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Mindset Changes for Dealing with Complex Climate Impacts - Experiences with a Tool from Courses on Digitalization and Climate-Adapted Urban Development

Günter Müller-Czygan[1]*, Manuela Wimmer[2], Julia Frank[3], Michael Schmidt[4] and Viktoriya Tarasyuk[5]

[1,2]*Professor,, Hof University of Applied Science, Germany*

[3,4]*Hof University of Applied Science, Germany*

[5]*PhD, Hof University of Applied Science, Germany*

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***Corresponding author:** Günter Müller-Czygan, Professor, Hof University of Applied Science, Alfson-Goppel-Platz 1, D-95028 Hof, Germany

Summary

Economy and society are currently exposed to multi-layered multi-crises. Against the backdrop of the covid pandemic, a growing shortage of skilled workers, increasing armed conflicts or persistent refugee flows, cities and municipalities in particular have to deal with resulting local impacts. Parallel to these highly dynamic crisis events, cities and municipalities continue to be called upon to face the now established challenges of climate change, sustainability and digitalization. More and more, there are organizational and also psychological overloads in coping with everyday tasks as a result of increasing complexities. Because of the excessive demands, there is a retreat to familiar and routine-related everyday work and the neglect of the search for adequate solutions to the increasingly complex problems. Especially in the field of municipal infrastructure, which requires rapid and comprehensive adaptation to the manifold impacts of climate change, this excessive demand increasingly leads to recourse to rather simple solutions, which, however, do not justice to the complexity of the situation. During two certificate courses at Hof University of Applied Sciences (Germany) on the development of climate-adapted urban planning and on successful digitalization in municipal water management, a novel tool for dealing with complex situations was developed to practice on examples. It was observed among the approximately 70 participants in both courses that used this method two to three times already led to a visible change in the perception and assessment of complex situations, without the need for psychologically accompanied training of change behavior.

Keywords: Climate Impacts; Complexity; Digitalization; Sustainability; Water Management; Mindset Changes; Multi-Level Analysis

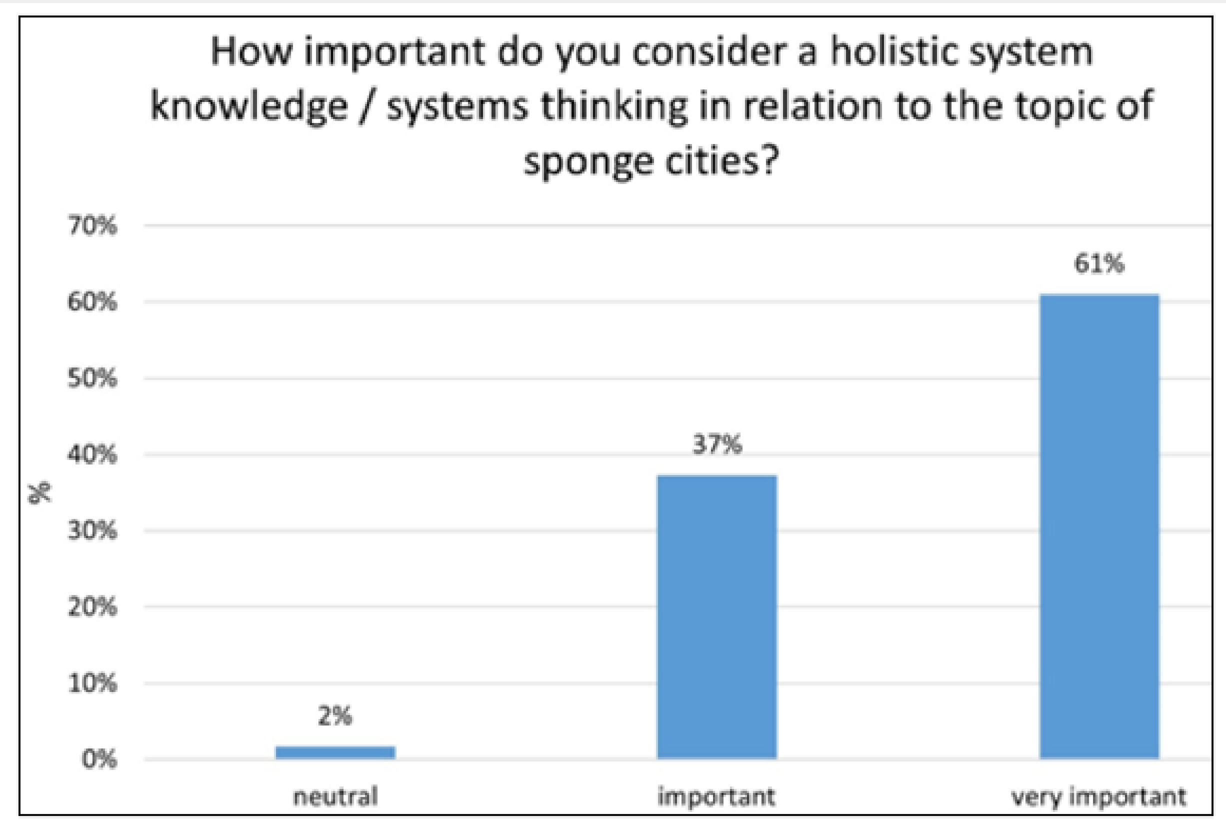
Increasing Multi-Crises - Decision Delay Due to Complexity Overloads

Crises require attention and generate pressure to act. While social crises involve a certain degree of control and an existing robust resilience (wait-and-see) can contribute to overcoming a crisis, climate change does not allow for a simple wait-and-see approach. Although dealing with climate change has been an issue since the 1992 Framework Convention on Climate Change [1,2] and has been integrated into municipal tasks (e.g. flood protection due to heavy rainfall). However, climate change has only been recognized as a real and acute crisis since 2019 [2] and especially since the heavy rainfall events in the summer of 2021.

First and foremost, it is the municipalities and cities that must deal with the consequences of climate change in the form of local extreme weather events to protect their populations. At the same time, in particular digitalization is seen as having a special role to play in combating the consequences of climate change [3]. Facing the enormous challenges posed by multiple crises, municipal actors are increasingly overstretched in terms of both technical and quantitative tasks. Researchers see not only the actors of cities and municipalities, but currently also entire nations in a kind of state of acute exhaustion as a result of permanent multi-crises[1].

Since the planning and approval structure of infrastructure-related measures is extensive and time-consuming, the preventive solutions required to adapt to the increasing extreme weather events are increasingly being pushed to the back of the list of acute crisis management due to their complexity [4]. From more than 200 discussions with German municipalities [5] it could be deduced that the probability of a climate catastrophe occurring is still considered to be low, and the belief exists that there is still enough time to be able to start later with the necessary adaptation measures for the medium and long-term consequences. This attitude is also attributed to the fact that most environmental disasters occur in countries that have the least anthropogenic influence on the climate. Most people in Europe do not see a direct link of their own behavior with climate change impacts [6].

On the other hand, those responsible in municipalities and cities are also aware that a further wait-and-see approach to climate adaptation is not acceptable. However, in view of the increasing complexity of tasks, they hardly see a target-oriented way to integrate and finance necessary climate adaptation measures into everyday (water management) life in addition to acute crisis management. Current studies on dealing with climate change in the projects SPORE (Smart Sponge Region Upper Franconia)[2] and in the certificate course "The Way to the Sponge City - Urban Development in Times of Climate Change[3]" at Hof University of Applied Sciences clearly reveal the discrepancy between decision-making delays due to everyday overload as a result of increasing complexity and the awareness of having to act. For example, the vast majority of nearly 60 participants in the "Sponge City" course rated the necessity of comprehensive system knowledge and system thinking as extremely important in dealing with the highly complex topic of the "Sponge City" (Figure 1). When asked what obstacles block the implementation of a complex challenge such as the transformation of cities and municipalities into so-called sponge cities/regions, the lack of an "overarching/systemic understanding of the sponge city system" was highlighted according to Figure 2.



Source: Hof University of Applied Sciences

Figure 1: Survey result of certificate course "The way to the sponge city - urban development in times of climate change, participants: [59].

