Building the Case for Nature-Based Solutions: Enablers and Barriers in Data-Driven Solutions for Climate Adaptive Developments

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1 ABSTRACT

Global climate change, urbanisation and increasing demand for limited resources are primary challenges facing the sustainable, long-term development of cities. Traditional mitigation of flooding and stormwater management focused largely on technical and infrastructural solutions (e.g. larger pipes, underground storage, 'out-of-sight / out-of-mind' mentality). Yet these 'trusted' conventional infrastructure systems are proving to be neither safe nor cost-efficient solutions for managing the effects of climate change (e.g. flash floods, extreme heat, extended drought) and mitigating the resultant impact on liveability as well as ecology.

In response to the need for more effective, 'climate adapted' tools, blue-green infrastructure (BGI), otherwise widely recognised as nature-based solutions (NBS) – or tools which echo or mimic natural systems and ecosystem services while providing the functional requirements of grey infrastructure such as pipes – have emerged in recent years as suitable measures to for complementing or replacing conventional solutions.

Current available methods for integrating climate adaptive solutions such as NBS and BGI within the urban planning practice are insufficient and lacking when compared to the complexity of city planning today. Calculating the impact of design concepts today is still a highly manual process. The lack of resources both in terms of personnel and finances limits the capability to efficiently test and validate optimal solutions. Often, methods utilized in practice for simulating the effect of climate adapted solutions take too long to get to meaningful results or largely stems from guesswork and assumptions. Viewed in parallel with observations that 1) the loss of green areas to urban development has further challenged the capacity of conventional engineering solutions to the point of failure; 2) global temperatures, heat waves and urban heat island effects will intensify in coming years, leading to issues with water scarcity and drought; and 3) planning cities of the future requires coordinating a diverse group of stakeholder interests, our conclusion that a new method for planning and design is deemed necessary.

We set out to answer the following questions: can the plethora of digital data available be used to create meanginful solutions that can manage, mitgate and adapt to the effects of climate change in the built environment? What barriers must one consider when utilising data-driven, software-based technology as decision-support tools in the field of urban planning? More specifically, what enables the acceptance and applicability of such methodologies compaerd to traditional planning and design processes?

These observations and research queries, combined with the experience of testing tools in the field; retesting and validating the results; and lastly reapplying the results again within professional practice led to the establishment of 'GreenScenario', a rapid iteration and software-based decision-support tool for simplifying climate adaptation planning. The following paper details this path by firstly describing the concept of nature-based solutions in relationship to climate adaptation. Secondly, the results of the 9-year+ R&D process that eventually led to the establishment of GreenScenario are detailed in relationship to the basis for the decision-support tool. Lastly, observations from practice regarding potential enablers and barriers to implementation of data-driven decision-support tools are summarised and compared to the initial results of implementing GreenScenario as a decision-support software, tool and process for urban planning and design.

Keywords: Process-Driven Software Collaboration, Data-Driven Decision Making, Nature-Based Solutions, Blue-Green Infrastructure, Climate Adaptation

2 INTRODUCTION

2.1 Global conditions and effects of climate change on the urban environment

Urban mega-trends pre-COVID predicted that there would be an increase of movement from rural into urban areas thereby increasing land scarcity, natural resource depletion and climate change issues. Globally, it is estimated that by 2050, approximately 70% of the world's population will live in cities; 80% of global inhabitants could still be living in unplanned settlements with the highest growth rates coming from Africa and Asia; the largest age group will be senior citizens; and population rates could grow by 12% resulting in approximately 8.5 billion people by 2030 (Department of Environmental and Social Affairs, 2017: 1; Revedin, 2014: 8; Stylianidis et al, 2017: 119). Although cities only occupy 3% of the Earth's land, they generate 80% of global gross domestic product (GDP) while responsible for 70% of global energy use and greenhouse gas emissions (United Nations, 2016: 24). By 2050, the cost of 'doing nothing' to mitigate climate change effects in cities is estimated to incur costs in the EU alone in the range of 100-150 billion Euros per year every year, dependent on the climate scenario (COACCH, 2018). The near and long-term effects of COVID-19 will also need to be considered when planning any future development.

