Hochschule Konstanz
Fakultät Bauingenieurwesen

Development of agile data workflows for climate-resilient urban planning in the use case of Constance

Master thesis by Verena Vögt
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Anlage zur Master-Thesis von

Verena Vögt

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Abstract

Cities worldwide are increasingly struggeling with the urgent challenges posed by climate change. The negative impacts of climate change are already evident, making adaptation a crucial mission for every city. Global best practices highlight various ongoing efforts in climate change adaptation (CCA) within urban areas. A key aspect of successful and measurable adaptation strategies is the integration of climate data, including remote sensing and in-situ data. These data serve as timely decision support tools for municipalities, aiding in the development of adaptation strategies, prioritization of actions, and securing support from local policymakers.

Implementing agile data workflows can facilitate the integration of climate data into climate-resilient urban planning. However, the complexity of (supra)national, regional, and municipal policies, laws, governance structures, as well as geographic and climatic variations, means there is no one-size-fits-all approach to climate-resilient urban planning. The challenge lies in effectively integrating agile data workflows into existing management processes and governance structures.

Agile management, a concept originating from software development, offers a solution to overcome traditional management practices characterized by static waterfall models and slow stage-gate processes. It enables increased flexibility and agility to address the urgency of climate change. This master thesis proposes an approach to make management processes more agile in the context of climate change adaptation, using climate data through targeted communication and regular feedback loops among departments involved.

The city of Constance in southern Germany is pursuing a transdisciplinary co-development approach through the CoKLIMAx project. Involving the population, city administration, and political decision-makers is crucial for successfully integrating climate data into the planning process and establishing a climate-adapted city. Building upon the survey responses from 72 administrative staff members, a literature review on agile management in municipalities, the legal situation of climate adaptation in Germany and leading pracitces worldwide, recommendations for an agile workflow for resilient urban planning was developed for the city of Constance. The exemplary workflow was presented to nine selected members of the city administration, and their feedback was incorporated to adapt the workflow. While the workflow can be effective under the local conditions in Constance, it requires change management to introduce agile processes. Clear commitment from city employees and local politicians is essential to drive this process forward and ensure its successful implementation

Table of content

List of figures

List of abbreviations

Abbreviation	English	German
AMCDS	Advanced Municipal Climate Data Store	Erweiterter kommunaler Klimadatenspeicher
BauGB	Building Code	Baugesetzbuch
BMDV	German Federal Ministry of Digital Affairs and Transport	Bundesministerium für Digitalisierung und Verkehr
CAP	Climate action plan	Klimaaktionsplan
CCA	Climate change adaptation	Klimawandelanpassung
CDS	Copernicus Climate Data Store	Copernicus Klimadatenspeicher
CI	Climate Information	Klimainformation
DAS	German adaptation strategy	Deutsche Anpassungs Strategie
EBK	Waste management	Entsorgungsbetriebe Konstanz
EU	European Union	Europäische Union
HAP	Heat Action Plan	Hitze Aktionsplan
HBA	Buildings Department	Hochbauamt
IPCC	Intergovernmental Panel on Climate Change	Zwischenstaatlicher Ausschuss für Klimawandel
LBO	State building codes	Landesbauordnung
NWS	National Weather Service	Nationales Wettersystem
PWWS	Philadelphia Heat-health watch warning system	Philadelphia Hitze-Gesundheitswarnsystem
ROG	Spatial Planning Law	Raumordnungsgesetz
SCAP	Strategic climate action plan	Strategischer Klimaaktionsplan
TBK	Technical operations	Technische Betriebe Konstanz
UBA	Federal Environmental Agency	Umweltbundesamt
UE	Department of urban planning and environment	Amt für Stadtplanung und Umwelt
UNEP	United Nations Environment Programme	Umweltprogramm der Vereinten Nationen
UNIS-D	Environmental and nature conservation information system	Umwelt- und Naturschutzinformationssystem

1. Introduction

The increasing urgency of implementing climate-resilient urban planning has become evident in numerous cities worldwide as they struggle with the severe impacts of climate change [1, 2].
Coastal cities, which constitute over 90% of all urban areas are characterized by high-risk geographical locations and high population density, are particularly susceptible to rising sea levels, coastal flooding, heatwaves, and fresh water scarcity [3]. Areas that are not directly on the coast, but along the course of a river, are also threatened. According to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the damage from river flow overtopping is projected to increase threefold with a global warming of 1.5°C, fourfold with 2.0°C, and sixfold with 3.0°C temperature increase [4].

