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Why climate change adaptation in cities needs customised and flexible climate services

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ABSTRACT

Cities are key players in climate change adaptation and mitigation due to a spatial concentration of assets, people and economic activities. They are thus contributing to and especially vulnerable to climate change. Identifying, planning, implementing and monitoring respective measures in cities is challenging and resource consuming. The paper outlines challenges for adaptation, discusses most common approaches and argues why implementation of theoretical methods has its shortcomings. Based on case studies, an innovative, practice-oriented approach has been tested to develop a climate service prototype product. It provides a general framework that allows a flexible and customised support for cities to adapt to expected impacts of a changing climate.

Practical implications

Urban areas are key players with respect to climate change. They are not only contributing to climate change, they will also be affected by expected climate change impacts such as urban and river floods after heavy rain events or heat stress, which will most likely occur more frequently and with increasing intensity in the future (Jacob et al., 2014; Revi et al., 2014; Collins et al. 2013). This is why cities need to adapt to the expected changes on time to protect inhabitants, assets, and elements of critical infrastructures. Given this background several questions immediately arise from the point of view of the city: how can we respond to climate change impacts or what information is needed to choose right and reasonable strategies and measures? Further questions arise from the point of view of climate services: How can we best support cities with respect to their individual needs? These are crucial questions especially when considering, that the focus has only been on climate change mitigation for a long time.

A common approach to support adaptation in urban areas is the provision of best-practices measures, for instance via web-portals such as the Austrian Database on Climate Change Adaptation,[1] the German *KomPass-Tatenbank*[2] with best-practice examples of adaptation measures or the Climate-Adapt web portal[3] of the European Environment Agency. This approach however has its shortcomings. It might be suitable as a first step to see what has been done elsewhere but solutions that worked in one city do not necessarily work in another. There are no one-size-fits-all-solutions because cities are complex networks with very specific framework conditions in many aspects such as location, urban climate, population density, financial and human resources, and stakeholder interests. To transfer a measure or strategy that was specifically designed for a given framework to another city, much meta-information is needed. However, they are rarely provided on web-portals. Moreover, adaptation measures that result from research projects often receive funding for the development, which other cities may not have. Thus, developed measures are only rarely implemented due to limited project durations. Since limited financial resources are a major topic for many cities, a lack of funding opportunities may prevent the next city from taking action.

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[1] http://www.klimawandelanpassung.at/ms/klimawandelanpassung/de/kwadatenbank/.
[2] http://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/tatenbank.
[3] http://climate-adapt.eea.europa.eu/.

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2405-8807/

Based on experiences gained from several case studies conducted in different cities in Germany, stakeholder consultation processes, interviews, literature analyses and survey evaluations it became clear that a tool is needed that addresses the whole range of actions needed for climate change adaptation. This tool needs to be flexible enough to ensure applicability in all cities, independent of their specific settings. This work refines the basic idea of an innovative tool to support cities in their adaptation process and presents an innovative climate service prototype – the *Stadtbaukasten* (adaptation toolkit for cities). It currently contains eleven module groups covering the most important fields that are relevant for planning, developing and implementing adaptation strategies or measures. While some of these module groups have been tested successfully and are ready for application, others are still under development. This development has been done in close cooperation with the cities to ensure that their needs are met.

The *Stadtbaukasten* contains some basic modules such as ''communication", which is needed to raise awareness to local problems and involve all relevant stakeholders such as representatives from different local authorities or from the private sector. It also includes more content-related modules such as the provision of local climate information that are inevitable for further adaptation actions focused on climate impacts. Officials or employees of cities can choose single modules from the *Stadtbaukasten*-portfolio or a combination according to their specific needs. The structure also allows for each of the modules, to be excluded if no longer needed. There is also the possibility to co-develop customized, new modules if required. The entire module-framework or only selected parts can also be integrated in existing decision-making process chains to reduce additional administrative efforts and thus facilitate adaptation action. This is of utmost importance since in many cases adaptation activities compete with activities in other sectors such as educational and cultural services. In conclusion, the climate service prototype enables successful adaptation by supporting the development of customised solutions according to the local situation on a case-by-case basis.

1. Introduction

Urban areas are key players when it comes to climate change. Currently, a little more than half of the world's population lives in urban areas with an expected increase of this share to approximately two thirds by 2050. This trend can also be observed in Germany with a projected increase in urban population from roughly 75% in 2014 to 83% in 2050 (United Nations, 2015). In addition, a major part of societies' assets and economic activities is placed in cities. This makes cities a contributor to climate change and, at the same time, particularly vulnerable to its impacts. To reduce both CO_2 emissions as an accelerator of climate change and the resulting vulnerability, mitigation and adaptation need to be addressed simultaneously. Even with a substantial reduction of emission rates, the stock of GHGs will continue to rise (Victor et al., 2014). Therefore, one of the main fields of work for city administrations in the future is the implementation of adaptation measures. It has to be highlighted that at the same time, climate change can also open up opportunities for cities (Groth et al., 2015; Ricardo-AEA, 2013; CDP, 2012). According to Moser and Ekstrom (2010), adaptation involves changes in social-ecological systems in response to actual and expected impacts of climate change in combination with non-climatic drivers such as demographic change or economic development.

Adaptation strategies can range from short-term to longer-term activities, which aim to meet more than climate change goals alone and may or may not succeed in moderating harm or exploiting beneficial opportunities. Furthermore, it is important to clearly define and distinguish between the terms adaptation, resilience and vulnerability, as they are strongly related. In its 5th assessment report the IPCC (IPCC, 2014) defines adaptation as ''the process of adjustment to actual or expected climate and its effects", vulnerability as the ''propensity or predisposition to be adversely affected", whereas resilience is the ''capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation". Therefore, a resilient system is less vulnerable than a non-resilient system, but this relation does not necessarily imply symmetry, and hence vulnerability is not the opposite of resilience (Gallopín, 2006).