2.2 Nature-based solutions (NBS), blue-green infrastructure (BGI)

'Nature-based solutions' (NBS), or similarly 'Blue-Green Infrastructure' (BGI) offer mitigation tools and measures that can adapt to the effects of climate change at the urban city and district planning level. NBS can be defined as 'actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits' (IUCN, 2019). NBS have the capability to complement or even replace traditional grey infrastructure solutions (e.g. pipes) by offering multi-functionality as opposed to monofunctionality (i.e. green roofs or rain gardens not only improve environmental and aesthetic conditions, they satisfy infrastructural requirements and functions while enhancing spatial quality and liveability).

For example, rain gardens are an NBS that can simultaneously manage stormwater, reduces run-off and improve water quality; they provide similar functions as piped solutions. Aesthetically, they are planted, visible and offer an open space element in the urban environment. Additionally, NBS provide ancilliary benefits or 'co-benefits', what could be also be termed as added values that are typically not considered in cost-benefit assessments but are added benefits that can be monetised or quantified in relationship to their effects. Examples include how NBS can directly or indirectly impact health, energy security or ecocsystem rehabilitation as a result of direct impacts to improve microclimate or increased biodiversity rates. These multi-functional advantages are diverse, validating how NBS provide the same functional requirements that hidden infrastructure (e.g. pipes) provide while summarily enhancing the experiential quality of spaces, especially when these elements are visible or tangible (Iwaszuk, Rudik, Duin, Mederake, Davis, Naumann and Wagner, 2019). While there are fine distinctions between the two terms BGI and NBS, for this paper, the term 'Blue-green infrastructure' will be used interchangeably with 'Nature-based solutions' as they both derive from ecosystem service principles. 'BGI integrates hydrological and biological water treatment trains into systems [that] …strengthen urban ecosystems by evoking natural processes in man-made environments and combine the demands of sustainable water and stormwater management with the demands of urban planning and urban life…[BGI] have positive impacts of the urban metabolism of natural resources (added green values) and on the experience and behaviour of people using these infrastructures (added social values).' (Ramboll Foundation, 2016). A comprehensive literature review of BGI was provided by Ghofrani, Sposito and Faggian (2017). BGI tends to be used in literature synonymously with terms such as sustainable urban drainage SUDS, low impact development LID or water sensitive urban design WSUD, terms can potentially vary dependent on country-specific terminology (See Fletcher, 2015).

3 FOUNDATIONAL RESEARCH PROJECTS

As aging city infrastructure fails and extreme weather events increase in intensity and frequency, it is critical that future planning not only plan climate resilient and adaptive but even more so with a climate first approach. This would additionally require integrating such nature-based solutions together with man-made technology (e.g. grey piped solutions), and this from the very beginning of the integrated process. Testing the technical feasibility and economic resiliency of the full range of planning solutions is critical especially at the pre-planning feasibility stage when decisions matter most, as Forziere et al (2018) predict that climate change has the potential to increase damage to infrastructure caused by extreme weather events ten-fold by the end of the 21st century.

Although several notable research projects related to NBS have been conducted, widespread application of NBS tools is still limited, especially in view of the lack of changes in governmental regulations or construction standards (OECD, 2020). The United Nationa's Sustainable Development Goal 11 supports this assertion – Make cities and human settlements inclusive, safe, resilient and sustainable – and points to the necessity of an integrated, non silo-based process for multi-stakeholder involvement in urban planning.

The following section discuss three key events undertaken by Ramboll / Ramboll Studio Dreiseitl in the exploration of methods to utilise decision-support tools in practice, and are ultimately precursors to the development of the GreenScenario platform.

(1) The Copenhagen Cloudburst Masterplan and subsequent pilot project implementation: this masterplan serves as the official strategic planning element for local area plans in Denmark. It was initiated as a result of large-scale flooding in the Danish capital in the summer of 2011 that caused over USD $ 1 billion damage (GDV, 2019), and was a primary initiator in combined large-scale / small-scale approaches to climate adaptation strategies in view of climate change effects on cities.

(2) The BMBF (German Federal Ministry of Education and Research) funded 'KURAS' project (Konzepte für urbane Regenwasserbewirtschaftung und Abwassersysteme / Innovative concepts for urban stormwater management and sustainable wastewater systems): conducted from 2013-2016.