To mitigate the adverse effects of climate change and build resilience in communities, urban planners and policymakers must prioritize adaptive strategies. This involves the development of sustainable infrastructure, green spaces, and efficient resource management systems to ensure the well-being and safety of residents in the face of a changing climate. Vulnerable urban areas offer compelling opportunities to implement strategies for climate change mitigation and adaptation, such as the development of adaptation plans incorporating rainwater harvesting systems or green infrastructure [1].
However, despite the pressing need for adaptation measures, a significant portion of funding has primarily been allocated to mitigation efforts [5]. The estimated funding gap for climate change adaptation (CCA) is tenfold [6]. It is crucial to recognize that mitigation and adaptation are not mutually exclusive but complementary aspects of climate protection. While early mitigation efforts can help prevent damage and adverse impacts, adapting to the irreversible changes that have already occurred remains essential [7, 8]. Striking a balance between mitigation and adaptation enables urban planners and policymakers to effectively address the multifaceted challenges of climate change and promote sustainable, resilient communities. As the European Commission aptly stated: “(…) we must prevent what we cannot adapt to and adapt to what we cannot prevent” [6, p. 2]. For these reasons, it is necessary to give the required importance to the adaptation to climate change, with financial and human resources.
Local decision-makers play a crucial role in implementing climate-resilient urban planning due to their firsthand knowledge of their cities' needs and their position at the forefront of climate change impacts [9]. Furthermore, they are optimally situated to drive change [7]. However, these decision-makers face constraints imposed by national and local regulations and must effectively communicate their requirements and progress to higher levels of government. Adopting a bottom-up approach facilitates the transmission of local knowledge to higher levels, thereby enabling access to funding for targeted measures [5, 7, 9]. To empower municipalities with the necessary knowledge, further training is required, especially in handling climate data and conducting climate analyses, as highlighted in a survey conducted by the German Federal Environment Agency [10]. Half of the surveyed municipalities identified this topic area as a training need.
An essential consideration in climate-resilient urban planning is the risk of maladaptation. This refers to the implementation of measures intended to promote adaptation but inadvertently exacerbate vulnerability due to erroneous decisions, such as neglecting biodiversity or autonomous adaptation [5, 11]. Ill-conceived planning not only wastes valuable resources but also increases societies' susceptibility to climate change impacts [7, 12]. To mitigate the risk of maladaptation, clear metrics for evaluating the effectiveness and efficiency of adaptation measures are imperative. This requires continuous reporting, reassessment, and utilization of data

[7, 13]. At the local level, this approach equips decision-makers and administrators with the necessary tools to make informed choices [13, 14]. By prioritizing evidence-based planning and ongoing evaluation, urban planners can better protect communities from the unintended consequences of maladaptation and enhance their resilience to climate change.

1.1. Research question

The current master thesis is conducted within the framework of the CoKLIMAx project, which aims to empower public administrators in designing, establishing, and preparing for the implementation of agile data workflows. Within the broader scope of this project, the specific objective of this master thesis is to explore and identify communication structures within the city administration and develop an exemplary agile workflow. The city of Constance and its city administration have been selected as the focus of this investigation. This thesis aims to address the following research question: What challenges hinder the integration of climate data into administrative processes in the city of Constance, and can they theoretically be overcome through the implementation of an agile workflow?

1.2. Methods

The initial stage involved conducting a comprehensive literature review to examine leading practices worldwide and the current status of climate change adaptation implementation in Germany. In the subsequent phase, an evaluation was carried out on a questionnaire developed by the CoKLIMAx team of scientists, which was administered to municipal employees in the city of Constance. The aim of the survey was to gain insights into the current processes related to climate change adaptation (CCA) and assess the strengths and weaknesses associated with incorporating climate data into urban planning. This qualitative approach sought to uncover existing structures, communication channels, and potential areas for improvement.
Drawing from the participants' responses, further literature research was conducted on agile management and the spatial planning framework in the state of Baden-Württemberg, where the city of Constance is situated. Subsequently, a workflow was designed to streamline the utilization of climate data and integrate it into existing administrative structures, such as the preparation of development plans. The objective of this methodology was to enhance the capacity of municipal stakeholders to make informed decisions and implement climate-resilient urban planning strategies. In the third phase, the agile workflow was presented to a selected group of city administration staff, and their feedback was obtained. Finally, the workflow was revised based on the received feedback.