This issue was given the second highest mean value of 3.39 by the course participants (1 = does not apply; 4 = clearly applies). Only the high costs for implementing the measures were rated slightly higher with 3.42. In five projects at the Institute for Sustainable Water Systems at Hof University of Applied Sciences (inwa), which deal with the complexity of climate change, sustainability

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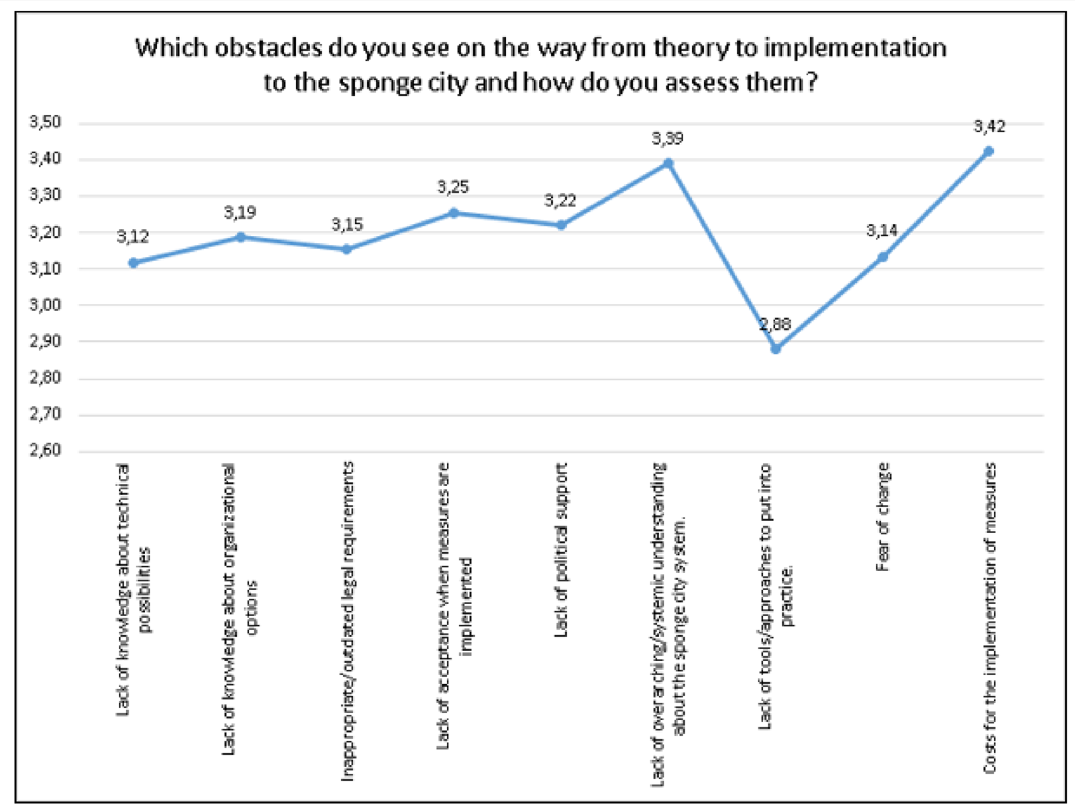
and digitalization[4,5,6,7,8] the almost 100 municipal stakeholders or stakeholders working with municipalities repeatedly emphasized that, as a result of the increasing complexity, they did not know how and where to tackle which problem. Moreover, there was lack of possibilities to first make the complexity, which has increased significantly in recent years, transparent in the first step to then be able to make meaningful and effective decisions in the further steps.



Source: Hof University of Applied Sciences

Figure 2: Survey result of certificate course “The way to the sponge city - urban development in times of climate change, participants: [59].

Due to the complexity of these issues and their strong interconnectedness, there is a great fear of making mistakes and wrong decisions. In order to be able to grasp and describe the complexity of the described municipal complexities at all, a municipal complexity cycle was developed within the framework of one of these projects (Figure 3).

Meaning:

i. **Extra-complexity:** Complexity that lies outside an organization, e.g. laws, social developments, weather events or legislation.

ii. **Intra-complexity:** Complexity within organizational structures and processes of an organization.

iii. **Inter-complexity:** requirements that need to be met in order to satisfy growing stakeholder needs (e.g. citizens, authorities, interest groups).

iv. **Color of the arrows:** the more intense the green color, the greater the influence.

v. **Time:** Depending on influences from the past, present or future, the overall complexity changes (e.g. existing long-term gas supply contracts of a municipality make the innovative use of alternative climate-neutral energy sources more difficult).

Making the complexity according to Figure 3 visible to stakeholders is the first step towards reaching that complexity that can be found at different levels and can therefore be influenced in different ways. Thus, in the following investigations, the focus should be placed on those areas of complexity that can be influenced and thus controlled in the respective organizational unit. To support these further steps, the Hof researchers developed

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their own method with the multi-level analysis during the SPORE project and the certificate courses "Sponge City" and "Digitalization of Water Management" in order to make the different complexity aspects and perspectives visible and to be able to derive effective measures for climate change adaptation. But before the results are presented, there is a brief overview of what science has to say about the relationship between complexity and climate change.

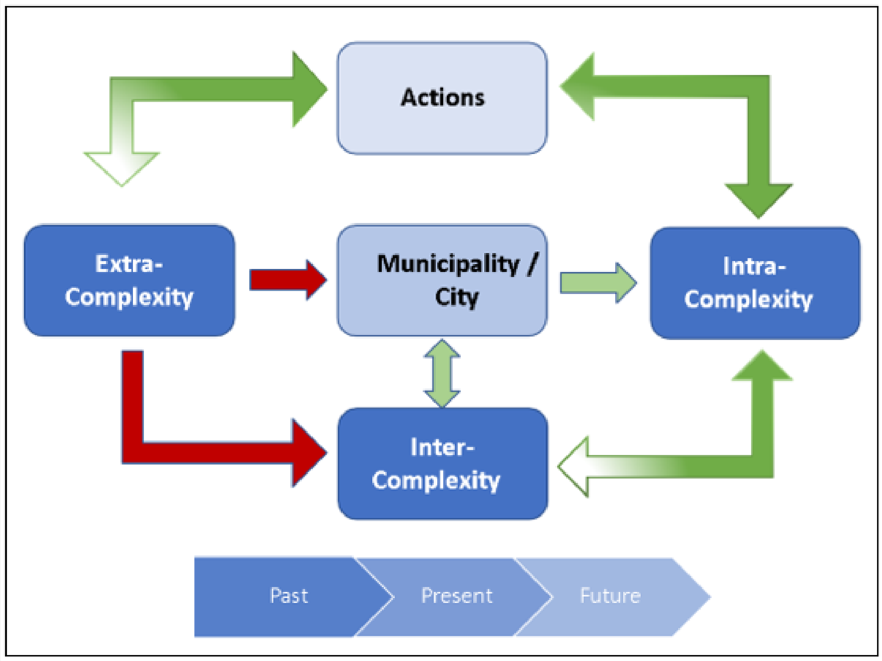

Figure 3: Municipal complexity cycle [7].

Connection between Complexity and Climate Change

In social science, for example, the responsibility for solving complex climate-related challenges is primarily seen as a problem of social action rather than a local task [8]. There is no doubt that tackling such complex challenges requires multi-level governance, ranging from the smallest local level to cross-border collaborations with different stakeholder groups. Different forms of knowledge need to be integrated and the inevitable uncertainties and conflicts of interest need to be dealt with carefully, especially as complexity increases [9]. Due to their long-term horizon, global nature and massive uncertainties, climate change and adaptation to it pose unprecedented challenges for policymaking. In order to capture this (locally varying) complexity to some extent, network and agent-based models are increasingly being used to describe unbalanced dynamics, tipping points and major transitions in socio-economic systems. These classes of models view the real world as a complex, evolving system in which the interaction of many heterogeneous agents, possibly reacting across different spatial and temporal scales, leads to the emergence of aggregate properties that cannot be derived by a simple aggregation of individual properties [10]. In addition, requirements and motivations for climate adaptation activities must be disclosed on the social side, action requirements in the region must be prioritized and demand orientated measures must be taken. To this end, relevant stakeholders and their climate change-related impacts must be identified. The effectiveness of climatic changes and dysfunctions in ecological-biological or socio-economic systems must also be determined. If an actor-specific impact analysis is added, various complex climate impacts must be considered. An impact analysis also provides information on potential (social) conflicts and synergies that may arise during the development of an integrated regional climate change strategy [11].

This contrasts with the need for local community action, in which decentralized strategies and techniques are becoming increasingly important [12]. How difficult it is to reconcile global decisions and locally specific individual needs in the fight against climate change is shown by the studies of [13] in rural regions of Ethiopia. Although local adaptation constraints were identified, new context-appropriate strategies could be developed so that the local community could develop appropriate adaptations through adaptive learning. From the analysis it can be concluded that the historical experiences of local communities are certainly suitable for taking local environmental and climate dynamics

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into account to develop nature-adapted strategies, which form an important element behind the background of currently needed climate adaptation. The greater global climate impacts effect locally, the less effective local adaptation strategies will be. However, [13] were able to show that initial good results were wiped out by governmental interventions, which interrupted previously free adaptations, and the adaptive learning of the community deteriorated. As local and global adaptation strategies are important elements in the fight against climate change, actors need a right balance depending on the context. At the community level, [14] investigated whether the adaptive capacity of individual households in a community differs from the adaptive capacity of the community itself. They analyzed 22 case studies on small-scale fisheries from 20 countries.

