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Municipal planning challenges in adapting to heat and the role of practical guidelines

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Studies worldwide document that climate adaptation is still insufficiently implemented in urban planning practice. Practice Guidelines are regarded as an important tool for municipal adaptation by providing measures for development planning. However, little is known about how this mainstreaming is accepted and implemented in practice. To address this, 24 heat adaptation measures were evaluated by two municipal planners over 7 h of semi-structured interviews. The case study was embedded in a research project accompanying an actual local land-use process in Germany. According to their assessment, the literature contained measures that are: (i) regularly used in the development plan (3 of 24), (ii) could be used reluctantly (5 of 24), (iii) only indirectly applicable or serve as overall objectives (6 of 24), (iv) unfamiliar or not trusted (2 of 24) and (v) not applicable in the context of development planning (8 of 24). This study provides firsthand insight into a planning department's perspective on integrating climate adaptation into development plans. The findings reveal fundamental shortcomings in the decision-making flexibility of planners and their support by ministries and politicians, but also highlight the planners' autonomy to ignore adaptation measures. Systemic and legal barriers currently prevent comprehensive municipal climate adaptation.

Climate change poses a variety of risks for the environment and humankind^{1,2}, with urban areas being especially vulnerable to climate change-associated hazards³. Climate change has a great impact at the local level^{1,4}, which is why municipal planning is seen as a key instrument to adapt to climate change, i.e., mitigate its impacts through appropriate adaptation measures locally and regionally by public authorities⁵. Climate hazards such as heat waves and drought in summer, flooding due to heavy rainfalls or rising sea level, require planning-based adaptation through measures such as roof and façade greening to absorb solar radiation energy⁶, specific areas for rainwater retention⁷ or elevating infrastructure⁸. After initial municipal efforts at addressing climate change focused on mitigation rather than adaptation^{9–11}, more and more municipalities have recently integrated climate adaptation into their planning and promoted understanding and acceptance of adaptation measures in different ways^{12,13}.

However, even as municipalities prepare climate adaptation plans as planning instruments more frequently, it has been shown that these do not necessarily lead to adaptation in practice^{11,14}. Evaluations of climate adaptation plans in Europe, the US, and Australia have shown, for example, that local governments were hardly able to react to the anticipated changes with geographically specific action plans despite their awareness of them^{4,15,16}. Reasons for this included a lack of necessary information or persuasive implementation options. In Germany, the German Adaptation Strategy

(DAS) and the Adaptation Action Plan were established at the national level in 2008 to promote climate adaptation in the medium term¹⁷. In 2018, a decade later, a nationwide online survey revealed that one-third of the municipalities surveyed had not even dealt with the topic at the conceptual level¹⁸. A study ranking climate change adaptation activities of German cities in 2021 indicated little progress, with 25% of cities showing no activities like adaptation plans or other commitments at all, and another 17% showing only very little activity¹⁹.

Findings from Germany and all over the world indicate that climate adaptation planning faces many significant barriers, hindering its adequate consideration in municipal planning^{8,12,20–24}. Municipal or local planning “represents a particularly important pathway for adaptation”⁵; however, various barriers for the implementation of climate adaptation have been identified so far and further summarized into manageable barrier categories^{25,26}. For land-use planning, barriers most commonly encountered were categorized, e.g., as procedural reasons, organizational-structural reasons, competition between planning objectives, uncertainty, influence of economic development agendas, or Institutional limitations and challenges^{20,24}.

In contrast, it was found that climate adaptation has recently been implemented mainly through individual adaptation measures, especially in small communities¹⁸. According to Moser and Ekstrom²⁵, these are so-called

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“coping-measures”, which are easy and quick to implement compared to a strategic reorientation of the relevant system. At the municipal planning level, climate change raises new issues that urban planners must consider. The integration of climate adaptation in urban planning, i.e., existing policy domains, is called “mainstreaming” and is seen as an effective way to integrate the new topic into policymaking and as an important pathway for municipal climate adaptation^{8,12,22,27–29}. However, there is still an uncertainty on how much adaptive capacity can be achieved with a measure-focused approach²⁹. Within existing planning systems and for daily planning practice, it can recently be seen as the most used and therefore most feasible way for adaptation¹⁸. The fundamental prerequisite for this, however, is that measures for climate adaptation are regularly incorporated into the planning process.

To provide municipal administrations with relevant adaptation measures, adaptation pathways, and comprehensive information on climate change for local development and planning, many reports and guidelines for German planning practice have been developed in recent years. Funding bodies are often federal or state ministries, which implement the regional and sectoral adaptation research called for in the DAS with dedicated funding programs. These guidelines offer planners a quick introduction to the topic and suggest a series of individual adaptation measures for different climate hazards. These are intended to support the selective implementation of measures which, as described above, are the most common type for municipal adaptation so far. Meanwhile, there are a large number of guidelines and reports, creating a problem of “too much information”, which was already recognized in 2014 and 2017 and has since increased with each new report^{30,31}. Kind et al. report a flood of information (“almost inflationary”), which makes it difficult for researchers and local authorities alike to deal with the topic in an appropriate manner³¹.

Climate adaptation activities are only developing slowly in Germany. The recent focus on adaptation strategies and concepts will be reinforced by the requirements of the new Federal Climate Adaptation Act (§3, §6, §12 KAnG), which came into force on 1 July 2024. However, the effective adaptation of cities and municipalities to impending climate hazards and impacts can only be realized through the practical implementation of appropriate measures. Although suitable measures have been developed and made accessible via guidelines in recent years, the extent of their integration in municipal planning routines and existing barriers to implementation are currently unknown.

The aim of the study presented was to evaluate adaptation measures proposed in guidelines in terms of their actual use and applicability in local land-use planning. This was done within the framework of a transdisciplinary project in cooperation with a planning department of a mid-sized city in southwest Germany, in which a team of researchers acted as consulting climate adaptation experts³⁴. The case studied was related to the land-use planning process for a new city district. Based on the local climate and its projections, a major climate risk in the future—among others—is summer heat and especially heat waves. Planning should integrate this climate adaptation concern by adjusting development regulations and integrating appropriate measures into urban land-use plans. Based on the local ecological and geographical setting, technically promising measures were drawn from existing guidelines.