2. Leading practices worldwide

Cities around the world are struggeling with the consequences of climate change and the implementation of climate change adaptation measures. Various approaches exist: some cities or regions focus on specific issues, such as developing a Stand-alone plan like a Heat Action Plan (HAP) and implementing individual measures that contribute to an overall adaptation strategy. Examples of such cities include Philadelphia, Melbourne, and Rotterdam [15]. Other regions adopt a different approach by implementing individual measures for different areas as part of a comprehensive strategy (e.g. Copenhagen [16], Durban [17] and King County [18]). In the following, two examples of each approach are described in more detail, highlighting their specifications and particularities.

In 1995, Philadelphia became the first city in the United States to introduce a heat-health watch warning system (PWWS). This system involves continuous communication between local city officials and the National Weather Service (NWS). The plan consists of four phases: raising public awareness about heat stress before the onset of the heat season, issuing warnings about potential heatwave outbreaks, taking immediate actions to protect the public during heatwaves, and collaborating with local utilities to manage extreme heat events. The measures during a heatwave are diverse and include informing the public about cool places, assigning "block captains" to check on the well-being of the elderly in their neighborhoods, and providing telephone services for medical advice [19]. The implementation of the PWWS has had a significant impact: Heat-related deaths have declined from the 1990s to the 2010s to one-fifth of their original level [20]. Following this success, approximately 50-60 other cities in the United States have developed similar plans based on the PWWS model, with a prerequisite of a population of at least 500,000 and access to a local meteorological office [21].
In 2018, Philadelphia launched the "Beat the Heat" project, taking a different approach by developing a heat response plan specifically for a highly affected neighborhood. The project placed a strong emphasis on engaging the local community to address the existing inequalities among population groups and the associated increased vulnerability to heat. The Hunter Park neighborhood was selected as the project site due to its high temperatures and high vulnerability. A 30-member team comprising community organizations, government departments, and stakeholders collaborated to organize projects, surveys, and initiatives to enhance Hunting Park's resilience to extreme heat [22]. The project has served as a showcase example and has been implemented in other neighborhoods, thanks to the high level of community participation. Philadelphia has successfully engaged all segments of society, raised awareness about the issue, and demonstrated simple solutions. The analysis of over 600 completed surveys regarding experiences with excessive heat and visions for a more climate-resilient and cooler environment has provided the Office of Sustainability with valuable information to develop a citywide Climate Adaptation Plan. The objective is to understand how climate change will affect different areas of the city. Climate data, including land cover data to identify potential tree cover and average surface temperature data to create the Philadelphia Heat Vulnerability Index, were utilized for this purpose [22].

Another illustration of a singular plan is the Heatwave Plan for Victoria, Australia. This initiative was prompted by a severe heatwave in January 2009, during which there was an alarming increase of 374 deaths compared to the previous five-year period [23]. The State Government plays a role in facilitating the implementation of the Heatwave Plan, officially declaring a heatwave

based on weather forecast data. The local councils are responsible for executing the measures and conducting evaluations at the end of each heatwave. The rationale behind involving local councils is that they "are the closest level of government to communities, have knowledge about local demographics, as well as the human services in their districts, manage a significant portion of community-based services, have mandatory planning requirements with structured processes to support effective heatwave planning." [23, p. 2]. When developing a local heatwave plan, it is important to engage external local experts such as doctors, nursing staff, and specifically, the isolated elderly population. This process is iterative, with the heatwave plan being used to initiate context-specific measures. The plan undergoes evaluations during its preparation and after each heatwave, at the latest, at the end of each summer. The Victorian government provides citizens with a review tool for this purpose [23, 24]. The Heatwave Planning Guide contains a communication strategy. This part of the plan advises the local authority to design an internal communication structure in order to clearly distribute roles (proclaiming and ending the heatwave, instructing measures) and thus enable a quick response in case of emergency. Tips on how to improve internal, as well as stakeholder communication are given. The communication between the local councils and the Department of Human Services seems to be constant and supporting [23].

As an alternative to standalone plans, some cities, regions, or countries have adopted comprehensive strategies to address climate adaptation. The Durban Climate Action Plan (CAP) is a notable example of such an approach. Established in 2019, this plan outlines the city's transition towards becoming climate resilient. Care was taken to ensure that the CAP complements national and local strategies, avoiding redundancy [17]. The environmental planning and climate protection department, which was in charge of preparing the CAP, is certain of this: “Implementing the CAP will require a shift in climate governance and engagement in cross-cutting approaches to implementation.” [17, p. 15]
In early 2020, Durban released a Municipality Climate Story Map (see Figure 1). This interactive map enables city residents, as well as municipal decision-makers and planners, to explore various climate scenarios and compare their impacts on the city through a comprehensive lens.