The following differences were identified:

i. Adaptive responses at the community level only occurred in situations where the community had access to assets, in combination with other areas such as diversity and flexibility, learning and knowledge, and natural capital.

ii. Adaptive households showed diversity and flexibility when supported by strong governance or institutions, and were often able to substitute learning and knowledge and natural capital for others.

[14] conclude that standardized measures of adaptive capacity are critical for developing effective strategies to promote resilience in communities that depend on natural resources and for understanding how social and ecological aspects of communities interact and influence responses.

In urban areas, case studies on urban challenges show the growing complexity of managing the interactions between population, infrastructure and institutions. Climate change increases the pressure on many urban systems and supports this complexity. Case studies examining urban dynamics in the light of climate change have adopted limited sector-specific approaches. Few projects have built on the insights of complexity theory and related fields of knowledge, which are more consistent with the perspective that urban infrastructure systems are closely interconnected and must respond to often subtle, long-term changes in technological, social and environmental conditions [15].

In addition, studies exist that show that necessary (local) adaptation strategies lead to positive synergetic effects in a climate change-related complexity matrix. Using the example of water management, [16] show that targeted and restrictive water distribution through urban water management accelerates necessary and previously neglected transformations in agriculture and industry (especially energy saving). [17] for example, argue that traditional risk management should be replaced by continuity management, as this focuses on the measures required to maintain the processes at risk and is more effective as a result than traditional risk management [18] show that the increasing pressure to adapt due to climate change in urban areas can also trigger and accelerate innovations based on a study of numerous Indian cities.

Psychologists are also increasingly investigating the effects of the complexity of climate change that impacts human psyche and how affected people can deal with it. Knowledge of this is particularly important for communication and thus for the acceptance of recommended or prescribed adaptation strategies. In their research, [19] identified three fundamental findings for strategies to promote adaptive coping and resilience to climate change stress:

i. It is unlikely that there is a single "right" or "best" way to communicate about adaptive coping to climate change, but there are established best practices that communicators can follow.

ii. Implementing best practices must regard the impacts of the different types of stress caused by climate change, as well as individual differences in how people chronically respond to stressors.

iii. Because individuals, communities and ecosystems are interconnected, work on adaptive coping with climate change must consider individual coping in the context of community and ecosystem resilience.

To prepare the young and youngest generation in particular for the consequences of climate change, [20] have investigated the inclusion of climate change in Australian schools. They conclude that the aim should be to prepare learners (students) for an uncertain future by helping them to acquire the skills (i.e. knowledge, skills, attitudes and values) to deal with future challenges.

For this to be achieved, educators need to rethink climate change mitigation and adaptation in a way that is not only technically transformative but also socially transformative, using teaching and learning approaches that harness creativity and empower students to act. It should be noted that purely problem-focused coping, which aims at direct action to solve the climate crisis, can easily lead to individual, especially young people, being overwhelmed because they are only able to do little about climate change on their own [21]. [20] further note that educational responses to climate change are best delivered through active social learning, which promotes the capacity for personal and societal change. However, current climate education tends to 'mirror society's response' [22], with curricula focusing on scientific knowledge or 'climate' in climate education and ignoring 'change', giving little attention to the consequences of climate change or the need to adapt to the impacts on human settlements and activities (see e.g. [23]).

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This brief foray through the literature on the complexity of climate change, and thus in dealing with climate change-based weather extremes already shows the enormous ecological, technical, social and individual-related complexity of the challenges. But who will manage the necessary adaptations and with which instruments? On the basis of which regulatory options and with which legitimacy and which priorities? What is managed locally and what needs to be managed globally? The advantage of a governance concept lies in overcoming the separation of regional and international governance regimes or modes of governance [24]. But as shown before, only a global focusing is not the solution. Although at the global level the potential of network-like and dialogical cooperation is increasingly relied upon. In this context, the term 'governance' is used when the aim is to transform complex regulatory tasks into forms of cooperation and coordination at different levels, stakeholder groups, policy fields and institutions [25]. Interestingly, earlier theories of political governance, especially in the 1950s and 1960s, were based on the model of cybernetics [26]. The recourse of politics to cybernetics was justified by its supposedly neutral terms such as black box, feedback, input, output, resonance, redundancy, etc., as this apparently also made it possible to describe and better model social and political processes. However, according to [27], there is a significant difference between political science and sociological system theories. Political science asks how the political system can be flexibly adapted to environmental changes through actions and thus maintain its stability. In contrast, sociological system theory focuses on autopoietic (process of self-preservation) coherence. An opening can be derived from [28] with reference to ([29]: "An act is always a process in time"), in the sense that actions are never closed in themselves, but only develop their effect through time and are therefore changeable.

The fact that neither the political nor the socio-logical model of autopoiesis is suitable for controlling complexity today is shown by the numerous failures of regional, national and international politics in relation to the fight against climate change from global perspective and action level [30]. The cybernetic-orientated theories of political control were based on the simplified assumption of a central political actor (the government), which formed a controllable control loop with the control objects and "inputs" from the environment [31]. This model was strongly influenced by the technocratic spirit of the 1960s and 1970s.

The spread of mainframe computers to government headquarters and the associated thinking in terms of rational algorithms reinforced politicians' belief that good governance was essentially a question of proper information management and that this in turn was a matter for experts [32]. The current impression is that digital systems are once again being ascribed a decisive role in solving the problem of climate change [33]. Attempts have also been made to transfer the model of autopoiesis to public administration processes, as organizational science in particular hoped to achieve efficiency gains through better self-control of administrative organizations [34]. One advantage of transferring autopoiesis to public administration is seen in the fact that it places the central concerns of a public administration in a complex picture of society as a whole, in which both the authority makes the decisions and the area affected by these decisions is included [35].

A major criticism of autopoietic-based political models has been that it only works in the absence of external constraints, i.e. it requires stable conditions [36, 37] emphasize in this context that the nature of self-regulation in relation to public or societal administrative domains is not yet fully understood and therefore suggest two possible perspectives for application. The first is a system-oriented perspective that focuses on the operational closedness of systems. The second deals with an actor-oriented perspective that emphasizes the situational dependency of actual opportunities to use self-governance. In addition, it is recommended to add a third, interactional approach that emphasizes the need to understand social interactions in all their complexity, dynamics and diversity in which self-governance capacities are tapped. [38] point out the importance of a multi-level analysis in connection with Luhmann's self-control models, which has a certain proximity to the multi-level analysis used in the Hof researchers' sponge projects, which will be discussed in more detail below. The extension of the investigation of self-governance capacities to several levels is an important aspect of the debate on the question of the correct governance of political and administrative systems and organizations. Using the Dutch system of spatial planning, [39] have used an analytical framework of systems theory to examine functions of attributions of failure and success in public administration in the context of rhetorical functions, performances, discursive configurations and consequences. It is shown how success and failure are mutually dependent, so that the "spatial planning system" is maintained in a kind of self-reproduction. The authors come to the conclusion that the planning apparatus cannot function from the perspective of autopoietic continuity if the process finds nothing that it can improve. Admitting previous failures (often the failures of other actors) is a small price to pay for this autopoietic continuity of the planning system: the answer to planning problems is more planning, and in order to "reproduce" itself this requires the constant finding (and thus the discursive creation) of planning problems.

This is strongly reminiscent of solutions that not : they do not solve the problem, but actually make it worse, because in the face of persistent difficulties, all living beings tend to apply the disastrous recipe of "more of the same" regading [40]. Watzlawick proposes three interventions to break through this self-referential problem-solution-problem-system:

i. Direct behavioral instructions: these are indicated when resistance appears to be minimal and clients are willing to follow the instructions of the "authority".

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ii. Paradoxical interventions: these are indicated when clients claim that the problem is uncontrollable and that they are powerless against its supposedly spontaneous appearance ("I didn't expect this").

iii. Positive connotations: this class of interventions is indicated when the counselor encounters maximum resistance to change. Members of organizations usually report that they have already consulted several consultants, none of whom have been able to help them or give them the "right" kind of help.

These three types of interventions require careful planning and they must take into account the seemingly most trivial details of a given problem situation. In particular, the manner of communication is crucial. They must be communicated in a language/form that corresponds to the way the recipients perceive reality and not on the basis of what the counselor thinks is "real" [40].

All this means that policy and management consistent with the insights of complexity theory must anticipate a wide range of potential development paths for urban dynamics, identify and implement strategies that are robust under a range of potential developments, continuously renew policy-making and management institutions, and intensify knowledge exchange between science and society. On the other hand, climate change management programs (mitigation and adaptation) tend to have a high degree of complexity, which can challenge their measurability and thus their evaluation [41]. Therefore reducing their acceptance by decision-makers [41] propose various evaluation methods for assessing complex systems (see Table 1).

Table 1: Suggested approaches from the literature on evaluating complex systems [41].