In addition to document analysis^{19,32}, semi-structured interviews with local experts are common approaches for analyzing barriers to climate change adaptation^{23,33–36}. Typically, these interviews are conducted with various stakeholders over a short period of time and with previously unknown persons. The study presented benefits from interviews conducted in an informal setting among temporary colleagues, allowing for continuous, open, and in-depth discussions about participants’ perspectives on the individual measures.

This article presents (i) the results of the review of adaptation guidelines and their use in planning practice (section “Review of adaptation guidelines and the use of guidelines in planning practice”), (ii) the evaluation of the measures by current planners, presented as categories of practical applicability, resulting barriers to climate action, their causes, and experiences from

planning practice (section “Evaluation of the measures’ applicability and resulting barriers to climate action”), and (iii) a reflection on the fundamental barriers behind the findings (section “Methods”). In addition, the methods section provides a methodological approach for planning practice to identify relevant adaptation measures as part of the local land-use planning process.

Results

Review of adaptation guidelines and the use of guidelines in planning practice

At the time of the literature review in 2017, a large number of guidelines had already been developed through previous federal and state funding programs, covering a wide range of adaptation-related topics, some of them focusing on municipal climate adaptation. The latter has been specially developed to provide municipal administration employees with all the necessary information on local climate adaptation. Due to the large number of existing guidelines on the topic of adaptation in general, the search for guidelines relevant to the pilot project proved to be time-consuming and complex. This problem of “too much information” and “too many guidelines” was also stated by Kind et al.³¹ and was confirmed by the current planners of the pilot project. For further verification, this topic was also addressed at the 2017 National Climate Dialog Conference in Dessau-Roßlau and confirmed by municipal climate protection officers from various German cities and villages.

However, after an initial review, many of them proved to be unsuitable for the purpose of the pilot project, as they either did not contain proposals for specific measures or were written specifically for other planning levels (e.g., regional planning) or other German regions (e.g., focusing on coastal protection). In the end, 12 guidelines proposed climate adaptation measures relevant for the identified climate hazards and risks of the pilot area. Five guidelines focused on rainwater management^{37–40} and were therefore excluded from the case study, except the one bridging the gap to heat adaptation⁷. One master plan exclusively covered mitigation measures for the impact of urban heat⁴¹ and six guidelines covered several areas of adaptation thematically^{42–47}. Publishers and/or sponsors were mostly authorities; the contents were developed by researchers and/or external planning offices in cooperation with authorities. These guidelines were supplemented by a scientific article on adaptation measures in urban areas⁶. An overview of the resulting 9 guidelines used in this case study is given in Supplementary Table 1.

The identification of the measures was also complex and time-consuming, as the guidelines i) are very long (average number of pages: 126 p.) and varied considerably ii) in terms of their structure with measures being presented in clear lists, factsheets or being embedded in the continuous text and iii) in terms of the level of detail and the type of information provided for each measure. For example, all guidelines qualitatively described the impact of an adaptation measure, but only a quarter (all on water management and heavy rainfall) suggested methods for quantitative assessment^{7,37,39} or provided detailed information on legal regulations in the local development plan^{40,42,48}.

The review gave the impression that the development of measures for planning is largely completed. This is based on the observation that across various guidelines, a set of typical measures for each adaptation field is recommended for planning (compare Table 1). Hence, this study regards these measures as a sort of general planning recommendations and the guidelines as examples, with their proposed measures finding resonance on government websites and in more recent guidelines as well. In this context, it is not the aim of this study to criticize individual guidelines. Rather, the aim is to reflect the planners’ views on the measures typically recommended, to point out challenges for their implementation, and to raise awareness for upcoming work in this important applied research field.

In the case observed, the current planners seemed to make little use of the guidelines, but the city’s climate protection manager did. However, there was no direct exchange between the current planners and the climate manager at that time. This can be explained by the fact that the climate

Table 1 | Categorization of measures and their reference to guidelines

| Cat. | Heat adaptation measure | Proposed in (guides/report) | Proposed in (no. of guides) |
|------|--|-----------------------------|-----------------------------|
| I | Minimize new impermeable surfaces (1) | 6,7,43,45,47,48 | 6 of 9 |
| | Green roofs (6) | 6,7,41–45,47,48 | 9 of 9 |
| | Pocket-parks (18) | 6,41–44,47,48 | 7 of 9 |
| II | Façade greening (7) | 6,7,41–43,45,47,48 | 8 of 9 |
| | Increase of the surface albedo (“reflection”)/light colors (10) | 6,41–47 | 8 of 9 |
| | Preservation and creation of open moving water surfaces (17) | 7,41,42,45,46 | 5 of 9 |
| | Tangible water/fountains, etc, in public areas (19) | 7,41,42,46 | 4 of 9 |
| | Position buildings to support air circulation (24) | 6,42–47 | 7 of 9 |
| III | Shading of streets, buildings, and green areas by trees (3) | 6,41–47 | 8 of 9 |
| | Green parking spaces or technical shading of parking areas (e.g., by a roof) (4) | 6,41,42,46 | 4 of 9 |
| | Providing recreational areas (9) | 6,42,43,45,46 | 5 of 9 |
| | Avoidance of multiple reflections from walls and windows (11) | 47 | 1 of 9 |
| | Green tramway routes (20) | 41,42,45 | 3 of 9 |
| | Social-ecological infrastructure, behavioral precautions (23) | 42,46 | 2 of 9 |
| IV | Street geometry (2) | 6,42,43,47 | 4 of 9 |
| | Natural infiltration and storage basins (13) | 45 | 1 of 9 |
| V | Shading of roof surfaces through photovoltaics (5) | 6 | 1 of 9 |
| | Technical reduction of the cooling effort in summer (e.g., external sun screens) (8) | 6,42,45,46 | 4 of 9 |
| | Air cooling through evaporation processes (12) | 6,7,42,43,45 | 5 of 9 |
| | Preservation, development, and creation of large green, forest, open space,s and cold-air production areas/tracks (14) | 6,41–47 | 8 of 9 |
| | Networking and connecting green infrastructure (15) | 6,41–43,45–47 | 7 of 9 |
| | Reduce anthropogenic heat emissions (16) | 6,41 | 2 of 9 |
| | Energy-efficient buildings (21) | 6,41,42,45,46 | 5 of 9 |
| | Thermal insulation against summer heat on buildings (22) | 6,41,42,45–47 | 6 of 9 |