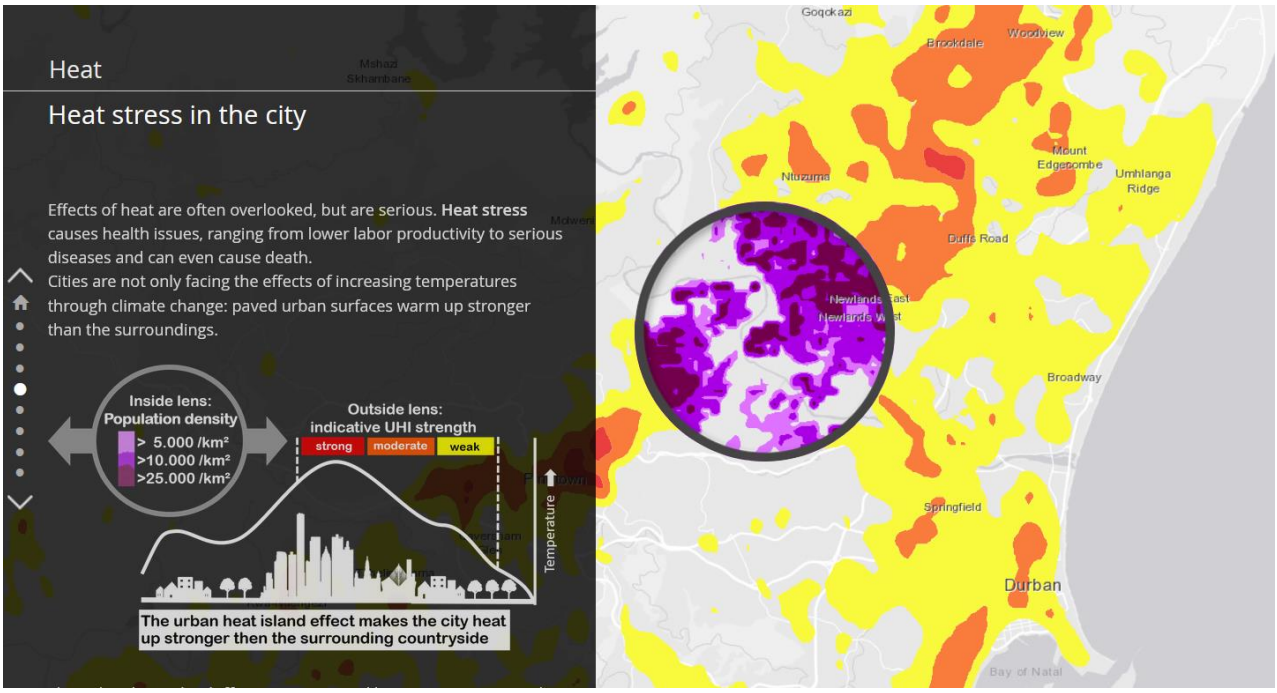

Figure 1: Municipality Climate Story Map, Durban [25]

The objective is to present the intricacies of climate change, its impacts, and potential adaptation measures in a clear and comprehensible manner through maps and graphics [26]. The story map is categorized into Heat, Drought, Pluvial and Coastal Flood sections. Climate change projections for RCP2.6, RCP4.5, and RCP8.5 are utilized in the data. The story map operates on ArcGIS [25].

In King County, Washington, USA, a Strategic Climate Action Plan (SCAP) has been implemented. Launched in 2015, it is updated every five years, with the latest version from 2020 [18]. The plan encompasses three sections: "Reducing Greenhouse Gas Emissions," "Sustainable & Resilient Frontline Communities - A Climate Justice Framework," and "Preparing for Climate Change." The middle section, addressing climate equity and community-driven policies, was introduced in 2020 [27]. The plan also emphasizes integrating climate considerations into the daily work of administrative staff. This entails the adoption of strategies, planning processes, and project implementation methods that incorporate climate concerns into agency operations [28].
Similar to Durban, King County has a Climate Change GIS Open Data Portal alongside the SCAP [7]. This portal is designed for individuals proficient in GIS and supports them in utilizing spatial analysis for climate change impact preparedness and adaptation. The information is made accessible through ArcGIS Hub [29].