Due to climatic and non-climatic drivers, numerous interactions between different sectors, and a high number of involved stakeholders with different interests, an integrated and holistic approach is needed to equivalently address the different mentioned dimensions. However, to date a large number of cities has neither developed comprehensive adaptation strategies, nor have they implemented respective adaptation measures in order to respond to expected climate change impacts. A large number of cities are still focusing on mitigation strategies only (e.g. Revi et al., 2014; Carter, 2011), and in other cases are starting to prioritize the development of an adaptation strategy once they have been affected by an extreme weather event. However, local councils are key actors when it comes to the development, implementation and monitoring of adaptation strategies and respective measures. In doing so, they are embedded in a complex frame that is influenced by internal and external factors (Groth and Nuzum, 2016; Umweltbundesamt, 2015; Kalafatis et al., 2015; Ricardo-AEA, 2013). This includes, but is not limited to, legislation, different (and conflicting) interests of administrative units, missing or incomplete knowledge of climate change and its impacts, limited financial and human resources, geographical location, city structure, size and density, urban-rural relationships, inhabitants, cultural habits, operational capability and individual backgrounds as well as interests of involved stakeholders. All this is equally important and needs to be taken into account (Bender et al., 2014, 2015; Cortekar et al., 2015; Dilling et al., 2015; Terenzi and Westerlind Wigström, 2014; Ricardo-AEA, 2013).

Finally, the needs of cities to adapt differ according to already established actions, different exposure, and vulnerabilities to climate change impacts. All this taken together raises the question how cities could best be supported in their efforts to adapt to climate change. The initial idea to develop a flexible and customizable consulting service is based on previous works particularly from the *KLIMZUG*-network (Biebeler et al., 2014) and an assessment of needs within the sectors agriculture and water management (Bender et al., 2012). Both activities indicated that needs and requirements of users vary broadly even within specific stakeholder groups. Therefore, novel approaches are needed to support cities in adapting to expected local and regional changes of climatic conditions and related impacts on an individual basis. The so far most common approaches were in many cases considered too rigid. This paper presents and discusses the results and conclusions of a long process starting with the simple idea to meet the needs of cities more properly, i.e. to provide a flexible framework that allows cities to choose exactly those parts relevant for their specific needs, and ending with the presentation of a climate service prototype. The whole prototyping process was focused on

German cities and thus, most activities described in the following chapters took place in Germany and are building up on findings generated in German projects and initiatives.

The whole process of development includes several different activities and methods. Each of them adds bits and pieces to sharpening the overall picture of the flaws in the current approach and leads to the recognized demand of a new, innovative and more customised framework. The paper is structured as follows. The different methods are based on several activities conducted by the Climate Services Center Germany during the past three years: i) case studies, ii) interviews, iii) literature analyses and stakeholder processes, as well as iv) an evaluation of cities responses to the CDP (formerly known as the Carbon Disclosure Project) Cities Program, a voluntary climate change reporting initiative for city governments. First of all, these methods will be described. Secondly, the respective results from the different approaches are presented. Based on these results the need for customised and flexible climate services in order to help cities adapt to climate change will be discussed. Furthermore, ideas for the conceptual development of a new, refined climate service prototype approach are highlighted. Finally the paper concludes with practical recommendations for future urban climate change adaptation.

2. Material and methods

Until now, adaptation processes in cities mostly start by retrieving information from one of the numerous adaptation databases in which many adaptation activities that were developed in scientific projects can be found (Groth and Nuzum, 2016). Some of the most relevant databases and supporting tools in Germany are for example i) the *Stadtklimalotse*[4] (city climate guide), ii) the *Klimalotse*[5] (climate guide) by the German Environment Agency, and iii) the QuickCheck[6] developed within the research project nordwest2050. On the European level there are among others i) the Adaptation Wizard[7] from UKCIP, ii) the BalticClimate toolkit[8] as well as iii) the Adaptation Support Tool[9] as part of the European Climate Adaptation Platform (Climate-ADAPT). These tools and databases either provide general concepts and advices or best-practice solutions. These platforms aim at providing basic information about adaptation measures in order to support transferability to other cities. However, this approach has its shortcomings due to a suboptimal connection between the practical, policy-related and scientific development of climate change adaptation (Sanderson et al., 2016). This, consequently, does often not lead to the desired outcome of successful implementation of adaptation measures that are suitable for the local situation and effective in their impact (Groth and Nuzum, 2016; Umweltbundesamt, 2015; Ricardo-AEA, 2013).

Our approach to develop the prototype climate service *Stadtbaukasten* is based on different methods including literature analyses, interviews, case studies and workshops that were combined to gain insights into processes and structures of cities and barriers that come up in practice.

2.1. Case studies

The initial idea of developing a new climate service prototype at GERICS that supports cities in their adaptation process arose by combination of knowledge gained at different workshops with stakeholders and the available in-house expertise in the fields of spatial planning, water management and climate sciences. The conglomerate of expressed needs from different sectors and the typical questions from cities in practice formed the idea to link local climate information with other information. This idea was supported by the results created in the large *KLIMZUG*-network (e.g. *KLIMZUG-Nord* (Bolle and Krebs, 2015), *dynaklim* (Hasse et al., 2014) and *REGKLAM* (Olfert et al., 2014) that was funded by the German Federal Ministry of Education and Research. GERICS was engaged in *KLIMZUG* on a cross-project level to gain insights from all projects of the network.