(3) The subsequent follow-up BMBF funded 'netWORKS4' project (Resilient Networks: Beiträge von städtischen Versorgungssystemen zur Klimagerechtigkeit / linking blue-green-grey infrastructure and their multi-functional benefit for citywide infrastructural systems, climate adaptation, and climate justice): conducted from 2016-2019.

3.1.1 <u>Key results Copenhagen Cloudburst Masterplan (See Leonardsen, 2013; Read, Nyerup Nielsen and Leonardsen, 2013; Ramboll, 2019)</u>

- Establishment of methodological process for managing issues with stormwater, flooding and cloudburst events for an entire city in response to design, engineering and economic principles.
- Integration of risk modelling and design iteration beyond municipal boundaries and borders.
- Inclusion of economic cost-benefit cost-of-doing-nothing assessments early in the planning process.
- Inclusion of 'co-benefits' to understand the full range of opportunities and potentials from BGI.
- Creation of a 'Toolbox' of suitable BGI elements flexible for use on multiple sites (e.g green roofs, green facades, changing street profiles, integrating with existing infrastructure and pipes, etc.)
- Acknowledgment of the important role played by stakeholders in the co-creation process.
- Current status: identification of approximately 300 pilot projects across the whole city to be implemented over a period of 30 years, with early projects including Sankt Anna Plads renovated in 2018 and Kokkedal Urban Renovation completed in 2019. These project aim at decoupling 30-40% of stormwater from the mixed sewer system in order to balance the expected increase of up to 40% more extreme rainfall over the next century.

3.1.2 <u>Key results KURAS research project (See Matzinger et al, 2014; Bundesministerium für Bildung und Forschung, 2014; Madichati, Möller and Otterpohl, 2019)</u>

- Through the involvement of academia, industry and municipalities the KURAS project pooled the multifaceted expertise of wastewater system and stormwater management technology and expertise to develop a standardised planning methodology applicable for integrated stormwater management (e.g. green roofs, swales, etc.) in urban arears.
- Results showed that a targeted combination of measures across various levels of interventions (from smaller building and plot scales moving up to the district, neighbourhood and up to the urban catchment area) have a positive effect on both the environmental quality as well as the less tangible yet equally important social quality enhancement for residents and visitors.

- Effects were made quantifiable via modelling, simulation as well as qualitative observation; the results have become a part of Berlin-specific planning with stormwater and water resources.

3.1.3 Key results netWORKS4 as they relate to establishing basis for the decision-support tool (See DIFU and ISOE websites (Networks 4, 2019); Roualt et al, 2019; Winker et al, 2019).

- Creation of communication material for expanding awareness related to the topic of BGI in the format of 'Info-Cards'. These info-cards are physical instruments that have been tested n real-life case studies with cities to develop concensus-based development plans.
- These practice-based tests allowed for a refinement of the planning process that was first established during the KURAS project. The 3-phase systematic planning process was revised to include Phase 1 (data collection, analysis, setting of project goals); Phase 2 (selection of suitable tools, testing and development of options); and Phase 3 (optimisation and refinement of solutions).
- Communication with stakeholders both internal and external was a key result of this research project. The two project sites, Berlin and Norderstedt, had stakeholders with varying levels of awareness of BGI as well as diverse interests. By testing the viability of the revised planning methodology on the real-life projects, the feedback and input of stakeholders could be utilised in the design process.
- netWORKS4 PLUS is a follow-up research project initiated that will continue research on the topic of blue-green-grey infrastructure, and will be supplemented by Horizon2020 RECONECT.

4 ESTABLISHING THE COLLABORATION PLATFORM GREENSCENARIO

4.1 Key research questions as basis for exploration

Various research questions regarding the barriers and enablers for planning with NBS and BGI tools began formulating in 2017 following the end of the KURAS research project and the start of the netWORKS4 project. In 2018, through trial-and-error testing in Berlin and Norderstedt as the two pilot project sites for netWORKS4, three concrete research questions were formed which have served as the basis for exploring and testing methods best suited when planning with digital decision-support tools and platforms.

(1) Why are elements for planning climate adaptive often adapted less frequently and implemented as exceptions rather than standards?

(2) What practical methods, material and information or data is necessary in order to properly communicate and convey the complex requirements of climate adaptive planning?