Successful plans and actions, as demonstrated by these leading practices, have largely been achieved through sustained community involvement. Research indicates that immediate action has been triggered not only in the mentioned examples but also in numerous other cities and regions worldwide [15, 23, 30].
The integration of plans and measures regarding climate change and adaptation to it is seen as a challenge by all researched regions. Especially the involvement of the population and the restructuring of administrative processes are described as hurdles [7, 15, 17, 31].

3. Climate change adaptation in Germany

In Germany, climate adaptation is overall guided by laws of the European Union (EU). The concretization of measure planning and regulation is further established by laws an regulations issued by the German government. This is followed by a further concretization with the consideration of the use case of the city of Constance. The project CoKLIMAx and the stakeholder survey conducted in this context and its results are presented.

3.1. Legal situation and status quo

As a founding member of the EU, Germany is subject to EU law and must act in accordance with its provisions [32]. In 2013, the EU adopted a strategy for adaptation to climate change for the first time [33, 34]. This was updated in February 2021 and is entitled "Building a climate-resilient Europe - the new EU strategy for adaptation to climate change". In this strategy paper, the idea of making climate information available to eager people from all dicilines and social structures is taken up and the urgency to collect climate-related data and to bring them and gained knowledge and information together is recognized [6].
Only a few months later, the EU Climate Change Act was passed on 24.06.2021. This law transforms political promises from the EU Green Deal (becoming the first continent to be climate-neutral by 2050 [35]) into binding commitments. It thereby provides legal certainty and predictability to be prepared for the upcoming change. Article 5 (4) stipulates the development and implementation of a national adaptation strategy [36].
In Germany, the German Adaptation Strategy (DAS) was already adopted in 2008 [37]. This strategy laid a first building block for sustainable development and showed a roadmap for the implementation of adaptation measures, which is to be concretized in the further process of adaptation. The German states are to be closely involved in this process. In this first version of the adaptation strategy, the German government speaks of two pillars of German climate policy: climate protection and climate change adaptation [38]. Already at this point, the question arose "how impacts of climate change could be systematically taken into account in future governmental and administrative action and what conditions must be created for this to happen." [38, p. 60]. The DAS is regularly evaluated and further developed with the help of monitoring reports, climate impact and vulnerability analyses [39]. In 2019, the Federal Environment Agency (UBA) conducted a survey on the impact of the DAS for municipalities. This showed that only a few municipalities have implemented a project with the help of DAS funding and that the newsletters, manuals and publications provided by UBA are also only known by a quarter of the municipalities participating in the survey. The lack of personnel and the lack of target group-specific applicability of the measures to the concrete needs of the municipalities are cited as hurdles here [10].
Adaptation strategies also exists at the state level. Germany has 16 states which have their own laws. They all rule under the organizational principle of federalism. That means that the federal states participate in the legislation of the federal government. Like this the exercise of governmental powers and the performance of governmental functions is supposed to be a matter for the federal states, unless the Basic Law permits otherwise [40]. In 2013, the state of Baden-Württemberg (in which the City of Constance as our use case is located) announced its first climate protection and adaptation law. At the 7th of February 2023 the law has been amended. One goal ist to become climate neutral by 2040 [41]. Paragraph 15 is the only one that mentiones climate adaptation. It is written there that beginning in 2023 and at appropriate intervals thereafter, the

state government shall adopt a statewide adaptation strategy and adaptation measures based on the adaptation report [42].
In 2015, the state of Baden-Württemberg published its strategy for adaptation to climate change. The strategy is divided into the following fields of action: forest and forestry, agriculture, soil, nature conservation and biodiversity, water balance, tourism, health, urban and spatial planning, and economy and energy industry. Each of these fields of action is introduced and effective climate factors, vulnerability and impact of climate change are discussed. For possible measures, examples are given and the respective responsibility and affected actors are named [43]. This strategy provides cities and municipalities with recommendations and implementation proposals for climate change adaptation. The climate change adaptation stragegy is currently being revised and a new version will be published this year [41]. The consideration of climate data does not play a role in the adaptation strategy. The Monitoring Report 2020 on the Adaptation Strategy to Climate Change in Baden-Württemberg, prepared by the Ministry of the Environment, Climate and Energy Management, clearly shows that there is a lack of reliable data for the further development of climate models and the analysis of climate impacts and the planning of adaptation measures [44].