Method	Description	Benefits
Emergent logic models	Convey multiple causal strands at different levels of analysis in a logic model and adapt the model as new outcomes emerge.	Addresses the challenge of overly simplistic single causal models by capturing emergent outcomes, which occur only during and after interventions as a product of interactions
Network Theory	Present agents in the system as nodes and the connections between them as networks. Analyze the behaviours and frequency of interactions between nodes.	Helps understand patterns in peer effects, cooperation and the spread of information
Most Significant Change	Collect and analyze stories on which interventions appear to stakeholders to have provoked the most significant change	Engages stakeholders in the evaluation process and helps recognize unanticipated emergent properties.
Time Series or Panel Data	Analyze data from multiple periods(time series) and/or for multiple different outcomes (panel data) to measure change over time	Facilitates the capture of trends that are not observable in a randomized setting due to temporal and feasibility constraints
Outcome evidencing	Identify outcomes that appear most important to measuring change in a program, examine critical linkages and who are experiencing change, analyze findings, and repeat this process	Allows for iterative and realtime learning; the evaluation can adapt as the complex system evolves
Sentinel indicators	Identify outcomes that act as "keystone species" to indicate the overall health or success of a system	Prioritizes the evaluation's most important outcomes; creates a simple decision rule as to whether an intervention is successful

When using complex evaluation systems, it is also important to ensure that the users of such evaluation systems have the necessary cognitive complexity. Since belief or non-belief in climate change also influences the evaluation of necessary measures, as [42] point out in their studies on the relationship between cognitive complexity and belief in anthropogenic climate change. It can therefore be concluded that systems for analyzing and evaluating complexity can only be used meaningfully if these systems are adapted to the cognitive complexity of the users.

The multi-level analysis presented below uses to the authors' knowledge for the first time` the findings of the scientific studies described above and the results of systems and complexity research into an engineering method in the field of infrastructure planning. Since engineering science, like politics, has so far assumed a stable environment in its "systemic" models and tools, many small impact criteria in particular, which are classified as insignificant for engineering science, are neglected and their effects are not taken into account. This is not envisaged in the multi-level analysis presented here; the system explicitly allows even small details to be taken into account, they are even already included in pre-assigned lists of standard criteria.

Dealing with Urban Climate Change while Incorporating Digitalization and Sustainability Requires Systemic Thinking

Against the background of the presented literature review and studies carried out at Hof University of Applied Sciences on the practical adaptation of cities and rural regions to climate change with a focus on water-sensitive aspects, a comparative examination of aspects of complexity and the system approach in the development of so-called resilient cities took place [43] understand resilient cities as their systemic adaptability as a result of socio-economic crises and climate change. According to [44] a resilient city is a sustainable network of physical systems

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and human communities. Here, the physical systems are the built and natural environmental components of the city, including, for example, streets, buildings, infrastructure, communication and energy systems as well as waterways, soils, topography, geology and other natural systems. Physical systems must be designed to be able to survive and function under extreme stresses. In contrast, human communities are the social and institutional components of the city. They comprise the formal and informal, stable and ad hoc human associations that operate in an urban area: schools, neighborhoods, authorities, organizations, businesses, work groups, etc. [44] describes communities as the brain of the city, as they direct urban activities, respond to (social) needs and (can) learn from experience. A city without resilient physical systems and human communities will be vulnerable to disasters.

In view of the large number of individual criteria that need to be taken into account, a solution-appropriate and effective, resilient approach to tackle impacts of climate change for the protection of people, society and material assets requires an understanding of complex factual and social contexts, especially when it comes to the transformation to water-sensitive cities or regions. Complex interrelationships in systems can, according to [45], only be recognized and controlled if the system has been sufficiently analyzed and understood. One of the skills required for this is systemic thinking, which has been one of the desirable basic skills of engineers and scientists for more than 50 years [46] but in environmental and water management teaching and practice it is rarely applied and usually incompletely [47-50] describe systemic thinking in general as the cognitive ability to solve complex dynamic problems with the help of a systemic approach. In doing so, methods of system science are used, such as

i. determination of system elements and their interrelationships,

ii. capturing temporal dimensions and dynamics,

iii. explanatory analysis based on modelling,

iv. making forecasts and

v. use of soft technologies (prudent influencing of systems to cause as little damage as possible).

The core of systemic thinking is the use of a qualitative system model to simulate, explain and comprehend complex sections of reality [51].

[52] describes three systemic properties for urban adaptability:

i. resilience as the measure for vulnerability to unexpected or unpredictable shocks

ii. the internal control and

iii. the density of the system, which determines the range of possible options

However, the systemic character is usually insufficiently considered in the discussion and development of urban resilience as in other infrastructure disciplines [53].

Building resilience capacity is a daunting task because of the multitude of components, processes and interactions that take place within and beyond the physical, logical (i.e. legal) and virtual (cyberspace) boundaries of a city [54]. Planning for resilience to the impacts of stressors within cities requires an assessment of the vulnerable components of cities, an understanding of the key processes, procedures and interactions that organize these components, and the development of the capacity to consider different structures of components and their interactions. They further need to be expanded to include the affected or involved stakeholders relevant for building resilient cities [55, 56].

The role of digitalization in the context of resilience in cities was highlighted in a study by [57] with regard to increasing urban problems and disasters. The results show that the impact of urban resilience on urban digitalization is positive under physical, social and environmental aspects, while the impact in the opposite direction can be both positive and negative under the three aspects mentioned above. [58] also investigated the impact of digital solutions with a focus on these four urban resilience:

i. economic resilience,

ii. social resilience,

iii. ecological resilience and

iv. infrastructural resilience.

The results of the study show that digitalization primarily promotes social resilience. Effects on economic and ecological resilience are rather low or hardly measurable and negative effects on infrastructural resilience were found in some cases. Digitalization has a beneficial effect as a strategic element in cities that have a solid industrial structure, enough high-quality companies, a large size and a large pool of highly qualified workers. They are highly likely to promote urban resilience.

Most disciplines working in the field of sustainable cities construct their own idea of what “sustainable city” means to them. Discipline-centered, specifically defined “ideal states” are widespread. In engineering, for example, the city is sustainable when resources, such as renewable raw materials, are used most efficiently. Systems are spatially located (mapped) and losses and uncertainties identified; particular consideration is given to infrastructure, energy sources, construction methods, etc. In the social sciences, sustainable cities are often described in terms of “social sustainability”. In particular, social justice and social dynamics of the current and future population groups are taken into account with cultural diversity, health and well-being. And it is precisely this that contradicts with the holistic, systemic approach in the context of sustainability. The defined “ideal states”

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are therefore to be merged as best as possible using the systemic view immanent to sustainability.

The use of digitalization is helpful here. It is precisely this linking of smart (i.e. digital) and sustainable measures that has often been propagated as an essential element of sustainable urban development, but has not always been successfully realized [59].

Method Description - Multilevel Analysis - Visualization and Assessment of Individual Challenges in Complex Environments

The studies of Hof University of Applied Sciences and international research on the development of resilient cities illustrate the high degree of complexity that arises or must be taken into account in the necessary linking of resilience, water sensitivity, digitalization and sustainability. In particular, the SPORE project in Hof has shown that in the field of resilient infrastructure measures, such as water-sensitive urban and spatial planning, two main perspectives essentially determine the handling of complexity and the derivation of measures for action. On the one hand, this is the spatial perspective: i.e. where do crises have an impact as a problem or challenge and where is the necessary solution to be placed? Secondly, a precise target perspective must be formulated: i.e. how and what is to be achieved with the planned measures? Once spatial and target perspectives have been defined, it is necessary to check which municipal departments, where measures can be included and which cross-cutting issues also play a role and need to be taken into account in the further course (see Figure 4).