(3) How can we enable informed decisions to be made early in the overall planning process and thereby reduce risks when investing in blue-green infrastructure or nature-based solutions?

Armed with these three questions, we entered long-term experiment that combined practice and theory that focused on how to support climate adaptive planning and design by utilising innovations in digital decision-support tools. The three steps are listed below and further explored in the following section.

Step 1: refine the planning methodology necessary by testing in practice

Step 2: ideate, explore and develop

Step 3: build, test and implement in the field

4.2 Step 1: refine the planning methodology necessary by testing in practice

The commencement of Step 1 can be concretely attributed with the process and results of the Copenhagen strategy enacted in 2011, which then systematically progressed with the start of R&D projects in 2013. In step 1, multiple tests for refining the planning methodology were conducted on actual projects with local stakeholders, moving beyond theoretical boundaries. Step 1 draws on the results of four selected municipality planning processes and include the cities of Mannheim, Neu-Ulm and Berlin (shown here twice). By refining the planning methodology, an understanding was developed for which key steps would be required. Additionally, the technical tools of climate adaptation could be examined and refined in terms of requirements and specifications. Combined with the observations, experiences and direct feedback from stakeholders as well as the results of several projects started or implemented since the Copenhagen strategy in 2011, the basis was formed from which the research questions began to develop in 2017 (see above).

Test City and Result	Timeframe and Notes
Mannheim: for the creation of an integrated water management strategy for city of Mannheim (Spinelli Baracks Development, as part of the BUGA 2023 program), a hybrid KURAS/netWORKS planning method was adapted for local stakeholders and utilised in both a larger and smaller setting. Firstly, a large stakeholder workshop for goal setting, tool selection and development of concepts suitable for the local site conditions was conducted. Subsequently, a series of monthly roundtable sessions were conducted over a period of approximately one year to ensure that the decisions undertaken in the initial workshop would be implemented in future stages. Stakeholders included city officials (planning, construction, streets, open space/green areas); utilities (water); investors (private); climate change and environment department.	Fall/Winter 2018-Fall/Winter 2019: Project planning has since been accepted and is moving into the planning permitting stages
Berlin 1: as part of a development for a new sustainable development near the Berlin-Tegel Airport (Schumacher Quartier) a sustainable stormwater management strategy was created utilising a hybrid planning method informed by both the KURAS and the netWORKS method. Stakeholders included city officials (planning, construction, streets, open space/green areas); utilities (water); investors (private); environment department.	Fall 2018-Fall 2019 Project planning has since been accepted and is moving into the next level of detailed planning
Neu-Ulm: for the creation of a sustainable stormwater management strategy for a residential mixed-use district in the German state of Bayern (Iller Park), the KURAS method and the netWORKS enhancements were used and adapted for local stakeholders. Stakeholders included city officials (planning, construction, streets, open space/green areas); utilities (water); environmental department.	Fall/Winter 2017-Fall/Winter 2018 Project planning is entering the construction documentation phase
Berlin 2: as part of the netWORKS4 research project, 6 case studies were selected in the city district of 'Pankow' within the approximately 80 hectare development area of Michelangelostraße / Greifswalderstraße. Three separate workshop were held utilising the netWORKS method as an extension of the previous KURAS method. Stakeholders included city officials (planning, construction, streets, open space/green areas); utilities (water); investors (private); environmental department; and specific to these projects, impacted end-users including school teachers, local municipal and distict level officials, and building operation administrators / facility management ('Hausmeister').	Early 2017-End 2019 Project planning in the review period.

Tab. 1: summary of case study tests prior to start of dedicated development (Source: Ramboll Studio Dreiseitl)

4.3 Step 2: ideate, explore and develop

Following the accumulated results of the four listed projects and the establishment of three research questions, an internal incubator program for startups commenced within the architecture and engineering consultancy Ramboll. Successful teams progressed from an initial selection of 250 ideas to 5 selected teams. This led to the start of Step 2 (ideate, explore and develop), and was a phase characterised by exploration and discovery. Several mock-ups of the product were reated; large-scale interviews were conducted; and research questions were tested direct with potential users via surveys, interviews and product engagement. Following the Lean Startup method (Ries, 2011), the process was guided by Rainmaking (2019). A timeline of key events and their timeframe for the concentrated ideation and start-up period as part of conceptualisation of the idea are shown below.