The table lists the categories of applicability (I to V, from high to not at all), the adaptation measures assessed and their order in the interviews (1 to 24), the guidelines in which the measures were proposed as reference, and quantities.

manager worked in a different department, and the directors of the two departments belonged to competing political parties at the time of the study. Therefore, the current planners largely avoided contact with the climate manager. For other reasons, there was also a longer history of avoidance behavior with specialist planners of the civil engineering department. According to their own statements, the current planners try to anticipate concerns of this department to minimize their negative feedback during the formal participation step.

Such internal maneuvers can hamper comprehensive and balanced planning, especially with regard to new planning interests, for which measures and processes have not yet been established. It was not possible to investigate the potential negative effects of this behavior on the integration of the specialized topics (climate, urban green) within the scope of the study. However, responses of the current planners, which can be found in the following section, indicate certain tendencies.

Evaluation of the measures’ applicability and resulting barriers to climate action

The subsequent evaluation of the responses to the individual measures ($n = 24$) showed that the measures can be divided into five categories. The results are illustrated in Fig. 1.

In the following, each category is briefly described and supported with quotations and corresponding measures. The allocation of the individual measures to the categories is shown in Table 1. The numbering of the measures in Table 1 indicates the order in which they were discussed in the interviews, and is retained for methodological clarity.

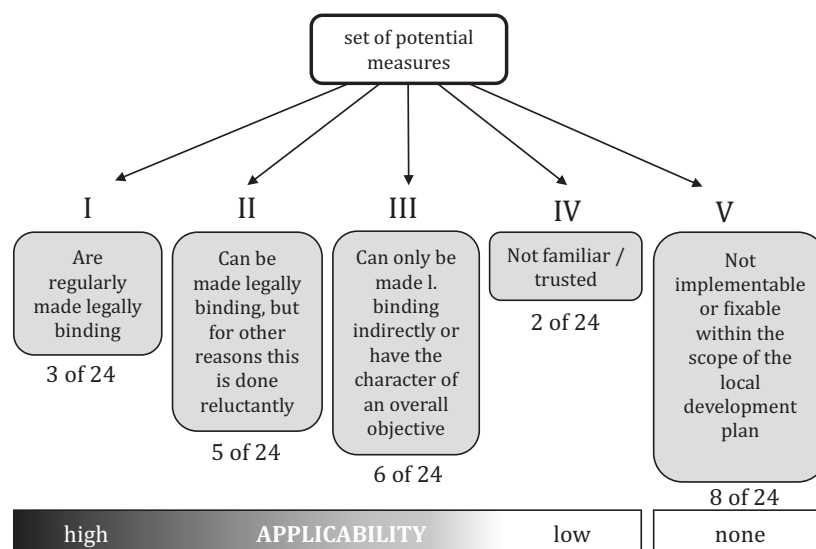
Only a minority of the measures proposed in the literature for local development planning are regularly fixed (made legally binding) or can be

easily implemented in the land-use plan (category I: 3 of 24 measures). Measures that can be implemented easily have the following characteristics: (i) they are enshrined in law by the Federal Building Code (BauGB)⁴⁹, (ii) they can be convincingly argued for in the justification for the development plan, and (iii) they show promise for implementation in the private sector. This applied to 1—*minimize new impermeable surfaces*, 6—*green roofs*, and 18—*pocket parks*. Pocket parks were conceived by the current planners as small parks in public spaces that can be designed as stepping stones for flora and fauna between larger parks. They could be stipulated in the land-use plan as public green spaces, possibly supplemented by tree planting. Pocket parks could be justified in the development plan as an element for overcoming larger distances between neighboring, larger green spaces and for improving greenery in the district.

But even these measures can fail in their climate impact and adaptation goal if the responsible department does not describe the measure in the right way: “Sometimes other departments just demand things in the wrong way and use the wrong wording, so we cannot implement them.” Case in point: climate experts should not be asking that “trees be used for shading”, but that “five trees of a certain species should be planted in front of the south façade of this building” or “four trees per ... m² of parking space should be planted”. This means, conversely, that a mere lack of knowledge of other authorities about the correct wording can prevent the integration of measures into the development plan.

Regarding category II, there were intense discussions around the topic of 6—*green roofs*, as the development plan can enforce planting, but not the preservation or maintenance (e.g., via artificial irrigation) of plants on private land. As a result, extensive green roofs are often specified as legally binding adaptive measures because they require little or no maintenance. In

Fig. 1 | Summary of the evaluation of the applicability of heat adaptation measures. The results of the evaluation of adaptation measures, proposed by current guidelines for climate adaptation in spatial planning, regarding their applicability to local development plans. Measures are grouped into five categories of applicability (I to V).



contrast, 7—*façade greening* requires high maintenance and depends on artificial irrigation. If property owners have no self-interest in green façades, the planner explained, they can simply let the plants die without legal consequences. Due to these disappointing prior experiences of the interviewees, they generally refrain from prescribing façade greening by law (‘it’s not worth it’). They argued instead that if property owners do have a personal interest, they will install and maintain a green façade themselves.

It was mentioned that some cities use façade greening mainly for public buildings, although some disadvantages, such as the possible damage to the building fabric and the high maintenance effort and costs for the municipality, were also pointed out. The practical implementation was also criticized in some points: “To be honest, the topic of greening (façade and tree planting) can easily be circumvented during the building permit process. Even if nothing has been planted yet, the builder simply says that he is not done yet and will do it—no building control fails because of that, and afterward nobody controls it anymore”.