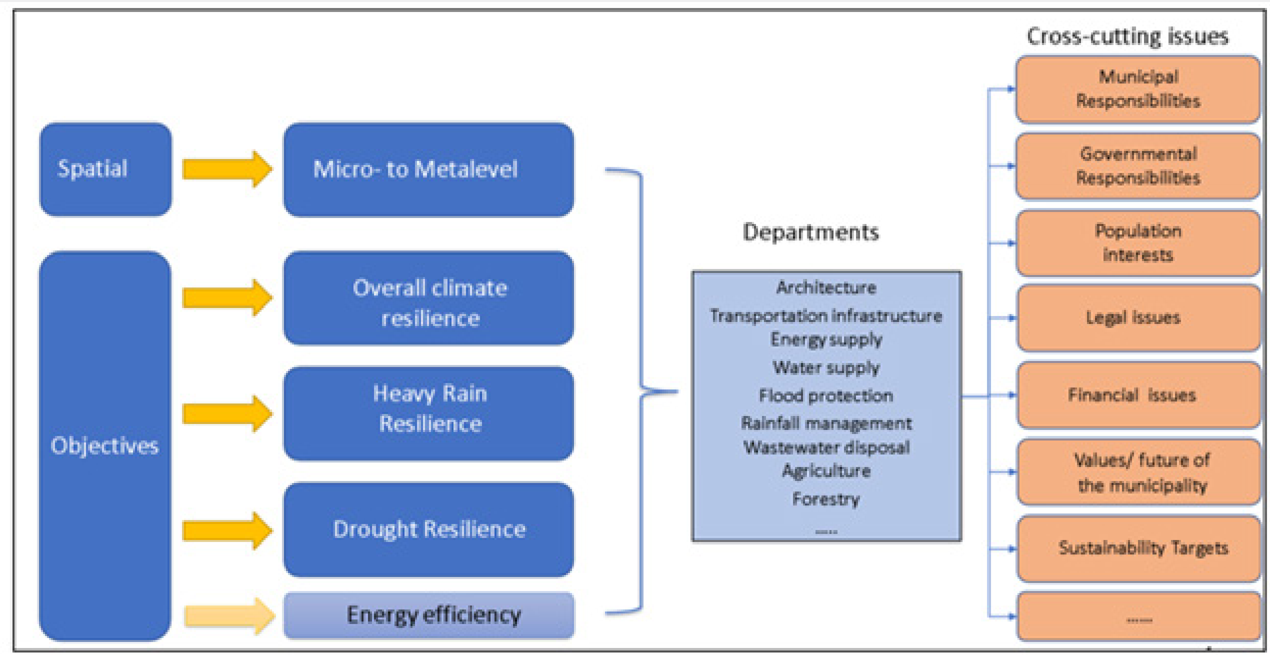

Figure 4: First step towards transparency of complexity in water-sensitive urban and spatial planning [7].

Thus, the spatial perspective became the central starting point of the multi-level analysis. This approach is understandable, since working in and with infrastructures always starts from the spatial object and is familiar to almost all actors. Water flows from A to B. Wastewater has to be transported from C to D before it is treated in E. Rain falls locally, heavy rain occurs in a district or at a specific location and causes damage at these and/or other locations. The introduction of a new tool, which involves a new way of thinking and analyzing, usually generates fears of the new/unknown. Therefore, the new tool should refer to a familiar behavior to keep application hurdles low [47]. The spatial perspective is a familiar starting point and was therefore placed at the center of the multi-level analysis.

The smallest observation area with considered in the multi-level analyses is called the micro-level (e.g. a groundwater well, a pumping station or an emission source with associated property). From this point, larger spatial "circles" are drawn around the starting area of the micro-level. Table 1 shows the starting definition of the levels, which has proven to be suitable for the analysis of water-sensitive urban and regional spaces. In the use cases investigated by the Hof researchers so far, these four levels have proven to be target-oriented. If necessary, other levels can also be added, but no specific designations have been defined for them so far (Table 2).

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Table 2: Level definition of multi-level analysis [7].

Level	Description
Micro level	Smallest field of action (e.g. building/object/property)
Meso level	Surrounding area of the micro level (e.g. neighboring properties, residential area, neighborhood, commercial area)
Macro level	Superordinate area of micro-level area (e.g. city/community/transition area to the next city/community)
Meta level	Superordinate area of the macro level (e.g. intermunicipal action area of two or more municipalities/cities, region, district)

Depending on the project background, the results of a complexity assessment serve as a basis for the further identification and development of related technical solutions. The development and application of the multi-level analysis are presented below using the example of a sponge project with integrated digital application development. It should be noted at this point that the main target groups of the multi-level analysis presented are actors in municipal water management and related infrastructure sectors such as the construction industry. A successful transfer of the multi-level analysis to other application sectors is estimated to be very high, but related studies have not yet been carried out.

The SPORE sub-project Schauenstein[9] will be used to illustrate the methodology of multi-level analysis. The starting point in the example of the German town of Schauenstein in the region of Upper Franconia/Bavaria was the renovation of the primary school, which was already planned and in preparation. The measure focused on the first-time installation of a so-called purple roof[10], a special form of green roof (Figure 5). In addition, a central rainwater management system was to be developed for the school grounds including all buildings. Furthermore, an irrigation management for the green roof and the further planting was to be provided. Both management tasks were to be implemented with an innovative digital solution.

Figure 5: Purple-Roof primary pchool Schauenstein (Image sources: City of Schauenstein, Hof University of Applied Sciences)

In the first step, the spatial level classification was carried out as the basis for the further multi-level analysis (Figure 6). The building of the primary school with the associated property was chosen as the starting point and defined as the micro-level. In order to identify and define direct influences on and from the primary school (micro level) on immediate surroundings, the residential and property area adjacent to the school was defined as the next spatial level (meso level). From here, the core town of Schauenstein was then defined as the next spatial unit, the macro level. Since the town of Schauenstein has other districts, the largest area under consideration, the meta-level, was defined for the entire town area.

In order to integrate the aspects and themes of the three types of complexity (Figure 3) into the analysis, the types of complexity and the four levels are linked (Figure 7). As already mentioned it is important to consider the factor of time as a separate dimension. Individual aspects of complexity or action can then be assigned to the three time periods past, present and future. Typical for an assignment to the past are, for example, contracts or current permits that have to be taken into account in the implementation of measures (e.g. missing transmission rights in current contracts for required pipelines turn out to be an obstacle to implementation).

Attention to the present is of particular importance in the timely and effective implementation of measures. In several studies of Hof University of Applied Sciences it was found that linking to already planned, approved or ongoing projects considerably facilitates the implementation of measures (so-called SOWIESO strategy), accelerates them and led to a much greater acceptance by the affected local representatives [5, 61,62]. Using the SOWIESO strategy, ongoing and new measures can also

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be better coordinated and bundled. More detailed information on the SOWIESO strategy can be found in [63].

For the Schauenstein SPORE sub-project, the expansion of the (anyway) planned rainwater management (green roof and rainwater storage) was identified as "SOWIESO potential". This will be designed as a digital twin in a separate project in 2024. The aim is to create a virtual 1:1 representation of the entire rainwater management system with the goal of being able to try out different case scenarios before a real test is carried out. First and foremost, the scenario option was to find out how long the green roof on the school can be supplied with rainwater, when an addition of drinking water is required (and how much), and under which conditions all other plants survive in different types of dry periods. The impact of various heavy rainfall events on primary school facilities has already been analyzed [64]. The (anyway) envisaged "sponge management" variant is strongly technical in design and is thus primarily suitable for training technicians and engineers. To ensure that primary school pupils can also use this system, which is planned anyway, it is to be expanded to include a software variant suitable for children/primary schools. Table 3 shows an excerpt from the multi-level analysis of Schauenstein primary school within the SPORE project, assigned according to the four levels.

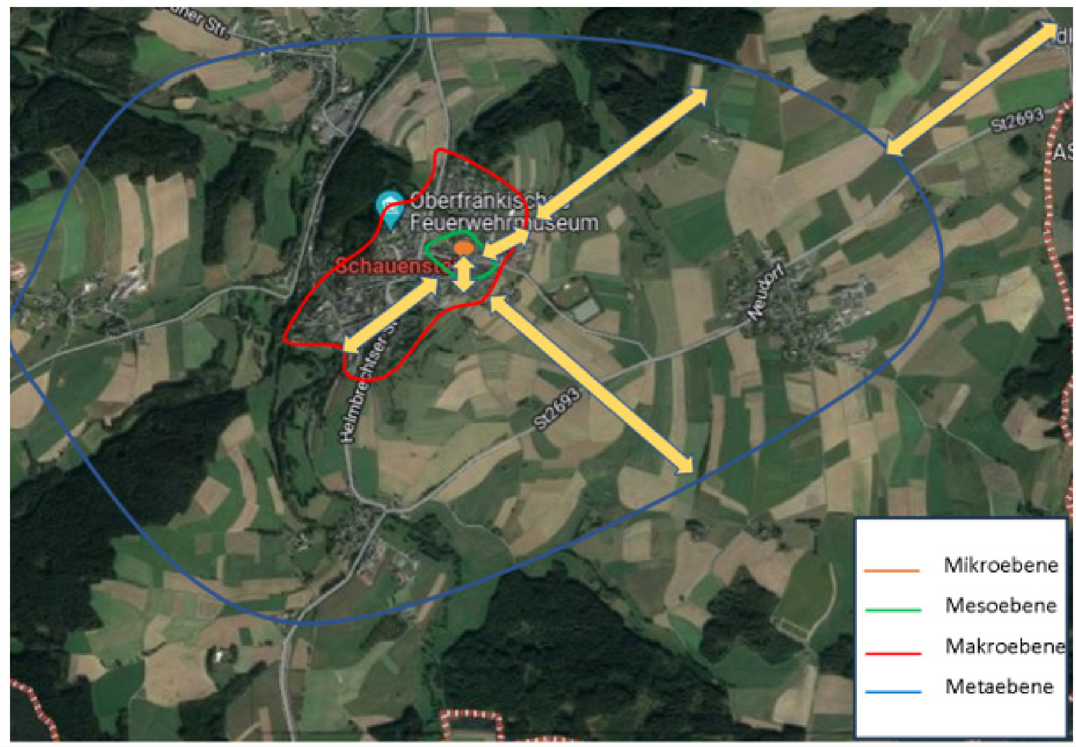

Figure 6: Circular spatial level assignment of the multi-level analysis in the SPORE sub-project Schauenstein (own representation, image source Google Maps)

Table 3: Summary of results of the multi-level analysis for SPORE sub-project Schauenstein (own representation).