Event Description (Phase 1, 2, 3)	Timeframe
Phase 1: Start of Conceptualisation Period within incubator program 'Innovation Accelerator' Phase 1 including interview, customer development, ideation and discovery lab (1 month)	February 2019
Phase 2: Transition from phase 1 to phase 2 on focused customer development including prototyping and piloting (4 months) with additional market testing and stakeholder feedback (3 months)	March-June 2019 / July-September 2019
Phase 3: Innovation Accelerator process ends, shifted focus to dedicated product development and market activities	October 2019-August 2020

Tab. 2: description of events in timeline of development (Source: Ramboll Studio Dreiseitl)

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Following the principles of the Lean Startup Methodology (See Rainmaking, 2019; Ries, 2011; Blank, 2006, 2013; Taney, 2017), which is characterised by a process of rigorous measurement and customer-focused development by testing multiple hypothesis through a triangle-based model entitled Build-Measure-Learn (BML), for Step 2, we focused on taking the lessons learned from the multiple project tests in practice and working directly with the potential target group (municipalities as well as developers with development projects) to understand the needs, requirements and limitations. Within Step 2, we conducted a wide-scale case study interview process to understand the requirements of stakeholders involved in the development planning process when integrating climate resiliency and adaptation. When asking approximately 35 people in over 18 different cities over a two-week period, three common trends were identified as barriers to implementation including: 1) limitations in acceptance are a result of a lack of quantitative justification of the pros/cons, leaving decision-makers skeptical, uninformed or unaware of the tools available at their disposal ('nature-based solutions are not new but I need an argument that is clear and based on facts'; 2) are burdened by limited resources in personnel and finances ('the planning process today takes too long already'); and 3) cannot translate the complexity of solutions into viable options for development ('I need to address a wide range of stakeholders with varying and oft competing interests').

Following the first stage of interviews conducted in Step 2, we developed a concrete idea based on the results of the discussions, and determined an early thematic focus on simplifying planning methods to manage extreme rain events or cloudbursts. A second round of interviews, focused on selected pilot cities (Norderstedt, Mannheim, Düsseldorf) led our team to pivot our thematic focus to a more specific yert broader focus on not just extreme flooding but the wider impacts of climate change on urban developments. Through a series of workshops with these selected pilot cities including 1-to-1 interviews and telephone calls, stakeholders engaged with us to co-develop and critique a variety of early prototypes for the eventual decision-support tool.

The results of the workshops led the identification of three key points: climate adaptation was the correct thematic focus; local requirements and site-specific simulations would be necessary so that the results matched specific conditions; and that the process of development would be a determining factor as much as any digital tool creation.

4.4 Step 3: foundation and continued development

In August 2020, final development of the market-ready version of the decision-support tool was reached and GreenScenario was officially released. This follow an approximate 11 month development track and a previous 9 month startup period. As of September 2020, several projects have either been completed or are in progress utilising the GreenScenario method.

Based on the results of Steps 1 and 2, GreenScenario a rapid iteration design tool and software-based solution for simplifying climate adaptation planning. Through a hybrid form of tech-enabled consultancy that combines people with a data-driven process, GreenScenario supports planning decisions taken by municipalities, property developers and designers responsible for planning residential, commercial or mixed-use development project. By using a data-driven software engine based on a combination of Rhino+Grasshopper programming code, GreenScenario evaluates the effects of all potential planning scenarios early in the design process and identifies exactly which tools are most suitable for the given development as well as most cost-effective for enabling a climate adapted design.

Suitable for early stage concept design, feasibility studies and master planning potential options, GreenScenario utilises a data set based on recognised standards (e.g. DIN, DWA, EPA, etc.) and norms as well as site-specific climatic data to run rapid simulations. The data sets are flexible, able to adapt to locally applicable standards while being evaluated based on a rigorous and standardised set of key performance indicators and metrics. This ensures a consistent evaluation framework that can be applied across borders yet remains robust enough to adapt to local requirements and variables, especially in relation to climatic data.