Justifying a measure in the development plan was seen by planners as a critical barrier to applying climate-related measures. Each desired climate adaptation measure must be individually listed in the development plan and justified based on the Federal Building Code. Since this is a land-related law, it is easier to justify land-related measures (e.g., minimizing sealing, developing green space, planting trees, etc.) than measures that are climate-relevant but not directly related to land use. During the planning process, climate-related measures have been viewed as easier to challenge by other public authorities and less promising in terms of their actual designation in the binding development plan (e.g., Tab.1: 10—*increase of the surface albedo* or 12—*air cooling through evaporation processes*).

The fundamental right to freedom of property ownership and development enshrined in the German constitution was cited as a further restriction on the implementation of measures. According to this, every property owner is initially granted the greatest possible freedom to develop their property. This freedom is then restricted by planners through the Federal Building Code⁴⁹, which should only be done to the extent necessary and with good justification. “Anything that cannot be well justified falls victim to the Basic Law”. For this reason, planners were reluctant to prescribe certain measures to subsequent owners in terms of planning freedom, such as specifying open space qualities (e.g., Tab.1: 18—*pocket parks*) or house colors (Tab.1: 10—*increase of the surface albedo* (“reflection”)/*light colors*). Some measures are defined only under special circumstances, because they are associated with high maintenance costs for the public sector, despite their high local microclimatic importance for visitors (Tab.1: 19—*angle water / fountains etc. in public areas*).

The planners further argued that the justifiability must be supported by politics and higher-level bodies (municipal council, mayor, framework plans, etc.), e.g., by formulating climate adaptation goals, enacting local regulations for the entire city, to enable planners to restrict the freedom of property ownership and development in a targeted manner. Above all, when it is a matter of demands that go beyond the usual level. This applies to stipulations in the land-use plan that exceed the legally required limit values (which exist, e.g., in statutory noise protection) and also to the use of climate adaptation measures if these are difficult to justify under building law. “What would happen if I simply demanded that the limit values be undercut? Then maybe the developer complains to the mayor why they have to do that, and others don’t—and the mayor doesn’t know about it, and if he or she doesn’t support the demand, then the whole thing gets politically overturned. In the worst case, the mayor then accuses the administration of interfering in matters for which it is not responsible.”

Some of the measures can only be specified indirectly (category III). That is, the measure itself has further requirements, but the area-relevant aspect or planting can be specified in the development plan in a legally binding manner. For example, Tab.1: 18—*pocket parks* can be implemented as green areas with tree plantings in the public space between buildings, provided that sufficient space has been planned in advance. And Tab.1: 11—*avoidance of multiple reflections* means reduction via absorption by plant foliage, which can be achieved by establishing greenery such as trees, shrubs, or facade greenery. The individual types of greenery can be regularly and simply stipulated in the development plan in conformity with the building laws. Another option is that a measure can be specified indirectly in the development plan; thus, planners can use the building line to arrange buildings in such a way that air circulation is impeded as little as possible (Tab.1: 24—*position buildings to support air circulation*).

In some cases, the effectiveness and meaningfulness of the proposed measures were questioned (category IV). Taking the example of a large square with light-colored facades and floor coverings, the use of very light colors in the outdoor area (Tab.1: 10) was criticized, as this could lead to strong reflections and thus to increased brightness in the public street space (“even in autumn you need sunglasses”). As a further example, the active greening of grass pavements (Tab.1: 4) was questioned: “if there are cars standing around all day, you can forget about the lawn,” which is why it is only reluctantly legally stipulated.

The adaptation measure 2—*Street geometry*, i.e., the influence of building and street orientation and width on heat gain through shading and ventilation, was largely unknown to the interviewees. This rather complex adaptation option is regularly recommended in scientific literature, and many

of the related issues have already been scientifically investigated. Another measure, not unknown, but considered “too scientific”, was Tab.1: 5—*Photovoltaic shading*. Photovoltaics are part of municipal climate mitigation requirements. The argument of using PV for roof shading as an adaptation measure seemed far-fetched to the current planners. Both measures were actually taken from a scientific publication on measures for climate change in urban areas⁶, probably explaining the planner’s reaction. Such findings indicate a deep gap existing between scientifically and physically promising adaptation options and their current feasibility in local land-use planning.

In the opinion of the two interview partners, the majority of the measures examined cannot be implemented in the process of municipal development planning (category V). The reasons for this can be summarized in five statements. The measures are not suitable for the binding local development plan because they

1. are part of a higher-level formal planning, such as the regional planning or preparatory urban land use planning (e.g., Tab.1: 14—*preservation, development, and creation of large green, forest, open spaces, and cold-air production areas/tracks*)
2. describe general objectives rather than specific measures (e.g., Tab.1: 3—*shading of streets, buildings, and green areas by trees*)
3. must be implemented within the framework of other, informal instruments (e.g., Tab.1: 16—*reduce anthropogenic heat emissions or 15—networking and connecting green infrastructure in framework development plans*) or by other departments or offices (e.g., Tab.1: 20—*green tramway routes, 23—social-ecological infrastructure*),
4. are not part of the building permit process but are part of the next step of building and open space planning—in which the current planners are no longer involved (e.g. Tab.1: 21—*energy-efficient buildings, 8—technical reduction of the cooling effort in summer, 19—tangible water/fountains*) and/or to be regulated by urban development contracts (§11 BauGB) in which, e.g., the rights and obligations of the investor in urban development projects are defined
5. are “too scientific”, i.e., the measure makes sense from a climate adaptation perspective, but cannot be implemented in this way in local development planning (e.g., Tab.1: 5—*shading through photovoltaics*).

Many of the planners’ arguments can be explained by the high pressure to justify individual measures in the development plan, which arises from the process of weighing up planning interests and the fundamental right to freedom of property ownership and development. The German Building Code stipulates that the interests of climate adaptation must be considered, i.e., that they must be comprehensibly incorporated into their decisions and weighed up against other interests. However, there is a lack of concrete standards and specifications for climate adaptation that enable planners to justify individual measures. As long as these or even legally binding regulations on climate adaptation do not exist, this concern will always be weaker than interests that are strengthened by legally binding regulations.