Level	Spatial allocation	Aspects of the study
Micro level	School grounds with buildings, paths and areas	Green roof on primary school; water accumulation and collection from paved surfaces (roofs, paths, etc.); digital rainwater management; digital twin; primary school variant rainwater management; water demand green roof and plantings and determination of water supply security; preparation of a special water balance[11].
Meso level	Residential and property area adjacent to the school	Influence of surface runoff to the micro level incl. supply to the rainwater tank (if rainfall on the micro level is too low); influence of water retention of the micro level on combined sewer; securing water supply if drinking water is required for irrigation on the micro level; transfer of results to other properties in the neighborhood.
Macro level	Core village Schauenstein	Influence of micro-level water retention on combined sewer; securing water supply if drinking water is required for irrigation at the micro-level; transfer of results to other properties in the core city.
Meta level	The core town of Schauenstein with districts	Examination of Schauenstein primary school as a model for other public buildings.

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Even in a small project such as the renovation of the Schauenstein primary school, the number of criteria to be taken into account should not be underestimated when applying the multi-level analysis. For this reason, the multi-level analysis was transferred into a separate Excel tool and is constantly being expanded. Figure 8 shows the first version of the Excel format of the multi-level analysis for Schauenstein. A revised version is already available and allows the processing of a much higher number of individual criteria per level and topic aspect. In addition, an evaluation of the individual criteria and weighting of thematic aspects can be carried out and a function for cost-benefit analysis is also available. However, the complexity of the current version is not suitable to be presented as a screenshot or in a similar way in a publication.

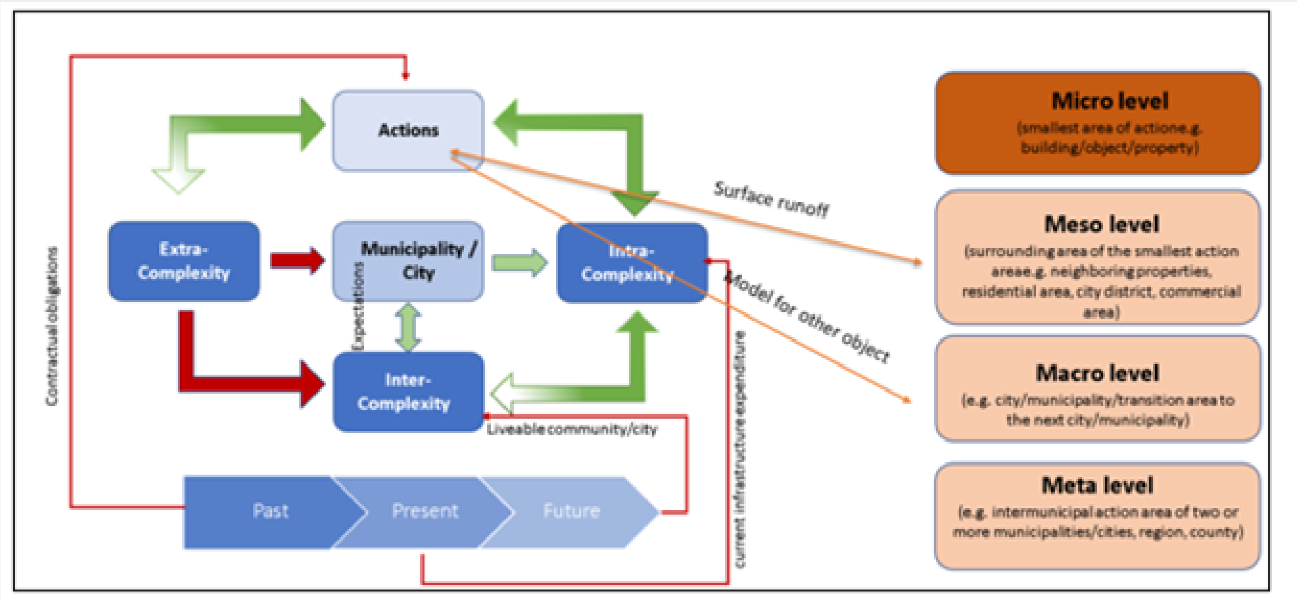

Figure 7: Relationship between types of complexity and multi-level analysis [7].

In the presented multi-level analysis, the "most trivial" criteria according to [40] are included. Furthermore, criteria that correspond to the elements of the evaluation methods proposed by [41] like "Emergent logic models", "Most Significant Change", "Outcome evidencing" and "Sentinel indicators" can be selected or individually supplemented. By defining weighting factors and the possibility of opportunity/risk assessment of individual criteria and main categories, an evaluation model is already integrated. Also, the focusing on spatial mapping captured in a best way the typical reality of the target group corresponding to [40].

Results and Discussion -Application Of Multi-Level Analysis Promotes Systemic Thinking

The newly developed multi-level analysis, that is described above, was the central systemic method for complexity analysis in a total of seven courses of the certificate courses "The Way to the Sponge City - Urban Development in Times of Climate Change[3]" and "Specialist Expert/Engineer for Digitalization in Water Management" between July 2022 and October 2023. More than 70 stakeholders in municipal infrastructure from the fields of municipalities/cities, specialist authorities, architecture, urban water management, urban planning, crafts and industry took part in these courses. Systemic thinking and acting is rather the exception in the respective fields of activity of the participants, as shown by studies already conducted with the participation of the authors [5, 47, 62]. Moreover, this observation can be derived from Figure 1 and Figure 2. This statement is surprising, since systemic thinking has a long tradition in the engineering sciences [65]. However, systemic thinking in engineering disciplines is usually limited to technical systems and the cross-disciplinary planning and methodological understanding of the interaction of system components and processes required. The fact that comprehensive systemic thinking in engineering is only a part of analytical and planning work is due to the highly fragmented Bachelor's and Master's structures of the Bologna Process [66].

Nevertheless, this partial application is a good start for a systemic complexity analysis with the method of multi-level analysis that goes far beyond this. After a technical introduction to the topics of sponge city and digitalization, the approximately 70 course participants received 90-180 minutes teaching units on systems of digitalization in water management and sponge city/region. Within the framework of this learning unit, the background,

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the systemic structure and a first application example of the multi-level analysis were also presented. In first small exercises, the participants were asked to make a simple assignment of the four levels (micro, meso, macro and meta level) using a practical example, which was selected by the course leader (e.g. redevelopment of an urban neighborhood with the development of water-storing roof and path areas) The spatial allocation of this example was presented in the form of a Google map section. After a short presentation of the practical example, the participants had to discuss possible allocations of the four levels together and then determine where the boundary lines of the levels should run on the Google Map extract (analogous to Figure 6). Together with the course leader, the decisions were discussed and reflected. At the end of this sub-module, the participants were asked for feedback on how they evaluated this small exercise and what learning experience they could identify for themselves. Even with this small exercise, the vast majority confirmed that in their everyday planning work, even in comparable projects, they had only considered the meso level, i.e. the streets adjacent to the apartment block. To include neighboring districts, the whole city or even the neighborhood of other cities/municipalities was completely new or at least unusual for almost all participants but was considered very valuable.

Source: Hof University of Applied Sciences

Figure 8: Detailed results of the multi-level analysis of the SPORE sub-project Schauenstein - old Excel model.

Thus, already with this small exercise, an essential criterion of learning success could be fulfilled: the formation of difference according to Bateson [67,68], presented in [69]. Bateson emphasizes that the exchange of information and the transformation of that information must make a difference for a learning result. This means that to learn something new it is not enough to simply present the new thing and learn it in detail. The learning effect only occurs when the new is directly confronted with the old or with alternative information and the differences between the two aspects become visible and understandable. The already described limited way of systemic thinking in technical disciplines has been experienced by course participants as an unchanging agenda for an average of 15-20 years (including the study period).

To the course participants, the related things, behaviors or attitudes often seem that they can hardly make a reasonable statement about what their routine behavior means or which consequences result [69]. Since all project participants act in a similar way, the other pole is missing to learn something new through the described differences. The feedback request consciously introduced by the course leader with the hint to compare the initial application of the multi-level analysis just carried out for the first time with one's own previous approach created the necessary difference formation. As the difference to the previous way of working was very large for some participants, a strong "aha" effect with a visible emotional reaction was generated. Thus, a second important learning factor was taken into account, the learning support through emotions. Emotions

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have a significant impact on human cognitive processes, including perception, attention, learning, memory, reasoning and problem solving.