Lastly, based on a cross-section of climate adaptation topics – including water, heat and microclimate and open space quality combined with green areas, – are holistically and simultaneously examined, and evaluated based on quantitative metrics. The results are paired together with economics, thus providing a framework for validating and comparing the costs and benefits of multiple solutions. The results are visualised quickly and placed on a dashboard. By working together, changes can be made and the effects visualised; rather than working in a blackbox, GreenScenario allows stakeholders to understand the impact of decision based on evidence, facts and data – and not assumptions.

5 ENABLERS AND BARRIERS

The complexity of the topics aforementioned – climate adaptation as it relates to urban planning; process-driven methodologies; software-based solutions, data-driven platforms; nature-based solutions and blue-green infrastructure – places a challenge on not only the technical feasibility of developing a decision-support tool but also on the continuous evolution of the body of knowledge. In combination with the impact of technological innovation both positive and negative, urban planning and design necessitates an approach in response to what Dorst et al terms as 'open, complex, dynamic, and networked problems [that] just do not gel well with the assumptions behind our conventional problem-solving methods' (2016: 12).

5.1 Literature Review related to Enablers and Barriers

Casual online searches today reveal a variety of digitally-supported solutions related to climate change, adaptation or mitigation. Decision-support tools as they relate to climate adaptation projects were researched extensively (See Palutikof, Street and Gardiner, 2018). In the development of the Australian decision-support tool CoastAdapt, Palutikof et al (2018) identified both inherent barriers in the actual use of the tool but also institutional and cultural barriers that could limit or potentially inhibit the acceptance and utilisation of the tool in practice. Often, the barriers were found to be beyond the scope of the decision-support tool itself.

Computational design techniques as they relate to decision-support systems or platforms, while practical at building and plot scales, are particularly challenging to apply at the urban scale due to increased computational expense, difficulty in limiting inputs, and more stakeholders involved in the process (Wilson et al, 2019). This suggests that the effectivity of a data-driven support tool must also remain in a relatively continuous state of development to be useful, pragmatic and relevant.

When considering how digitalisation will impact society in the not-so-distant future, critics warn of the blanket acceptance of technology as a cure-all for managing and curing the problems previously mentioned with cities (See Hollands, 2008; Greenfield, 2013; Graham and Marvin, 2001). The question must be asked not only as to how to utilise the benefits of digital technology but, perhaps most importantly, why such solutions are necessary, who they are impacting and what unintended effect may result, or per Stimmel: 'improved liability is the focus, not how and where the technology is installed' or utilised to enable decision/making (2016: 37). When considering the growing complexity of cities, from not only their physical planning but their administration, management and regulation, and, as digitalisation continues to impact contemporary society, issues and conflicts with governance processes, accountability and compliance, privacy and public citizen inclusion will only continue to rise.

5.2 Relationship to Posed Research Questions

When analysing the initial implementation results of the methodology that led to the creation of GreenScenario, we find causal links for the three initially listed three research questions.

For question 1 ('Why are elements for planning climate adaptive often adapted less frequently and implemented as exceptions rather than standards?') we approached cities, developers and a wide variety of stakeholders to understand their concerns. We saw that from the approximately 35 people contacted across 18 different organisations or cities over a concentrated two-week period, key responses were that it was due to complexity and the extended length of the planning process today (80% of respondents); the lack of evidence to present arguments that there are clear benefits when planning with 'new' tools such as NBS (65%); and lastly the missing link between tools and (socio)economic considerations in an easy-to-understand matter (45%) continued to be major barriers. While the desire to plan towards what can be termed a liveable city philosophy was confirmed through the interviews (90% of respondents), further issues with permitting and regulations as well as finding funding sources for NBS were the next implementation barriers.

For question 2 ('What practical methods, material and information (data) is necessary in order to properly communicate and convey the complex requirements of climate adaptive planning?') and question 3 ('How can we enable informed decisions to be made early in the overall planning process and thereby reduce risks when investing in blue-green infrastructure or nature-based solutions?'), we could find causal links between between the success of the projects conducted under the netWORKS4 project in Berlin and Norderstedt correlating with the use of a standardised planning methodology, as asserted by Matzinger et al (2014). Physical and visual tools such as the 'info-cards' combined with an integrated stakeholder workshop enabled buy-in early in the process. Continuous discussions and roundtable meetings were necessary to understand project goals, extenuating circumstances and location-specific conditions. With the clear presentation of the results and planning efforts conducted as part of the process, namely how stakeholder feedback informed the decision-making and design process, coupled with visualisations of what benefits planning scenarios would offer in the future (Madichati, Möller, Otterpohl, 2019), there is a strong indication that process was of equal importance to product. By focusing on the communication aspect – collaboration in creating ideas, input when optimising solutions, relating the results to both overarching city objectives as well as localised requirements – as much as the technical requirements, an effective strategy could be tested and validated within the context of a living lab.