Discussion

This case study provides a qualitative micro-analysis of the practical application of heat adaptation measures in municipal planning and insights into the inherent logic of local administrative action within the German planning system. These measures were proposed concurrently with an ongoing planning process, offering unique and novel insights into how planners routinely handle guidelines and adaptation measures. While many barriers of climate adaptation have been studied and described before^{26,50}, to the author’s knowledge, no other work has focused so intensively on the applicability of adaptation measures in local development planning. The findings reveal a significant gap between the broad range of heat adaptation options proposed in guidelines and their actual application and practicality from a planning perspective. In the following, two fundamentally different aspects of the planners’ arguments are discussed: the topic of guidelines and the topic of planning systems and their requirements.

There are five main insights regarding the applicability of climate adaptation measures at the local planning level. First, even if adaptation

measures are technically and scientifically sound, this does not guarantee that they can be applied in daily planning practice. Second, since implementing measures in municipal planning is crucial for mainstreaming climate adaptation, the findings question the effectiveness of this approach. Third, the planners surveyed utilize guidelines only to a limited extent, thereby minimizing the potential impact of these guidelines on local climate adaptation. Fourth, planners have not been sufficiently challenged to address climate adaptation and can still evade this challenge through skillful argumentation. They often choose not to use suggested measures due to previous negative experiences, systemic issues, or political reasons. Lastly, planners lack the flexibility and decision-making power to integrate more measures—even if they wish to do so. From their perspective, increased support at ministerial and political levels is necessary.

One third of the proposed measures was rated as not implementable for technical or legal reasons within the scope of local land-use planning and thus as not applicable. The planners argued that the Federal Building Code⁴⁹ refers to land aspects, so climate aspects per se are not justifiable. The planning system in Germany is characterized by a decentralized decision-making structure and a strong legal framework, where municipalities possess a right to self-administration with high autonomy while being embedded in a structured planning framework⁵¹. The observed shortcomings in the decision-making flexibility of planners primarily relate to restrictions imposed by statewide legal regulations. The so-called legal barriers have recently been identified as a distinct category of barriers to municipal climate adaptation²⁴, with this study offering the first in-depth analysis in this regard.

At the same time, the high self-administration autonomy of municipalities may foster a planning culture focused on optimizing processes over content²⁴, allowing specific measures to be ignored. Given the identified conditions and causal mechanisms of the observed planning culture⁵², it can be assumed that the identified barriers are likely to be present in all German municipalities and in related federal planning systems characterized by strong legal regulations^{53,54} and high administrative autonomy^{14,32,55}.

A rather case-specific statement is the number of measures which are regularly implemented, although 3 out of 24 (“minimize new impermeable surfaces”, “green roofs” and “pocket-parks/green areas”) were surprisingly few. The effectiveness of the measures for climate adaptation was seldom questioned. From a planning perspective, concerns often refer to a measure’s justification to the building owners under building law⁴⁹ or to their practical implementation. Some measures were only considered suitable for other planning levels or instruments—even though the guidelines were specifically designed for urban land use planning and prepared in cooperation between authorities and researchers. This indicates that the current procedure for the creation of tools and guidelines might not be fully mature.

At the same time, this study revealed that even with the best intentions, planners perceive that they can only apply a part of the measures under given circumstances. More fundamentally, the findings question whether mainstreaming climate adaptation objectives into existing practices via guidelines is effective if key actors are not yet able or willing to implement adaptation measures in daily planning practice. It is noteworthy that neither the necessity of climate adaptation nor the credibility of the urgency to act (uncertainty of science) was questioned. Both aspects were frequently identified as relevant barriers^{8,20,36} but can be considered as overcome in the observed case.

In addition, in the course of the project, specialists and overall planners frequently noted that they hardly work with reports and guidelines for diverse reasons (too technical, contain too little practical assistance, do not contain the information they need). Whether and to what extent these reasons are true or a pretextual argumentation for other reasons (e.g., time constraints) could not be determined. However, if the planners’ assessment is considered justified, the reasons for this must lie in the guidelines. A possible explanation based on the development process of guidelines is presented below. Climate adaptation reports in general aim to condense a highly complex topic into relevant facts and to offer various adaptation options. This allows a wide range of municipal actors to be addressed

simultaneously, resulting in a combined presentation of measures for different planning levels (e.g., regional/ urban land use/ object planning), planning instruments (formal and informal), and different departments, e.g., refs. 41,42,47.

The diversity is necessary from a climate-related perspective, and its comprehensible presentation must be acknowledged as a great achievement. Conversely, however, this means that neither specialist departments nor specific planning levels are addressed specifically. This strongly contrasts with the structure of the administrative system, where each department acts separately and thus requires and compiles information that is specifically tailored to its needs³⁶. Judging from this study, this could be one reason that prevents the appropriate use of the guidelines in practice. As a conclusion, future guideline preparation can improve its usability by focusing on single planning topics or levels. It seems to be particularly useful if such practical guidelines are developed and published by the responsible authorities themselves, as has been done, e.g., by the municipal water management department of Cologne for heavy rainfall prevention and water sensitive planning⁴⁰.

The expert interviews revealed that planners predominantly argued from their own perspective, focusing on their roles, routine processes, and needs. That indicates that scientifically formulated measures, as presented in guidelines, do not fit with land-use planning frameworks. The differing work cultures and communication styles can lead to comprehension and implementation difficulties in planning practice, a barrier that was also described in the context of guidelines for urban green space design⁵⁷. Regarding the global implementation of climate adaptation planning, each planning culture has its own logic, processes, and requirements that directly impact the potential for implementing adaptation measures. These logics and the specific needs of planners must be identified and considered when developing tools and guidelines tailored to the requirements of a specific planning system.