Emotions have a particularly strong influence on attention, especially on the modulation of the selectivity of attention and on the motivation of action and behavior. This attentional and executional control is closely linked to learning processes, as intrinsically limited attentional capacities are better focused on relevant information [70]. This also applies to learning in an informal academic context such as the courses studied. Studies e.g. by [71] could show that higher emotional arousal, less pleasant feelings towards the content and stronger environmental values led to greater short-term learning outcomes. In the practice case of multi-level analysis, it can be assumed that the concept of emotions as transformation comes into play (cf. [72], described in [73,74]. Emotions are released as a result of an experience or event that enhances understanding and gives meaning.

With the first application exercise and the creation of a strong difference to the previous approach with positive result evaluation, a strong curiosity for the "big exercise" was generated for the participants. This refers to the final module, which includes a whole day of practical practice with the multi-level analysis. Here the introductory exercise is considerably extended. To increase difference making and emotion elicitation, participants bring current projects they are working on during the course. In the average participant size of 8-10 people, 2-3 people in the 7 courses brought their own project with them. Half the day was available for one project, so that two projects could be dealt with in detail. The multi-level analysis was carried out in the whole group, everyone could contribute their own thoughts, the course leader moderated the process and documented the results on meta walls. To maximize the learning effect, the course leader repeatedly ensured that sufficient differences were formed through reflection questions and comments, unless the participants created them themselves during the case study.

Already while working on the introductory exercise, it was noticed that towards the end of the exercise the participants increasingly used the basic terms micro, meso, macro and meta level independently and also assigned them almost without errors. In the feedback round, most participants emphasized the systemic structure of multi-level analysis as an advantage and used attributes of this systemic structure several times in their own words. From the respective day's discussion, the impression arose in almost all seven courses that a basic systemic understanding had already developed in the group of participants. The listening participants rarely asked questions about understanding, which reinforced this impression. During the "big exercise", the impression of a basic systemic understanding was further consolidated. In the second part of the exercise, the role of the course leader changed from controlling moderator to co-discussing participant. In the joint solution discussion, the systemic vocabulary of multi-level analysis was applied almost without restriction and the systemic perspective was adopted. In the final feedback round, there was without exception a majority acceptance of the advantages of multi-level analysis. The presentation of the participants' own experiences of the course were made with a systemic description that seemed natural. Another indication that the courses triggered initial mindset changes in the direction of stable systemic thinking was the self-evident use of the four levels in the professional experience exchange of everyday tasks and projects between the participants during the breaks. A few days after the end of the course, the same phenomenon was observed in conversations between the course leaders and individual participants.

Of course, there were also participants who had difficulties with the application of multi-level analysis, and these people did not develop a self-understanding of systemic description. A rejection of multi-level analysis or even of the course content could not be detected; most of these participants said that they saw the advantages but that the application still needed some time of practice.

As a learning test, the participants had to complete a transfer task at the end of the course, in which they had to answer the following questions, among others:

i. What insights did you gain from the event?

ii. Describe the use of the method "multi-level analysis" using your own example. What is advantageous and what is disadvantageous for you when using this method?

iii. How does the course concept fit into your own everyday work? Which contents are easy to integrate into your projects or your work structure, and which are difficult?

On average, this task was completed 3-4 weeks after the end of the course, which made it possible to check the extent to which systemic thinking was still present or could be deepened. The following exemplary statements as an excerpt from transfer tasks support the assessment that already the professionally oriented work with multi-level analysis can trigger and effectively strengthen a change of mindset for a strengthened systemic approach. The indications of limitations and negative effects in the use of multi-level analysis also point to a growing systemic understanding of using the method.

Here are exemplary statements from the transfer tasks:

a) To the question "What insights did you gain from the event?

"The advantage lies in a "comprehensive approach". From the implementation of individual measures, one can recognize a "development trend" and, if necessary, also control it."

"But it is not only about rainwater and groundwater formation. Heat management will also be a task of the future, but also already of the present. The sponge city concept can do all this where it is

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implementable."

"The complexity of the sponge city issue was a great insight. It starts with the numerous factors/implementation options that make a city a sponge city in the first place and ends, most importantly, with the realization that a multitude of agencies/authorities/businesses/providers/householders/customers/municipalities/legislation etc. need to work together to make the sponge principle feasible across the board in the future."

"The event on sponge city showed how present, complex and relevant the issue already is. It is important to know that some of the principles of the sponge city are already being implemented and that the wheel does not have to be reinvented. Nevertheless, a combination or bringing together of the different sectors is needed to accelerate important sustainable, water-sensitive urban developments."

b) To the question "Describe the use of the method "multi-level analysis" with your own example. What do you find advantageous and disadvantageous in using this method?"

"Multilevel analysis allows a broader view of the measures to be taken."

"This approach is good at mapping and revealing interrelationships. But it can also lead to 'fragmentation'. The task, often set and to be solved on the micro level, can uncontrollably inflate and in the worst case lead to a failure of the whole project if project-related prioritization by all parties involved do not take place."

"Advantageous in this multi-level analysis is the "working out" in context of approaches to solutions that need improvement and are sustainable. Disadvantageous is that decision-making bodies are less and less place-based and concerned, and the issues become more and more complex for individuals."

"Advantageous: detailed recording of influences and measures; ideas developed are not lost; connections between different topics, ideas and measures can be better recognized. Disadvantages: time-consuming research for a possibly only first survey regarding feasibility; no recognizable tendency in advance about the expenditure for the implementation of the following measures; wrong approach of the meta-levels can lead to costly revision later on; extensive local knowledge necessary so that the analysis also exploits the corresponding potentials".

"Multi-level analysis allows to dive deep into the examination of the "sponge possibilities" of a construction project and to grasp the complexity in a structured way. The complexity of multi-level analysis can also be viewed adversely. It is important to maintain clarity and not inflate the analysis to the point of absurdity. Furthermore, one should not blindly follow the given keywords, but question them and adapt them for one's own project where necessary/meaningful. You need to have gone through a few analyses until you can apply the advantages of the tool well."

"The main advantages of multi-level analysis are the effects that can be taken into account at different levels, which in turn have an impact on each other. Thus, diverse interrelationships can be taken into account. A disadvantage of this method could possibly be the lack of a detailed view of the task, or the difficulty of maintaining an overview and the complexity of the interrelations. Multi-level analysis is a supportive tool to make the complexity visible and to disentangle it at the same time. By defining the micro, meso, macro and meta levels, one can define the mutual influence and then concentrate on the respective levels. For me, the advantage is that you can quickly get an overall picture, identify stakeholders more quickly and thus establish contacts as early as possible. Afterwards, the details of each level can be looked at much more closely without digressing into other levels and these can even be worked on partially detached from other levels. A possible disadvantage could be that the level delimitation is emphasized too much and thus possible intersections with the other levels are not illuminated enough at the beginning and later a planning section that has already been done has to be changed or adapted afterwards. This could cause a considerable delay."

c) On the question "How does the course concept you have learned about fit into your own everyday work? Which contents are easy to integrate into your projects or work structure, and which are difficult?

"The course conveyed the context of the sponge city system well. In the future, concepts need to be developed and implemented that address heat and drought on the one hand and precipitation events on the other. Sustainable measures can be developed through the multi-level approach."

In a survey launched at the end of the course on October 23, 2023, around 60 participants in the "Sponge City" certificate course were asked about their initial experiences of using the new multi-level analysis tool. By the time this article went to press, 10 of the 60 participants had already answered the questions.

For 6 out of 10 participants, the presented multi-level analysis is a predominantly easy-to-understand tool for analyzing different and complex interrelationships in a sponge city/region project (see Figure 9). This is primarily due to the limited presentation of the highly complex interrelationships. The planned web version is intended to be more user-friendly.

For the investigation of different degrees of complexity of a sponge solution and to increase the transparency of the examined complexity, 7 out of 10 participants attest the multi-level analysis is highly suitable (see Figure 10).