5.3 Observations from Initial Implementation in Practice

Yet the three research questions posed have only begun to be answered by the use of the tool in practice. GreenScenario as a method to support smart, data-driven design decision-making is but a first step in utilising innovation in digital technology to transfer expert knowledge (planning, climate adaptation, stakeholder communication) into an open collaboration platform (software). Continued research is necessary.

Initial barriers observed in practice during pilot implementation and further validated by the research conducted by Palutikof et al (2018) include initial apprehension in new, untested methodologies; data-source and quality of data being entered into the system; trust and acceptance; and also financial considerations, especially in consideration the effect COVID-19 has and will have on resources and budgets.

Yet these barriers tend to be more an issue in the initial short-term start up period. One of the more positive consequences as a result of COVID-19 has been the recognition of new working patterns, and has thus been an enabler. Especially for stakeholder groups and workshops, digital tools and a collaboration platform such as that enabled by GreenScenario provide a method to rapidly develop solutions and communicate results, effects.

Can data-driven tools provide a new method of approaching planning climate first with tools such as nature-based solutions or blue-green infrastructure aligned with conventional infrasturcutre to improve our cities today? Research in not only the technical aspects will continue be critical but also in the acceptance, adoption and governance methods for encouraging, co-funding and financing as well as embedding climate-first practices within the planning and urban design field.

We even see that there is widespread potential beyond just a 'collaboration platform'. A recent research effort termed 'Sandworm' (See Hermansdorfer, Skov-Petersen, Fricker, Borg, Belesky, 2020) saw the use of tangible tables (hands-on use of digital sandbox tools or 'augmented reality sandbox') utilising open source software based on a Rhino-Grasshopper set-up. Tested with students, the session utilised real-time visualisation in an interactive workshop format. 'The PhD workshop demonstrated how…'physical' participation [with] the table…can be adapted to different design challenges with relative ease' (Hermansdorfer et al, 2020: 10).

6 CONCLUSION AND EXTENDING RESEARCH THEMES

The complexity of the topics aforementioned – climate adaptation as it relates to urban planning; process-driven methodologies; software-based solutions, data-driven platforms; nature-based solutions and blue-green infrastructure – places a challenge on not only the technical feasibility of developing a decision-support tool but also on thGreenScenario is its early implementation phases. Even with the multi-year research and development periods that preceeded the creation and current application in practice, there are several aspects that will require testing to confirm or disprove enablers and barriers to acceptance, use and implementation. Over the past year, the political situation in Europe as well as globally focused more and more on issues related to climate change. Corona and COVID-19 has led to reexamining values of urban design that were commonly held as standard or given. Listed below are topics that will need to be further considered in future research to determine the viability of GreenScenario being able to positively impact urban planning, encourage collaboration and respond to market requirements.

While GreenScenario is still in its pilot implementation phase, we see data-driven decision-making combined with integrated planning processes key to enabling the acceptance of climate adaptation approaches for the future development of our cities and places.

- More seamless integration within practice and especially as part of the public participation process
- Integration with established sustainability systems such as the German DGNB (German Sustainable Building Council) or LEED from the US Green Building Council, amongst others
- Integration with existing processes in urban planning for Building Information Modelling (BIM)
- Further data review of methodologies and processes, as well as continual management of the database
- Consideration of the creation of a machine-learning databank would utilise further advances in digitalisation with access to a wider array of open source material
- Determining a network of cooperations and partnerships for knowledge sharing and awareness
- Critical consideration of data privacy laws such as GDPR
- Acceptance and awareness for both the application possibilities digital decision-support tools offer in practice combined with governance models for adopting a standardised approach that is locally tailored to site, country or cultural-specific requirements

Fig. 1: GreenScenario's two components: combining process and methodology with software (Source: Ramboll Studio Dreiseitl)

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