Based on these previous activities a basic set-up consisting of nine module groups was developed at GERICS in 2013. These can be connected, but can also stand on its own (the number of module groups was later extended to eleven). The concrete content of the module groups was pre-structured by GERICS but is by no means set in stone. Some of the modules have been tested in case studies in close cooperation with German cities of different geographical locations, sizes and densities. While some cities were only interested in the application of one module, others agreed to participate in testing several different ones. The modules focus for instance on the development of adaptation strategies, provision of local climate information, conduction of vulnerability analyses, climate-proof urban planning, implementation of climate-proof compensation areas, or water-related questions.

Case studies were chosen as a methodological core element of developing the structure and content of each of the module groups. The advantage of case studies is the depth with which a topic can be tackled (e.g. Stake, 1995). For sure, several case studies on the same topic need to be conducted, as one issue related to case studies is their limited breadth (Flyvbjerg, 2006). They allow to include local knowledge and to jointly find practical solutions to real world problems.

In order to achieve this, every single case study includes initial stakeholder consultations, e.g. workshops or individual meetings to identify the specific needs and expectations. Moreover, intensive communication with city representatives (e.g. head officials from the local Environmental Protection Agency and Environmental Agency, contact persons from local water suppliers and sewage companies, Local Park Agency, Health Agency and many more) took place during the whole development processes.

All case studies and applications have been user-driven and science informed, so that joint learning and developing of solutions in a transdisciplinary way is central to all case studies. It is important to mention that the case studies were not embedded in a strictly scientific context such as research projects, in which external funding is usually available to develop and test certain applications and to reimburse partners efforts. However, since limited financial resources are a major barrier for many cities to take action in climate change adaptation (e.g. Weyrich, 2016) and in order to reflect actual decision-making contexts, the participants on the city level did not receive any financial reimbursement for their contribution in the discussed case studies. This aims at proofing, whether or not the procedures can also be applied in cases where only limited resources are available.

2.2. Interviews

To learn more about the framework in which adaptation to climate change is typically embedded and that could hamper to start the process or cause severe delays, an interview series was initiated in 2015. Barriers to climate change adaptation were analysed based on semi-structured interviews (e.g. Schnell et al., 2011; Flick, 2002) with city representatives (Weyrich, 2016). The study was compiled in nine cities in Germany that already had some experi-

[4] http://www.stadtklimalotse.net/english/.
[5] https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/werkzeuge-der-anpassung/klimalotse.
[6] http://www.nordwest2050.de/index_nw2050.php?obj=page&id=179.
[7] http://www.ukcip.org.uk/wizard/.
[8] http://toolkit.balticclimate.org/en/home.
[9] http://climate-adapt.eea.europa.eu/adaptation-support-tool.

ences in climate change adaptation as they participated in the national funded Program "*Stadtklima*". In order to cover different city characteristics, the cities were chosen according to their size, density, demographic profile, geographic location, urban structure, city type (e.g. state capital or belonging to a district), socio-economic conditions, and their respective vulnerabilities to climate change impacts. Interviews were conducted in December 2015 and January 2016. They were focused on the background of the participants and their work places, views on climate change and adaptation, the status of adaptation in the agency, and process descriptions as well as associated barriers. Thus, while also capturing more general information about participants (personal views, roles, positions, and experience), the interviews were centred on the different phases and stages within the adaptation process. The primary interest was to find out where the city is in the adaptation process, what challenges the participants had to face, and what they had done to overcome them.

2.3. Agenda process – literature analysis and workshop

Another approach to identify and learn about cities' needs for information and assistance regarding climate change adaptation is a focussed review of existing literature that had been carried out in 2015. To cover a broad spectrum of available information, the literature analysis included scientific papers as well as grey literature such as project reports, both in German and English. The core issues identified by Groth and Nuzum (2016) were as follows:

i. What kind of climate change related data and information as well as tools and other forms of support are needed in municipalities?
ii. How can these needs be categorized and prioritized?

Within the study the needs have been categorized into three different parts:

i. The decision-making chain of adaptation (divided into problem understanding and solution approach).
ii. The process organization within the community.
iii. The exchange of experience between municipalities.

The decision-making chain includes the various processes and decision steps of municipalities, like the understanding of the relevance of climate change impacts, possible solutions and the evaluation of the adaptation measures. The process organization comprises internal and external communication, access to (human and financial) resources as well as internal structures and decision-making processes of local authorities. The exchange of experience between local authorities consists of the categories models and trial municipalities as well as networking and interregional cooperation.

The literature analysis served as basis for a workshop entitled "Needs and Requirements on Climate Change Risks in Municipalities" which took place in October 2015 in Hamburg. Roughly 40 participants attended the workshop, most of whom were representing local administrations. The objective of the workshop was particularly to better understand the information needs of cities and municipalities regarding regional impacts of climate change. The workshop was organized as World Café (e.g. Brown and Isaacs, 2005).

2.4. Assessment of European cities' responses to the CDP Cities Program

An additional activity to learn about cities' risks, opportunities and adaptation actions that goes beyond experiences gained from case studies, the conducted agenda process, and interviews was an in depth analysis of cities' responses to the 2014 CDP Cities Information Request. The CDP Cities Program is the world's first global platform for municipal governments to disclose greenhouse gas emissions, climate change risks and adaptation strategies and delivers relevant data for cities, the private sector, and other stakeholders. It is open to any city government, regardless of size or geographic location, and currently used by over 200 cities across the globe. While city governments and public companies are vastly different in size, scope and structure, the annual disclosure cycle of CDP can offer an important impetus for cities to measure and report their climate change related information (CDP, 2014b). Groth et al. (2015) analysed the individual responses for each of the 40 European cities – ranging from metropolises like Moscow to small villages like Kadiovacik in Turkey – focusing on the modules "risks & adaptation" as well as "opportunities" within the CDP Cities Information Request. It has to be mentioned, however, that the participating cities are already familiar with climate-related issues.