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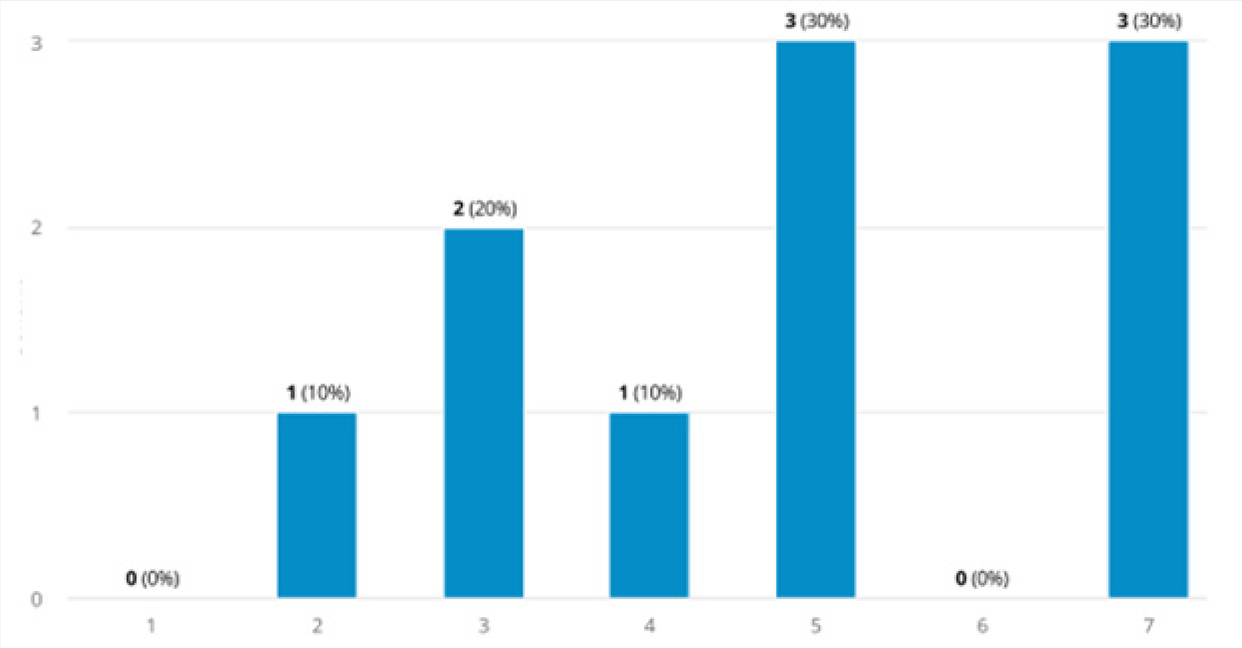
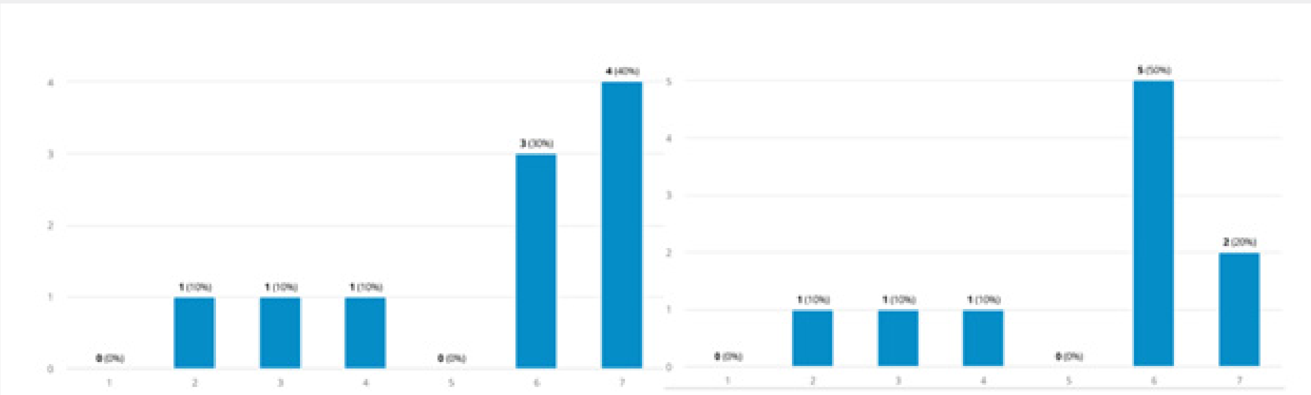


Source: Hof University of Applied Sciences

Figure 9: Question "Multi-level analysis is an easily understandable tool for analyzing different and complex relationships in a sponge city/region project"; Participants: 10; 1 = I do not agree at all; 7 = I fully agree



Source: Hof University of Applied Sciences

Figure 10: Left: Question "Multi-level analysis allows the application of different degrees of complexity in a sponge city/region project"; right: Question "Multi-level analysis increases the transparency of complexity and thus the understanding of different perspectives". Participants: 10; 1 = I strongly disagree; 7 = I strongly agree

When asked for a comparison with conventional/previous processing of sponge city/region projects and the use of multi-level analysis, the following individual responses were given with regard to easier processing (excerpt from the survey responses):

"The multi-level analysis makes it easier for me to...":

i. weighting possible measures

ii. accessing (creating) a functioning and proven structure for project evaluation/baseline analysis

iii. structured communication with the client

iv. the comprehensible, concretization of processing/contract goals

v. clarity and transparency towards the client

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vi. initial discussion with the client about what is relevant where and at what level

vii. the narrowing of the perspective on responsibilities is avoided

"Multi-level analysis offers the following advantages":

i. Overview of the protagonists involved, their interaction and interdependence in the project

ii. Facilitates entry into the project

iii. Increases understanding of the measure

iv. Simplifies the standardization of planning processes

v. It helps to determine who the stakeholders and the general effects of a project could be, especially at the higher levels.

vi. Systematic approach enables comparable technical evaluation.

vii. Create awareness of spatial relationships.

viii. An open and holistic view of the situation/necessities

As the application was more difficult for 3 to 4 of the participants than for the others, critical statements were also made in the final question "What else did I notice about the multi-level analysis".

i. It should be made more intuitive (web surface needed).

ii. It is difficult to define the levels as there are no fixed rules for this. You need to gain some experience with multi-level analysis before you can make this classification with confidence.

iii. The "flight level" of the individual elements is very different, i.e. a comparison is sometimes not meaningful, e.g. individual components with analysis tools.

The answers provided so far are not representative. Nevertheless, they give an indication that many users expect high added value from multi-level analysis.

Conclusions: Future Action and further Development

Dealing with climate change takes place against the backdrop of parallel multi-crises. Cities and municipalities in particular, as places where people live, must react to climate impacts such as heavy rainfall or drought and take protective measures. In addition to integrating temporary crises, those responsible are also called upon to take into account trends and solution approaches such as digitalization and sustainability in order to create resilient places with a sufficiently high quality of life and protection. From the perspective of urban and spatial development, these challenges must not be limited to technical aspects alone. Rather, systemic thinking and action is required at all levels of infrastructure planning and implementation, as well as social development, to make the complexity of the upcoming challenges transparent, to structure them and to be able to derive target-oriented measures from them. Conventional approaches, which originate from engineering sciences, include a proportionate systemic thinking, but this no longer does justice to the comprehensive complexity of the multitude of tasks in cities and municipalities. At the same time, psychological stresses are increasing among those involved in the fight against climate change, especially the fear of losses or of change, the preoccupation with banalities or the resort to simple and past-oriented solutions as an attempt to reduce complexity.

With multi-level analysis, researchers at Hof University of Applied Sciences have developed a method to anchor systemic thinking more firmly in established processes of urban and regional infrastructure planning without the need for active and openly discussed minimum change. This new method was presented in two courses with about 70 participants. After a theoretical introduction to the systemic understanding of climate change and related measures to reduce climate impacts on several real examples, the practical testing took place. Already in the first one or two hours of applying the multi-level analysis, the participants observed a first form of integration of the systemic approach into their own problem assessment and search for solutions. This was visibly during the course of the one-day practical module, which formed the conclusion of the courses. The effect observed after a short period of use, that systemic thinking without targeted mental coaching apparently became an unconscious part of one's own problem analysis and solution development, could still be observed 3-4 weeks after completion of the courses. In the reflection questions that had to be answered to receive the participation certificate after the end of the courses, systemic terms and descriptions were found with high frequency, which left the impression when reading them as if they were part of everyday vocabulary. It can therefore be assumed that regular use of the systemically oriented multi-level analysis leads to an unconscious shaping and strengthening of systemic thinking.

In the courses, practical examples of infrastructure planning were analyzed and evaluated using the multi-level analysis, both with the current Excel version and in the face-to-face sessions using table templates and meta walls. This revealed the limits of the flexibility of an Excel version, especially when it came to processing different scenarios and climate impacts. Therefore, the development of a web version is planned, which will allow the necessary flexibility and diversity of criteria. In addition, the tool is to be more universally oriented and, beyond the previous focus on infrastructure planning, also applicable to other disciplines. The current findings indicate that the complexity diversity and depth that can be captured with the tool but overtaxes the individual user if he or she strives for comprehensive project processing and undertakes this without professional support.

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Therefore, it is planned to map the web variant in several levels of complexity so that, on the one hand, unaccompanied analyses are possible and, on the other hand, highly complex processing can take place in accompaniment. In further projects, the development of the multi-level analysis is to be supplemented by an empirical accompanying study. The aim is to determine to what extent the sole use of multi-level analysis brings about a significant change in systemic thinking and how long this effect lasts.

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