The next step of this thesis was to take a look at how the Federal Republic of Germany deals with (climate) data.
In 2021, the data strategy of the Federal Government was published [45]. According to the federal government, there is room for improvement at the municipal level: "With around 11,000 municipalities, there are only about 90 municipal Open Data portals, although this is where most data is generated" [45, p. 52]. One goal of the data strategy is to develop a new generation of climate information services and local climate modeling. The development and operation of a central national portal for environmental and conservation data and information (UNIS-D) is highlighted here as a possible tool. Through this environmental and nature conservation information system, a broad group of the population, from the interested layperson, to the administrative employee, to the specialized scientist, should be granted access to all collected environmental and nature conservation information from the federal, state, and local governments [45].
In 2021, a feasibility study on UNIS-D was published by the Federal Environmental Agency. It speaks of a time frame for implementation of five years. According to the authors, basic feasibility from a technical, organizational and legal point of view is possible. The current fragmentation of specifications for the provision of environmental information and data is seen as a major hurdle [46]. However, no information on the current status of UNIS-D implementation was found in the course of the present research.
The position of geoinformation as basic data is seen in the data strategy as follows: "Geoinformation and Earth observation data are indispensable when it comes to providing answers to societal challenges such as climate and environmental protection (...) and thus form a cornerstone for a digital value chain." [45, p. 53]
In summary, intensive research is being conducted at all national levels and across the EU on the topic area of climate change adaptation and also the provision of environmental data. In the next chapter, some projects in Germany will be presented, which deal with climate change adaptation on the municipal level.

3.2. Use case city of Constance

Constance, the largest city located at Lake Constance in Southern Germany, is home to a population of over 87,000 people [47]. Being a regional hub within the state of Baden-Württemberg and a border city to Switzerland, it holds significant importance on a superregional scale. In a pioneering move, Constance became the first city in Germany to declare a climate emergency. On May 2, 2019, the authorities signed a declaration, symbolizing the city's commitment to unite all sectors of society - social, political, cultural, and economic - to mitigate the impacts of climate change and prepare for the future. This resolution underscored the city's recognition of the urgent need to address climate change comprehensively, providing a political and legal framework for swift and prioritized administrative and decision-making processes [48]. On November 25, 2021, the City Council adopted the Constance Climate Protection Strategy, setting the course for achieving maximum climate neutrality by 2035 [49]. Another significant step toward sustainable urban development and planning occurred on July 19, 2022, with the establishment of a dedicated Climate Office under the direct mandate and guidance of the Mayor [50]. It is to be built up as shown in Figure 2. The department is divided into a top level with assistance, the office management and coordination of climate protection strategy (from left to right) and on the bottom level climate-neutral administration, mobility management and municipal support programs Climate protection (from left to right). It can be seen clearly that the topic of CCA is not seen in this department.

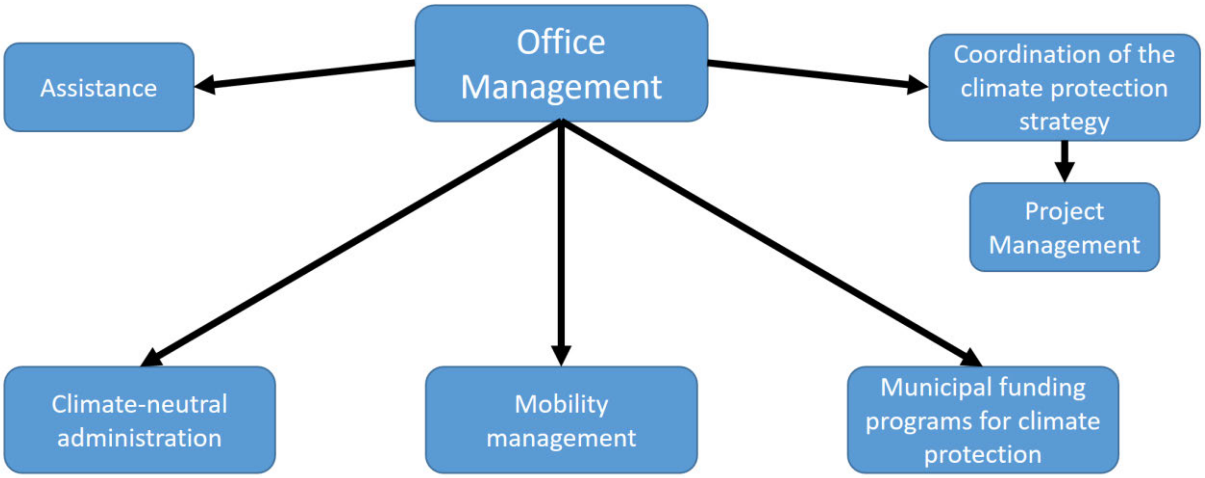

Figure 2: Organizational chart of the Climate Protection Office, own illustration, based on [50]