3. Results

The results of each of the activities described above provide information on how cities are currently trying to adapt to climate change and how they can be best supported in their adaptation process in the future.

3.1. Case studies

The results generate in the several case studies can be distinguished between those on a meta-level and those on a content level. The results on the meta-level have continuously been mentioned in several case studies or result from the interaction between two or more case studies, which could not have been generated by one case study alone. The more content-related results are the outcome of an explicit case study.

Experiences gained from the case studies on a meta-level are equally important to those related to content of specific modules such as the development of an adaptation strategy. Since the most work done was not part of a financed scientific project, the results of the participatory work with cities reflect actual decision-making situations and current local questions. As discussions with city officials show, the main attraction of the co-development of specific applications was the answer to questions that address current issues of the administration. The participation solely for the purpose of creating scientific knowledge or serving as a guinea pig was not considered attractive (Bender et al., 2016). Overall the results show:

i. Applications have to address actual needs.
ii. Applications have to fit in existing decision-making processes and structures to diminish the extra efforts needed to pass the process.
iii. Needs articulated in the initial stakeholder consultations are sometimes fuzzy and might change during the adaptation process.
iv. Restricted human and financial resources are a limiting factor.
v. Even though initially all applications had a sector-focus, this focus is in many cases not sufficient to tackle actual adaptation issues.

The most important result from a content point of view, which confirmed the necessity of a modular set-up of the *Stadtbaukasten*, is that one-size-fits-all solutions do not exist in practice due to varying preconditions, city characteristics, and involved stakehold-

ers. One case study carried out aimed at the development of an adaptation strategy. Activities within this case study included the analysis of already existing strategy papers on the city level such as a sustainability strategy and, in addition, an analysis of 24 scientific projects in the Baltic Sea region with a main emphasis on adaptation measures. This assessment shows the bandwidth of open questions, varying interests, adaptation activities and barriers to adaptation (Meyer-Nehls, 2014). In most of the 24 assessed projects it was pointed out that for the evaluation of ecosystem services and adaptation measures as well as for the optimization of monitoring and early warning systems there is still a lack of practice-oriented and easy-to-use indicators that can easily be transferred to the context conditions in the given context. Attention was paid to the use of integrated and sustainable approaches. Since all projects ended before adaptation measures could be implemented, there is no answer to the question how to embed adaptation issues into urban planning. Due to the fact that similar results are typical for adaptation research projects, there is a high need to tackle this issue. This point was also mentioned in several discussion and talks between GERICS and stakeholders because practitioners are very interested in closing the gap between theory and practice. For the design of the measures, it should be kept in mind that climate change is a dynamic process ("moving target"). This requires flexible solutions that need to be harmonized with existing administrative processes and structures. For this purpose, it is useful to clarify the responsibilities.

Another case study revealed that typically two or more sectors are affected by one impact. Various solutions were proposed but without considering the links between sectors. In cities as complex systems cascading effects occur that need to be addressed appropriately. The example of the relations and interactions between the water and energy sector show, that disruptions in energy supply affects water supply in a broad sense (Groth et al., 2016). In the given example, the water supply is directly affected by an electric power failure because pumps and control elements do not work without electricity. This means a breakdown of the water supply. The missing water supply has an impact on many other public facilities such as economy, health care, and public transport. With respect to wastewater treatment, the missing water supply starts a second cascading step, because the malfunction of the sewerage has a further impact on other public facilities, too (see Fig. 1). Consequently, adaptation strategies have to focus on the whole system not only on single elements. In addition, the same case study showed that the expressed needs at beginning can change or expand when communicating with the local actors.

Furthermore, adaptation is competing against policy actions in completely different fields such as education, transportation or expanding or maintaining of infrastructure elements. It therefore needs convincing arguments to make a scientifically sound decision. One way to bring together competing demands is using no-regret or low-regret-options, which create benefits even if the expected impacts of climate change do not occur (Bender et al., 2016). These options, however, are not easy to identify in practice due to conflicting interests. The same applies to the theoretical approach to find measures that address two or more goals, e.g. multiple functions of urban green spaces for the reduction of the urban heat island effect, the temporary retention of rainwater in case of extreme precipitation events and the use as recreational areas. Discussions with practitioners show that in practice each addition of a further function causes new conflicts with new parties that have to be involved in the process.