A guideline tailored to the German planning culture, particularly for land-use planning where robust justifications are essential, should address specific climate hazards (e.g., heat), planning objectives (e.g., increasing shading), explanatory statements (e.g., shading reduces surface heating and perceived temperature), and related measures for land-use plans (e.g., adapted tree planting, facade greening, technical shading). This approach provides all information necessary for legal stipulation, facilitates justification, and thus should support adaptation interests in the planning process⁵⁷. Given the time that has elapsed since the interviews and the literature review, many new German guidelines have been published. In addition to those resulting from research projects, there is a significant increase in guidelines issued directly by ministries and municipalities themselves. This exacerbates the already described issue of an overwhelming number of guidelines, yet these new guidelines may be more suitable for practical application due to their closer alignment with real-world practice.

At the same time, the results can also be seen as a line of argument of two planners. Some measures could be legally stipulated (greening of the façade), so the non-use cannot be attributed to guidelines or a missing legal basis. This leads to the conclusion that it is obviously possible to limit their own options in a targeted and argumentative manner, which is supported by findings from Sweden⁵⁸. The argumentation and motives behind this were presented in the results. Some of the arguments even gave the impression that the planners were seeking to retain procedural decision-making power or to insulate themselves as much as possible from the demands of other departments for internal political reasons. In conclusion, these findings also question the power of formal instruments to ensure practical implementation. Comparable insights were gained from a Dutch city, showing that formal-legal rules are not sufficient to bring key actors into action⁵⁹. These findings imply a certain room for maneuver for planners to consider climate adaptation, in the direction of less adaptation. In other contexts, this freedom can support more innovative action, for example, driven by a higher risk perception due to local extreme events³³.

In addition to the applicability of measures, the interviews also identified many system-related and institutional barriers. In fact, planners

mentioned having very limited options for integrating measures beyond the normal scope and discretion, and would welcome more support from local politics. More policy support for planning was also seen as an important component of improving municipal climate adaptation in the course of the pilot project of this study in other contexts^{8,24,60}. It was also critically noted that the personnel capacities are not sufficient to check the actual implementation of the measures afterward, or that the maintenance of measures is not legally required, e.g., for green infrastructure elements on private ground. The latter, together with the high maintenance costs and competing planning agendas, seems to result in a conservative use of green infrastructure in planning, even if greenery is described as an important element of climate adaptation in cities^{35,57,61–63}. The pilot project also revealed that institutional fragmentation prevents closer cooperation between overall and specialist planners²⁴, which is seen as a major obstacle to climate adaptation in municipal departments^{14,22}. It appears to be the underlying reason why some specialist planners do not know exactly how to formulate their statements for the two times of participation within the planning process to demand individual measures. Consequently, this weakens the integration of this topic. These findings are in line with a Swiss study that identified horizontal cooperation and inter-organizational mainstreaming as important success factors for municipal climate adaptation¹⁴.

The Federal Climate Adaptation Act (KAnG), coming into force on July 1, 2024, aims to provide a binding framework for climate adaptation in Germany⁶⁴. Among other requirements, the Act mandates the development of strategies at the federal and state level, and of adaptation concepts at the municipal level, which will frame the instrument of land-use planning in the future (§12 KAnP). The significance of the guidelines must be reassessed in this context, as their broad and comprehensive contents make them valuable tools for developing the legally required strategies and concepts. Climate adaptation would be significantly strengthened if the new law exceeded the existing demands of the Federal Building Code, which is not the case. Climate adaptation is still only to be considered (§8 KAnG), even lacking closer specification regarding its weight and consequences with which the goal of climate adaptation must be considered⁶⁵. The initial draft's prohibition on deterioration that guarantees legal enforceability, which would have significantly reduced the justification burden on planners during the balancing process, was ultimately not incorporated into the law. The extent to which the adaptation concept and consideration requirement can and will nevertheless strengthen implementation in planning practice is, therefore, an important research question for the coming years.

This raises the question of which instruments would be better suited to support the actual implementation of climate adaptation at the municipal level. A more direct and flexible support would be given by municipal advisory committees⁶⁶ or climate adaptation managers, which are already integrated in many larger cities. For the latter, however, transfer challenges may arise due to organizational silos and organizational-structural barriers^{22,24,58}. Smaller and medium-sized municipalities rely on more economical options, such as guidelines or additional training programs for current staff. Over time, integrating the topic into the training of urban planners should become standard practice, facilitating natural inclusion in planning considerations. Further research could evaluate the actual use and preferences of guidelines and web tools over a broad range of cities and municipalities, to get more insights about the usage in Germany and other planning systems and cultures worldwide. From a scientific perspective, a comprehensive review of the guidelines would clarify which heat adaptation measures are proposed in the numerous guidelines, whether more recent guidelines have expanded this range, and what the added value is when these individual results are considered in context.

Methods

Pilot project

The study presented was embedded in a municipal pilot project, which was funded as part of a larger funding program of the Ministry of the Environment of the state of Baden-Württemberg to investigate the consequences of climate change and the possibilities for adaptation measures. In the pilot

project, researchers accompanied an ongoing urban planning process over a period of 1.5 years with the aim of incorporating adaptation measures into the draft of the local development plan and master plan for a new urban district. The project was developed together with the city administration and was strongly supported by the head of urban planning and conversion.

The new 20-hectare city district is developed on an 80-hectare conversion area of a former military site, next to an existing building area. The remaining area will be developed as a green belt as part of an overarching concept for the development of fresh air corridors to improve thermal comfort in neighboring districts. The region in which the city is located is one of the warmest regions in Germany and is also the most affected by global warming. Its annual average temperature has risen from around 8 °C to over 9 °C since 1901, with the largest portion of the increase occurring since 1980, and its number of hot days (>30 °C) is expected to increase by 15 days per year by 2055 compared to the average of the years 1951 to 2000⁶⁷.

The development of the cities' conversion areas was managed by a special team within the planning department and supported by external planning offices. One of the researchers worked directly in the planning department as a consulting climate adaptation expert 2 days per week for 1.5 years. To strengthen the bond and exchange with the city administration, the researcher connected with the planning team and other departments as often as possible. In the role of an expert, the researcher gave internal presentations on climate adaptation and made specific suggestions for climate adaptation measures in various internal meetings and workshops, as well as in meetings with external planning offices. Further details on the method and case of the pilot study can be found in a previous publication²⁴.

