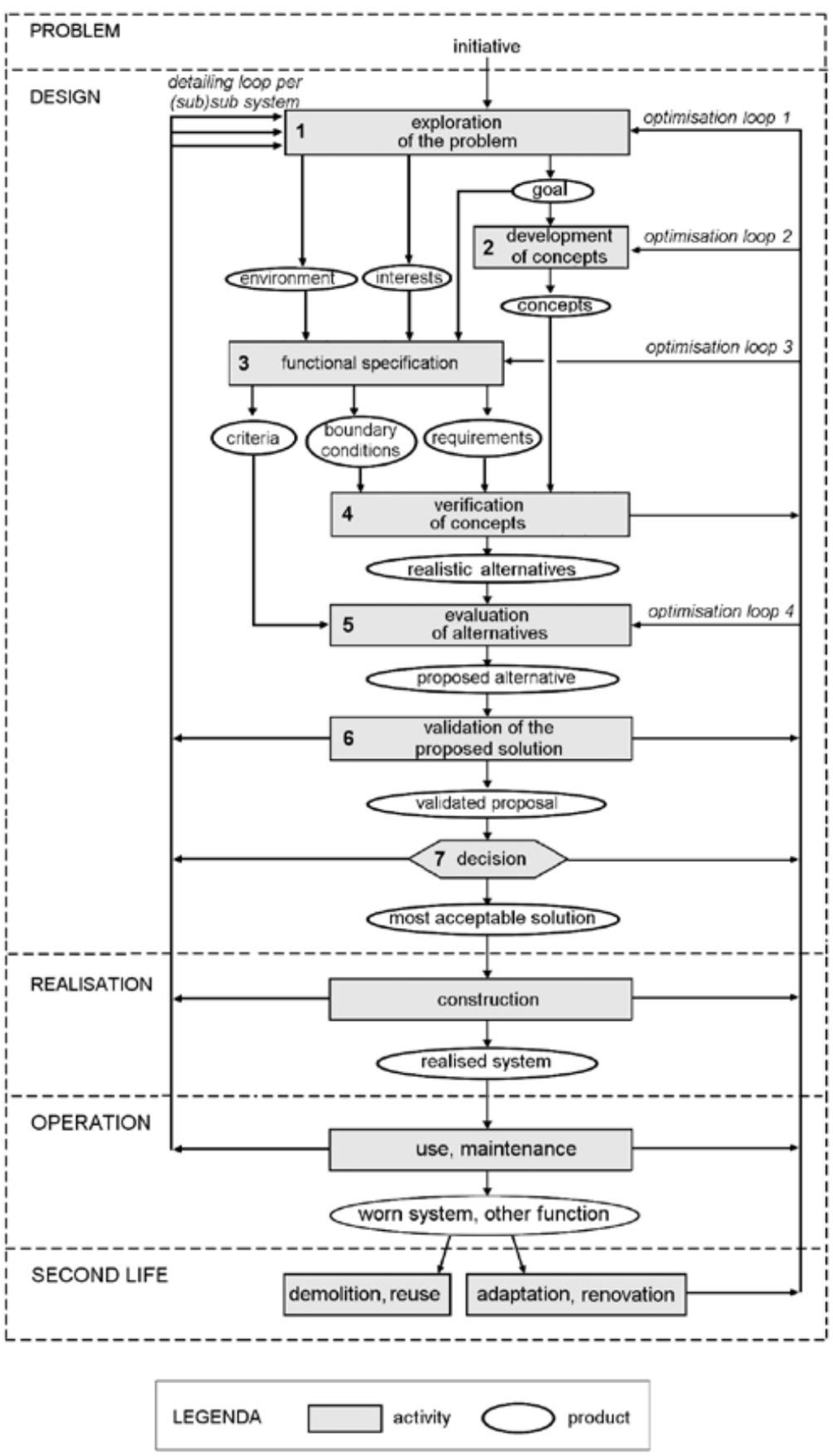

Figure 10: The proposed process for integrated design (including other life-cycle stages) (Voorendt, 2017)

Challenge-Based Learning

Preferred methods for Challenge-Based Learning focus on experiential learning and guide learners through three distinct phases: (1) Engage, (2) Investigate, and (3) Act, see figure 11. As Malmqvist et al. (2015) suggest, challenge-based learning is characterised by learning through the process of identifying, analysing, and then designing solutions to highly complex, socio-technical problems. The goal is to work towards a solution that is co-produced, viable, and sustainable.

Challenge-based learning starts with a specific problem and requires establishing a connection between the problem and larger, overarching grand challenges. This approach grants students greater autonomy and responsibility, as it is up to them to move from a more abstract 'big idea' to a concrete challenge. In fact, challenge-based learning can foster the development of a crucial transdisciplinary skill: joint problem framing (Pearce & Ejderyan, 2019). Challenge-based learning is inherently value-driven, and its multidisciplinary nature necessitates ample time for developing a joint understanding and framing of the problem. The scope should be defined in co-creation with stakeholders relevant to the overarching challenge. For this reason, challenge-based learning often involves stakeholder mapping and the application of user-oriented design thinking principles.

In the next phase, learners engage in research together to develop actionable pathways for solutions. Given the complexity of the challenges, this may involve various activities, including desk research, simulations, focus groups, games, or experiments. Because challenge-based learning is rooted in problem-based and experiential learning, this educational approach aligns with Kolb's (1984) learning cycle for complete learning, which includes (1) Active Experimentation, (2) Concrete Experience, (3) Reflective Observation, and (4) Abstract Conceptualisation. Embedding students in the process of framing a problem alongside stakeholders enables them to experiment actively and reflect on their experiences with complexity. Developing this reflexivity is crucial in shaping actionable, sustainable solutions that are not just based on theoretical mono-disciplinary insights but adopt a more holistic approach. The Engagement phase should lead them to Investigate specific knowledge or experience gaps, which they then analyse collectively. For instance, local environmental factors can be significant in determining the success of sustainability solutions. Employing multi-level analyses can provide important insights into feasible pathways that address both local and global aspects of grand challenges.

Figure 11: Phases of challenge based learning (Nichols, Cator, Torres; 2016)

The third phase of challenge-based learning pedagogies always involves some form of prototype testing with an authentic audience. The extent to which learners can test and evaluate implementation may vary, but it remains a required element. This goes back to Kolb's experiential learning cycle. Challenge-based learning is an iterative process, relying on evaluation and feedback collected in this final 'acting' phase. Solutions can be adapted to ensure they align with the initial challenge and achieve the desired impact. However, the value of challenge-based learning is centred more on the process than the product, as defining the end product learners will produce is challenging. Additionally, while an authentic audience determines the product's value, teachers can monitor and evaluate the process. Challenge-based learning is especially suited for conceptualising interconnected, complex problems that represent the grand challenges of the 21st century. Students learn how their disciplinary knowledge contributes to solving these challenges at both micro and macro levels, enhancing engagement, agency, teamwork, effective communication, and design thinking. This approach is particularly effective for multidisciplinary sustainability challenges (Gutiérrez-Martínez et al., 2021). Depending on the level of engagement and course duration, challenges can take various forms, such as hackathons, design projects, or long-form participatory action research projects.

The portfolio of the DIMI is challenge-based, aiming to address current societal problems with a longer-term perspective on greater challenges. Collaborating with practitioners in these challenges is vital because practice is also keen on researching and improving concepts and methods. Research is not confined to academia.

Colophon

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