3.2. Interviews

Many case studies and surveys conclude that barriers to adaptation exist, but they rarely address how barriers arise and where they appear in the adaptation process. Furthermore, only few studies have focused on the relative importance of barriers to adaptation and on how to overcome them (Biesbroek et al., 2011; Ekstrom and Moser, 2014; Eisenack et al., 2014). The interviews conducted by Weyrich (2016) were carried out to close this gap. The results clearly show that, even though it seems to be simple to plan, implement and monitor adaptation measures and strategies, many barriers impede this process. Typically, barriers can

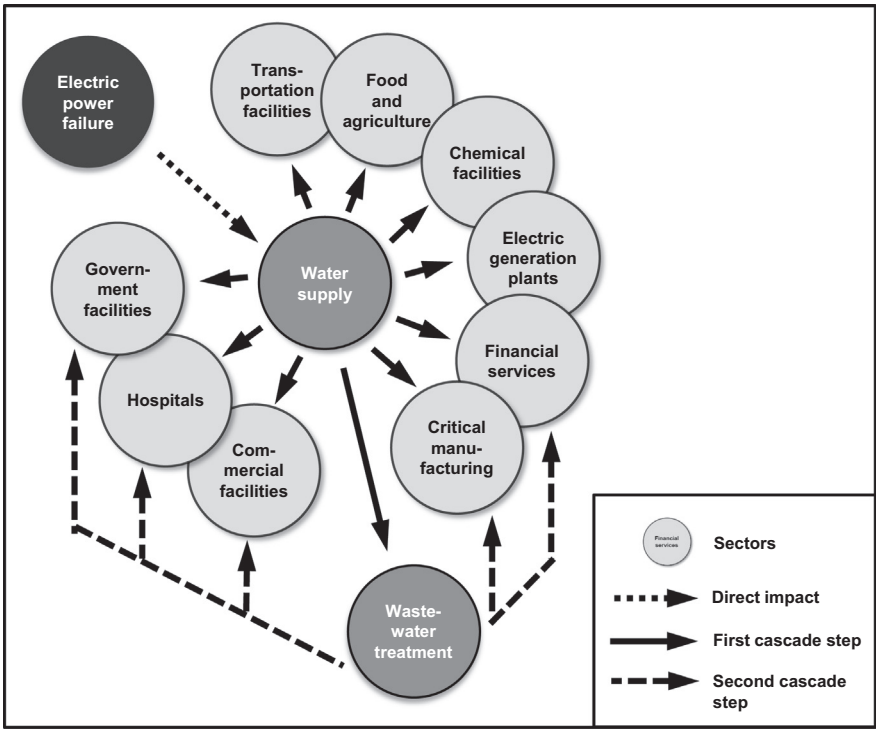

Fig. 1. Cascading effects using the example of the energy-water nexus.

be found throughout the entire adaptation process (Fig. 2), starting from the understanding of possible impacts caused by climate change (U1 to U3), to planning (P1 to P3), implementing and evaluating selected options (M1 to M3).

On average, most barriers occur in the understanding phase and are related to attitudes and awareness in U1 and the availability and accessibility of data and a lack of appropriate staff capacity on climate related issues (vulnerability assessments, expertise on climate change) in U2. In U3 a combination of both can be observed. A further problem that occurs is the inability to define the needs, which sometime change during the adaptation process. Different interests and unclear responsibilities and competences form another barrier. As adaptation options are currently not considered in many administrative processes, their implementation requires a modification of existing workflows and the allocation of responsibilities to reduce negative predispositions. Adaptation often causes additional workload, which is difficult to cover with financial and human resources being limited in many cases. In addition, it is difficult to implement projects today when the benefits accrue several years later, if at all, regardless of their economic advantageousness. And finally, local governments are often afraid to take actions that are not prescribed by law because they run the risk of being sued in civil court. As an example when publishing a risk map for heavy rain impacts, property owners can take legal actions due to the depreciation of property value. All of these barriers, though not necessarily exhaustive, impede the adaptation actions and need to be taken into account.

The two most important results of the interviews suggest that no blueprint or 'one-size-fits-all' solutions exist and that adaptation processed require a modification of existing workflows or the adaptation planning needs to be somehow integrated in existing workflows. The interviews further revealed that the institutions and people involved make the biggest difference, whether it is about constraining or enabling adaptation activities. On the one hand, institutions and governance structures shape, guide, enable or constrain on-going processes, and can thus help or hinder human actions. On the other hand, individual people are the primary agents of change and all efforts to climate change depend upon them. Cognitive filters interfere with human perceptions, influence attitudes about climate change adaptation and manipulate the decision-making process. Overall, adaptation is proceeding incrementally, often in response to already occurred climate change impacts, or as a logical extension of work on climate change mitigation. In order to be successful, adaptation has to be recognized as a crosscutting topic and strategies need to be integrated across sectors and within multiple governmental scales (Weyrich, 2016). These findings are well in line with the findings from the case studies, in particular those related to cascading effects. They impact different sectors and require an integrated, holistic approach understanding cities as a complex system. This argument can be well connected to a set of dominant strategies found by Moser and Ekstrom (2010). To overcome or circumvent barriers to adaptation, several strategies have been developed, of which the most important strategy involve identifying and prioritizing no-regrets measures, measures that have co-benefits and that are politically feasible. However, these measures are mostly not easy to identify. The results suggest that adaptation takes place in response to multiple stimuli and not just climate (Berrang-Ford et al., 2011; Carter, 2011).

3.3. Agenda process – literature analysis and workshop

The synthesis of results of the agenda process was carried out concomitantly to the workshop. The literature analysis revealed, and this finding was confirmed at the workshop, that communities have very diverse and city-specific needs for information and tools to plan and implement adaptation measures (e.g. Groth and Nuzum, 2016; Umweltbundesamt, 2015; Terenzi and Westerlind Wigström, 2014; Ricardo-AEA, 2013). The requirements include the need of specific climate data and information, but also go far beyond (Groth and Nuzum, 2016). Particularly important is the need for support regarding

i. The institutionalization of climate change adaptation within the administration, taking into account internal structures and processes.
ii. Region- and sector-specific information.
iii. The communication of climate change and adaptation with internal and external stakeholders.
iv. The evaluation of adaptation options.
v. Risk and vulnerability assessments.