Case study

During the pilot project, specialists and external planners repeatedly criticized or even rejected proposed adaptation measures with various justifications. This reaction was unexpected, as measures had been deliberately taken from guidelines that had been developed specifically to support municipal climate adaptation. The latter was done under the assumption that the measures would be highly applicable and accepted in planning practice.

This observation led to the research question of whether the measures were rejected on a case-specific basis or if there exist more fundamental barriers. To address this inquiry, the researcher developed a case study with the primary objective of evaluating the applicability of individual adaptation measures in routine planning practice. For this purpose, two current planners, who were not involved in the planning area of the pilot project, were consulted to assess the applicability of the adaptation measures proposed in guidelines for local land-use planning.

In German planning culture, current planners develop and approve plans and regulations for new building areas as part of local land-use planning (Bauleitplanung). Specialist departments (e.g., green spaces, civil engineering) can formally introduce their interests into the planning process at two stages. The current planners weigh the comments and objections of the specialist planners against each other on a case-by-case basis, and ultimately have the authority to decide between competing interests. This weighing procedure, as part of the decision-making process, is required under German law⁶⁸. The success of climate adaptation at the municipal planning level thus depends crucially on the assessment and actions of current planners.

The case study itself was embedded in the pilot project, using the measures selected so far as a basis, and extended this set through a literature review. For completeness and clarity of the overall, multi-step methodology, both the preliminary work of the pilot project (Fig. 2, top) and the methodology of the case study (Fig. 2, bottom) are described below. Simultaneously, Fig. 2 also provides a methodology for planners and climate experts to identify relevant adaptation measures in planning practice.

Pilot project: preliminary work

Step 1 of the preliminary work was the identification of climate hazards. The main questions were: what is the climatic situation; which stresses are already occurring today; and which additional effects will occur as climate

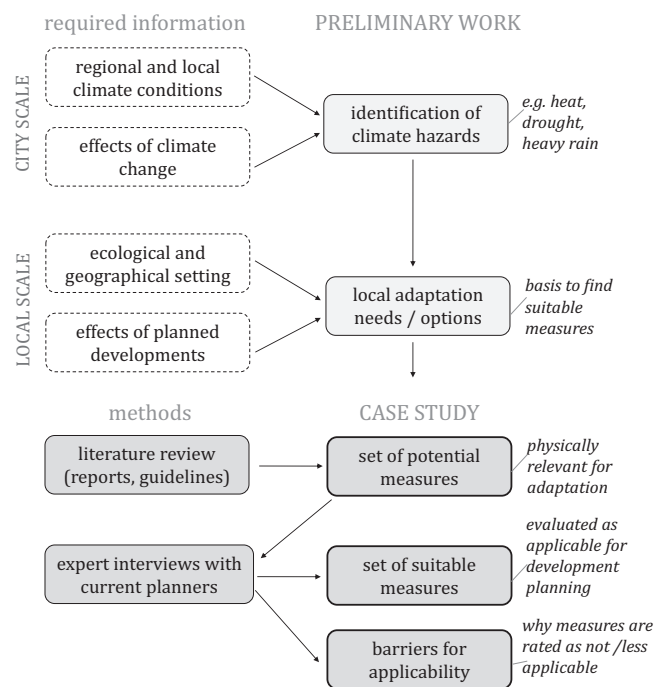


Fig. 2 | Methodological framework of the case study and preliminary work. The graphic illustrates the individual steps used to identify relevant adaptation needs in the pilot project (top, preliminary work), to identify adaptation measures related to these needs and their subsequent evaluation for applicability via expert interviews, resulting in a set of suitable measures and, based on the planner's argumentation, existing barriers for applicability (bottom, case study).

change progresses in the medium to long term? The required information on the climatic conditions and climate projections was taken from German government reports^{67,69} and from the city's climate report. The identified climate risks relevant to the case study relate to the impacts of more frequent and intensive summer heat and heat waves.

Step 2 of the preliminary work focused on local adaptation needs and options. The identification of local adaptation needs relates to the effects of the planned development on existing conditions and to the ecological and geographical setting of the area. Within the pilot project, the researchers had access to several expert reports on the climatic impact of the planned urban district on the neighboring areas to identify local needs, which the city administration had commissioned in advance. Ecological and geographical characteristics were also needed to clarify which adaptation measures were promising for implementation. For this purpose, information had to be collected to identify adaptation options (e.g., the use of cold air currents for cooling) and to determine the technical potential for implementing certain measures (e.g., infiltration potential of the soil for local infiltration of rainwater).

Case study: literature review, expert interviews, and categorization of barriers

Potential measures were identified through a literature review. The focus was on German reports and guidelines, specifically developed for municipalities and urban land use planning or local development planning. This focus on municipal adaptation guidelines offered several advantages. The measures proposed should be aligned with the German system in terms of climatic, technical, planning, and legal aspects. This was linked to the expectation of a high level of acceptance and applicability for the planning process of the pilot project. From a scientific perspective, those resources were used that are most likely to be utilized by local administrative staff, in order to reflect the actual conditions of the research system as realistically as possible.

The search for guidelines was carried out using Google searches, on websites of the ministries such as the Federal Environment Agency (UBA), the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), and the State Institute for the Environment Baden-Württemberg (LUBW), as well as in the references of the guidelines themselves. Key words were, e.g., “Klimaanpassung” (climate adaptation), “Kommunal” (municipal), “Planung” (planning), “Bauleitplanung” (local land-use planning), “Anpassungsstrategien” (adaptation strategies), “Leitfaden oder Handlungsempfehlungen” (guidelines or recommendations). In addition, there was a lively exchange between the researcher and the city’s climate protection manager about the guidelines, and the manager supported the researcher’s search for suitable guidelines. In total, 9 guidelines were chosen, which are described in detail in Supplementary Table 1. The table provides a summary of the guidelines reviewed, their page number, a link to the document, and information on funding and, if applicable, the project context in which they were developed.