Simultaneously, the Urban Planning and Environment Department (UE) is undertaking the development of a comprehensive set of measures for future climate change adaptation in both private and public spaces. This catalog is scheduled for completion by 2024. As a preliminary step, the climate function maps, which were initially created as part of a climate analysis in 2015, need to be updated. Additionally, a vulnerability analysis encompassing the entire urban area is currently in progress [51]. This process runs independently of the structure and staffing of the Climate Office and is entirely dedicated to the area of CCA.

Furthermore, there is a climate change adaptation project group within the city administration consisting of employees from the department of urban planning and environment, the waste department, the department of real estate and geoinformation, technical operations, the buildings department, the department of underground construction and often the press department. They meet as needed about once a month. The aim is to draw up a concept of measures and to coordinate immediate measures on the subject of climate change adaptation [52].

3.2.1. The CoKLIMAx project

Within the CoKLIMAx lighthouse project, which receives funding from the German Federal Ministry for Digital and Transport (BMDV), researchers from HTWG Konstanz, the University of Stuttgart, the German Climate Service Center GERICS, and city administration officials are collaborating to explore the practicality of climate data, including Copernicus data products [53] and in-situ measurements, for urban szenarios. The primary objective is to develop an Advanced Municipal Climate Data Store (AMCDS) Toolbox that enables climate-resilient urban planning based on reliable climate data [54]. The architecture of the CoKLIMAx project is depicted in Figure 3, with the AMCDS Toolbox highlighted within the blue circle. One goal of this thesis is to include the toolbox into an exemplary municipal process.