Groth and Nuzum (2016) highlight that cities' needs for increasing their resilience to the impacts of climate change are highly context specific, not only due to its location, structure, inhabitants and operational capability. Equally important is the consideration of

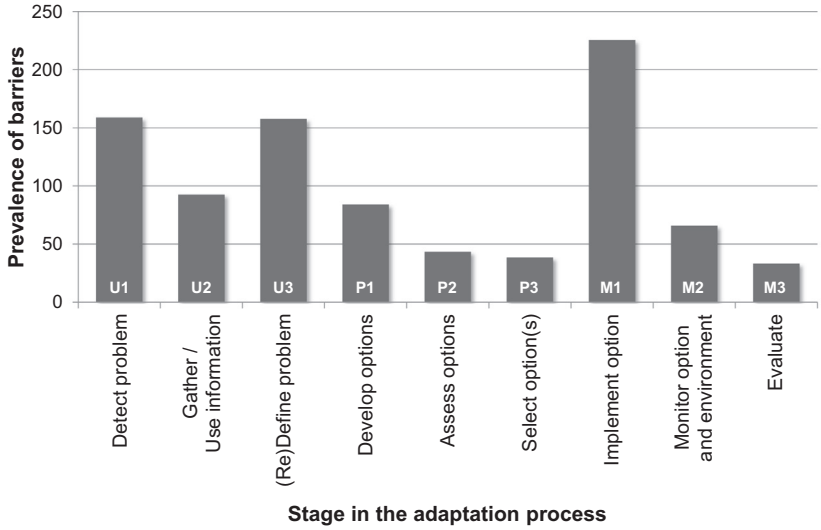

Fig. 2. Barriers occurring in different phases of the adaptation process based on interviews in nine German cities. The number of barriers is normalized by the total number of barriers per city in order to enable comparison (Weyrich, 2016).

the individual and oftentimes diverse backgrounds of the stakeholders involved in the process of adaptation.

3.4. Assessment of European cities' responses to the CDP Cities Program

The results outlined above are also in line with an in-depth analysis of cities' climate change related risks, opportunities and adaptation actions based on responses to the "2014 CDP Cities Information Request" (CDP, 2014a), carried out by Groth et al. (2015). 92.5% of the responding cities report that they face physical risks arising from climate change. According to the assessment of the participating cities, the top-five reported physical risks for cities are i) more intense rainfall (62.5%), ii) more frequent heat waves (37.5%), iii) more hot days (35%), iv) hotter summers (32.5%) as well as v) an increased urban heat island effect (32.5%). Moreover, more than half of the cities (55%) indicate that they are facing social risks due to climate change, whereby medium-sized cities (600,000–1.6 million inhabitants) feel especially affected (75% say that they are facing such risks). The most relevant social risk identified by the cities are i) an increased risk to already vulnerable populations (35%), ii) an increased incidence and prevalence of disease (25%), iii) an increased demand for public services, including health (22.5%) and iv) fluctuating socio-economic conditions (15%).

However, 72.5% of the cities also report that they see economic opportunities in climate change. It should be pointed out that almost all medium-sized cities (87.5%) anticipate economic opportunities, while in this case large cities (75%) and small cities (66%) seem to be slightly less optimistic. More than half of the reporting cities (57.5%) identify development of new business industries as the main economic opportunity arising from climate change. In the face of the risks arising from climate change, 55% of the observed European cities indicate that they have already implemented an adaptation action plan, with large cities being frontrunners in this area (75%). Additionally, 82.5% of all cities are already putting adaptation action into practice and most adaptation actions deal with i) more intense rainfalls (50%), ii) an increased urban heat island effect (27.5%), iii) hotter summers (25%) and iv) more hot days (25%). These areas overlap greatly with the top-five reported physical risk for cities. The particular adaptation actions which were indicated the most by participating cities were tree planting and/or creation of green space, followed by resilience and resistance measures for buildings and crisis management including warning and evacuation systems. Taking into account the variety of answers regarding risks, opportunities and adaptation actions based on subjective self-assessments by 40 European cities, the study concludes that there is a great need to take into account the specific cities' situation when it comes to adapting cities to climate change. A need that should also be addressed by the development of flexible climate services (Groth et al., 2015).

4. Discussion

The results presented above prepare the ground for innovative approaches supporting cities in adapting to expected impacts of climate change. Best practice examples and databases with case studies have been frequently used in the past to disseminate information; yet, they do not provide sufficient support. While examples do a good job in illustrating possible adaptation options and giving impulses for other cities, more detailed and specific information is necessary to transfer the same option to another location. Web portals and published case studies need to give appropriate meta-information on the approach, used methods, practical implementation, monitoring options of adaptation measures, and ideally information on possible risks related and how to deal with them. Additionally, it is necessary to document failures and bad-practices, because this information is particularly helpful to avoid these mistakes and barriers at other locations. Even in case all useful information from case studies was available, the above-described uniqueness of each city would complicate the reproduction of measures. Furthermore, in cases in which measures would be transferable from a technical viewpoint, the success of a measure or strategy is still connected to the qualification, knowledge, motivation and skills of staff. Thus, it is usually not possible to find a universal adaptation strategy or measure, as the local framing is too specific and needs to be analysed