This was followed by an extensive review of the identified guidelines in search of appropriate measures. Only guidelines providing measures related to specific climate hazards were considered. An adaptation measure was considered relevant to the study area if it addressed current and future local climate hazards, was relevant for new developments (in contrast to measures for redevelopment areas, such as unsealing or deconstruction), and for the local scale (in contrast to the city scale), and helped to adapt the new city district to future climate impacts.

After the review, the interviews were conducted, and the barriers noted were then categorized. This study approach differs from the usual approach of interviewing many, mostly unknown people, on a specific topic. Instead, two current planners from the planning department, with whom the researcher had been working during the project for about a year, took many hours to discuss the individual measures in detail with the researcher. Regular meetings and shared coffee breaks over half a year before the interviews ensured a relatively open and trusting relationship between the planners and the researcher.

To support the status of the researcher as being part of the team—an external researcher—the interview had to have an informal character, which made the use of recording devices impossible. Accordingly, quotations are based on notes taken during the interview or directly after and may therefore differ slightly from the actual wording. All quotations in the results section were originally in German and have been translated afterward.

The planners interviewed had supported the researcher in their general questions on local land-use planning in the first course of the pilot project. One planner has been responsible for the routine planning of buildings in the administration for many years; the other planner has been responsible for the additional task of planning for the conversion of former military areas into new urban districts. Neither of the current planners was directly related to the pilot project.

The time required to discuss the individual measures and interviews as a whole turned out to be considerable. While the initial plan was to first discuss adaptation measures for heat and then for heavy rainfall, this was limited to heat after the first interviews to minimize the overall effort to a manageable level for the planners. Measures selected included those already introduced in the pilot project, as well as new measures promising for the adaptation purpose of the pilot area. In total, 24 heat adaptation measures were evaluated by the two current planners for their practicality for this particular planning project and daily planning work.

The interviews were always conducted with the two planners together. The measures were discussed in sequence, in the order shown in Table 1 (no.). In total, four semi-structured, narrative interviews were conducted:

- 15.11.2017, 2 h: measures 1 to 4
- 21.11.2017, 2 h: measures 5 to 11
- 01.03.2018, 2 h: measures 12 to 17
- 6.3.2018, 1.5 h: measures 18–24

The following gives a brief description of the interview process. First, the measure was mentioned without further explanation to

provide an open setting to see, e.g., if the planners were familiar with it, if the two planners have the same associations, and which related aspects come to mind spontaneously. This often resulted in an open discussion about whether and to what extent this measure has already been used in planning and which experiences are associated with it, giving the planners the opportunity to address general difficulties or to make suggestions on how implementation could be improved. During the interviews, the planners made both measure-specific statements, but also repeatedly embedded these in the general context of local land-use planning.

Although barriers were a focus of the pilot project and of the results of the case study, they were not explicitly queried in the interviews to avoid biasing the planners’ responses. Instead, planners were asked for their assessment of the applicability of measures proposed in guidelines. This approach allowed barriers to emerge indirectly from their explanations of why certain measures were not included in legally binding land-use plans. Consequently, the results provided a set of measures considered suitable by the planners, with the remaining measures identified as unsuitable due to various barriers.

In the course of the first two interviews, five key questions emerged, which subsequently served as interview guidance:

- a. What are the advantages and disadvantages of this measure from the perspective of urban land use planning?
- b. Is this a purely “scientific measure” (i.e., it is not applicable at all), or can it also be implemented in the planning process? Can it be legally stipulated in the development plan? If not, how could it be implemented in other ways?
- c. Is the measure relevant to the planning draft, i.e., should it be introduced at an early planning stage?
- d. Which specialized authority would be responsible for introducing this measure into the planning process or for checking its relevance?
- e. Can this measure be implemented only in public areas or also on private land?

After the interviews, the notes taken were digitized, resulting in a Word document of 18 pages (5113 words) and, finally, manually analyzed. Through the many hours of interviews and repetitive lines of argumentation and justifications from the planners, the categories already emerged during the discussions and were refined afterward. Finally, a category system was developed to sort the measures according to their applicability. The measures were initially divided into those that can in principle be legally stipulated in the local land-use plan (Cat. I to IV) and those that planners consider impossible to apply via the local land-use planning instruments (Cat. V). The measures that could be applied in principle were further subdivided into measures that are actually used in everyday planning (Cat. I), and those that are rarely or not used were divided into three groups (Cat. II to IV) according to the planners’ justification. Thus, two outcomes were generated: (i) a list of measures sorted by their applicability for heat adaptation planning and (ii) the reasons that (currently) hinder or prevent the application of proposed measures in practice.

Limitations

Some limitations of the method used are addressed below.

In this study, only heat reduction measures were evaluated. It is possible that adaptation areas that allow for more technical solutions, e.g., mitigation measures for heavy rainfall, may lead to a different or more positive assessment of suitability. Furthermore, even though the interviews were of particular quality due to the trustful collaboration between planners and researchers, they only represent the opinion of two current planners in a particular community and do not represent, e.g., a wider range of key actors³⁵. The results could be supplemented for a more holistic view by extending the assessment of the measures to current planners in other German cities or even other countries to determine how adaptation measures are rated in other planning cultures, and why.

Within the diversity of German adaptation guidelines, only those specifically for municipal climate adaptation were reviewed and used to extract measures for the assessment. This subset was assumed to include the majority of measures, given the current state of the art and know-how, but individual measures might be missing. Moreover, the subsequent categorization of the planner's responses specifically referred to the applicability of a measure for local development plans and practical implementation. Other aspects of the responses that were not considered. Finally, the categorization is based on the assessment of a researcher from the natural/geographical sciences, which is why other classifications and resulting categories are conceivable from another scientific perspective.

Data availability

For confidentiality reasons, the interview data cannot be made publicly available. However, those interested may contact the author to discuss the analysis.

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Author contributions

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Competing interests

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Additional information

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