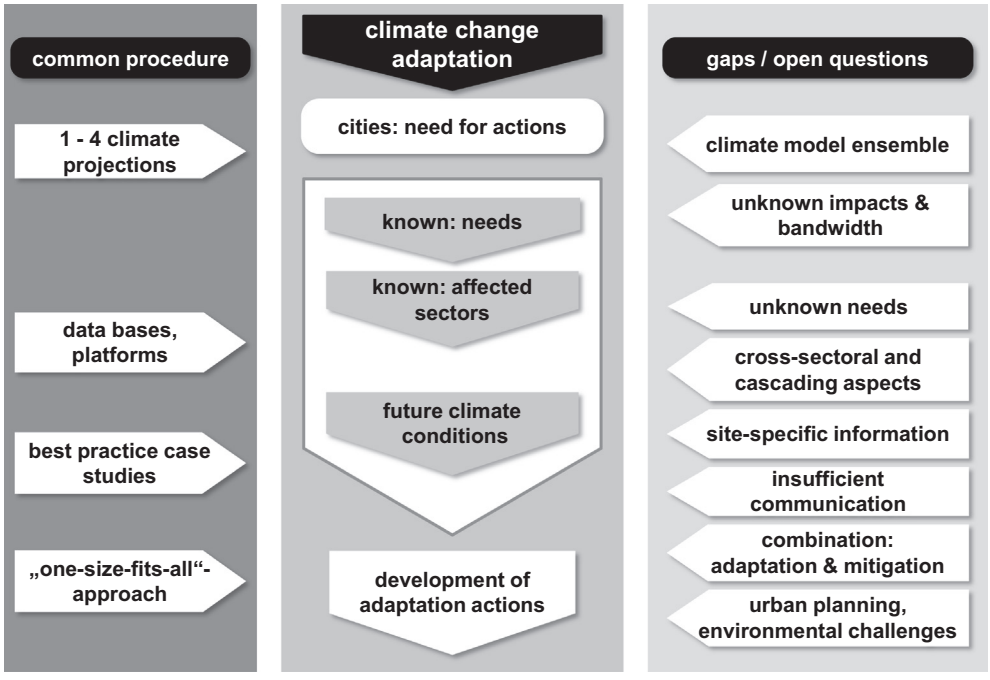

Fig. 3. Common procedures and current gaps in climate change adaptation.

very carefully in order to customize measures to the respective purpose (Bender et al., 2015; Cortekar et al., 2015).

Several gaps and open questions (see Fig. 3) could be identified within this study that contribute to the development of an alternative approach. In nearly all cases there is, due to technical reasons, a gap between available spatial and temporal information (e.g. rainfall distribution, wind turbulence, soil conditions, land coverage) and the desired individual local or regional information from stakeholder side. However it has to be admitted that in many cases stakeholders do not really know, what information they really need to answer pressing questions. Major challenges are still the communication of uncertainties and the necessity to use information from climate model ensembles instead of using only few climate projections. As people tend to only look at their domains, sectorial views prevail and cross-sectoral and cascading aspects are mostly not considered. For instance, measures to maintain or improve the thermal comfort of inhabitants must consider – among other factors – the frequency, intensity and length of heat waves, the temporal and spatial distribution of surface and air temperature, the arrangement of build-up structures, characteristics of the paving (colour, degree of sealing), existing blue and green infrastructure, as well as the climate resilience of the associated infrastructure elements. To close some of the identified gaps and to support existing administrative process chains we developed the *Stadtbaukasten*.

The *Stadtbaukasten* is conceived as an innovative, practice-oriented climate service prototype based on a modular setting, which simultaneously provides a general framework and allows a

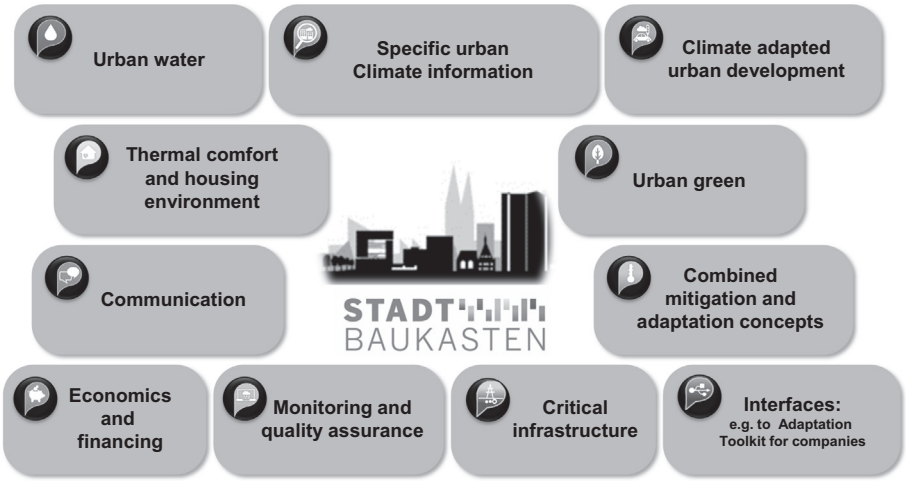

Fig. 4. Framework of the *Stadtbaukasten* consisting of eleven module groups.

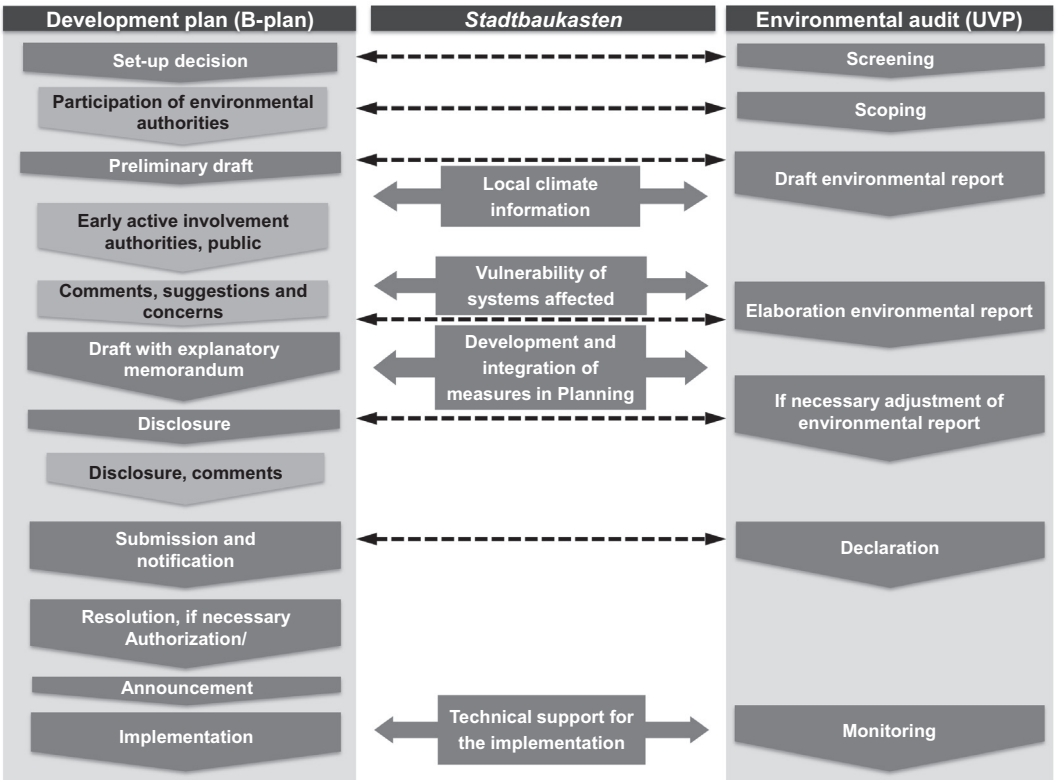

Fig. 5. Integration of the *Stadtbaukasten* in existing workflows.

flexible application. Even though flexibility is not per se an adequate methodological approach to deal with complex systems, it here refers to the possibility for decision-makers to choose those tailored elements of the framework that fit best to their needs. Depending on already established actions, different exposures to climate change impacts and the individual context conditions each city can chose one or an arbitrary combination of up to 11 module groups (Fig. 4).

In its current layout it covers the most important fields that are relevant for cities to plan, develop and implement adaptation actions for different sectors or at different locations. In contrast to web portals and best-practice solutions that can be found on the web, all activities in the *Stadtbaukasten* are done in close cooperation between city representatives and GERICS. This ensures that expert knowledge from both sides, i.e. local knowledge and scientific knowledge, is integrated to develop sound solutions.

To ensure the best possible preconditions for the application of the *Stadtbaukasten*, basics such as moderation processes, stakeholder consultations and dialogues that are all part of module group "communication" are needed. These competences are necessary to overcome the gap between adaptation in theory and practice, to start the exchange of existing knowledge, to understand existing needs and associated conflicts, to identify administrative barriers for the implementation, to build consensus about threats and preferences for adaptation measures between the stakeholders, and to analyse what has been done so far. In many cases, different actors have for instance collected data of which others are not aware. The inclusion of all relevant stakeholders from the start of the process supports the integrative view on all relevant aspects.

Brasseur and Gallardo (2016) recently acknowledged that the sole dissemination of information from scientific experts to local practitioners ("top-down" approach) should be replaced by a new approach in which knowledge is co-produced hand in hand by scientists together with users. This proposition perfectly reflects the underlying idea of our approach by including city representatives and other relevant stakeholders. To foster the implementation of measures that create synergies and co-benefits (e.g. between mitigation and adaptation) it is necessary to integrate local actors, who are familiar with the situation at hand. This co-development of solutions has the advantage that acceptance is usually higher if decision-makers were involved right from the start. Possible conflicts can be solved early along the way (Weyrich, 2016). If they are only detected at a later stage, conflicts could otherwise cause measures to not be fully implemented. In addition, this bottom-up approach is also apt to avoid over- or under-adaptation as over-adaptation is too costly since it is not needed and under-adaptation cannot prevent negative impacts in an appropriate way. Planning new adaptation measures that improve, for instance, shading, circulation of cold air, reduction of surface temperatures or better combination of green and blue infrastructure requires participation of local water authorities, urban planning offices, possibly the urban green areas office and most likely the urban environment agency as executive office for climate affairs (at least in most cities in Germany). This simple example shows that different actors should be included.

The *Stadtbaukasten* also takes into account the limited financial and human resources available in many cities. To avoid disproportionate allocation of resources (and thus decrease scepticism), it can be integrated in already existing processes (Fig. 5) such as for urban development or environmental audits.

5. Conclusion

Within the scope of this paper, current challenges in urban climate change adaptation and advantages and disadvantages of commonly used approaches were analysed. It was shown that today's common approaches have several shortcomings. The main reason why adaptation processes so far did not work as efficiently as they should relates to the fact that each city has its own unique setting, exposure to climate change impacts, preconditions, assets, and physical and structural characteristics that distinguish it from other cities. Furthermore, due to interrelations between several sectors there is a basic prerequisite to understand the whole system before changing single components. This cannot be done by transferring best-practice examples or results from databases and web portals from one city to another.

Instead, a more flexible, holistic, practice-oriented, and tailored approach is needed for urban climate change adaptation that allows an integration of all relevant aspects and stakeholders in the city at hand. This, however, requires well-organized and implemented communication processes and flows to ensure that expert knowledge from both sides, i.e. local knowledge and scientific knowledge, is integrated to develop sound solutions and that possible conflicts can be solved early along the way.

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