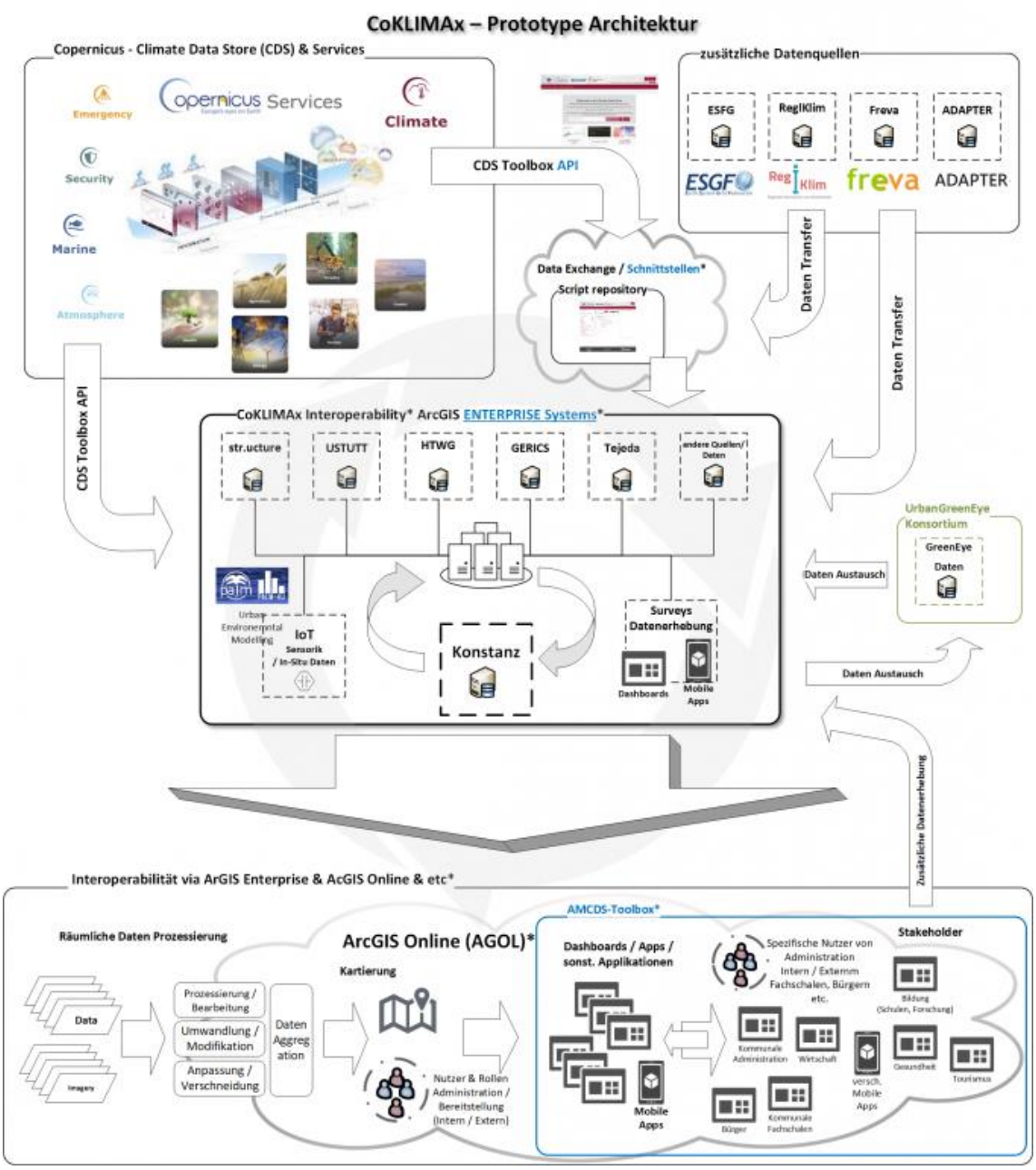

Figure 3: Data sources, data streams and data processing functionalities in the present application context, including the AMCDS toolbox [54]

The project structure offers a unique advantage by being integrated into the administrative framework of Constance. The project management, situated within the city administration, maintains direct contact with scientific experts from various partner organizations and engages closely with key administrative officials. Furthermore, a direct link to the City Council is established through the participation of a Council member who also serves as a key researcher in the CoKLIMAx project. This collaborative effort, encompassing diverse disciplines and levels of governance, ensures a holistic understanding of the opportunities and challenges associated with utilizing climate data for urban planning and decision-making. It fosters a participatory and co-creative process that promotes comprehensive development.

In addition to the important collaboration between the scientific and administrative spheres, the involvement of civil society is a significant aspect of municipal climate change adaptation. The

project includes Citizen Science workshops, providing an accessible platform for the local population to contribute their valuable expertise and actively participate in the process [55].

A key aspect of the project involves utilizing existing climate data. For instance, the comprehensive datasets from the Copernicus Climate Data Store (CDS) [56] are evaluated, categorized by relevance, and provided to city administration personnel along with simplified explanations tailored for non-scientific users. This utilization of CDS data by municipal staff is a component of the AMCDS Toolbox. The overarching goal of this toolbox is to provide accessible access to Copernicus data, climate data, as well as maps, dashboards, (mobile) apps, and other applications that include visual imagery. Ensuring a user-friendly and intuitive interface is highly important for both administrative stakeholders and the general public [54, 57].

Conducting a comprehensive assessment of requirements is an essential initial phase in order to tailor the toolbox according to the specific needs of stakeholders for utilizing climate data in municipal operations. The following section will introduce in more detail the stakeholder survey that was conducted among administrative staff.

3.2.2. Stakeholder survey

To establish trust and ensure a high response rate, the stakeholder survey was carefully introduced to the administrative staff of the City of Constance by the project management. A selected group of employees from various departments involved in climate change and protection, geoinformation, urban planning, and development were targeted.
As part of the co-development approach, the survey was conducted among 72 administrative employees between May and July 2022. The primary objective was to assess the current utilization of climate data, the willingness to employ such data, communication channels within the administration, and major challenges faced by stakeholders. Bivariate statistical methods were applied to analyze the survey results, revealing correlations between different questions and providing valuable insights into administrative management and governance structures.
The survey addressed several key questions to guide the development of an optimal workflow for integrating climate data into urban planning processes, including:

1. Is climate data currently used in your field of work?
2. Are you interested in utilizing climate data within your area of expertise?
3. Which departments should be more actively involved in communication regarding climate change adaptation?
4. At which level(s) (administration, citizenship, and City Council) do you perceive the greatest challenges in incorporating climate adaptation measures into urban planning?

This survey represents an important step towards achieving the project's goal of developing a requirements analysis for effectively utilizing climate data in municipal operations. For a more detailed analysis of the survey, please refer to Harrs et al. (in prep.) [58].

The largest group of participants in the survey are employees from the Department of Urban Planning and Environment (UE), followed by Waste Management (WM). Figure 4 shows the number of participants and their assignment to each department. The distribution of participants

does not reflect the size ratio of each office. This has to be taken into account in subsequent interpretations.

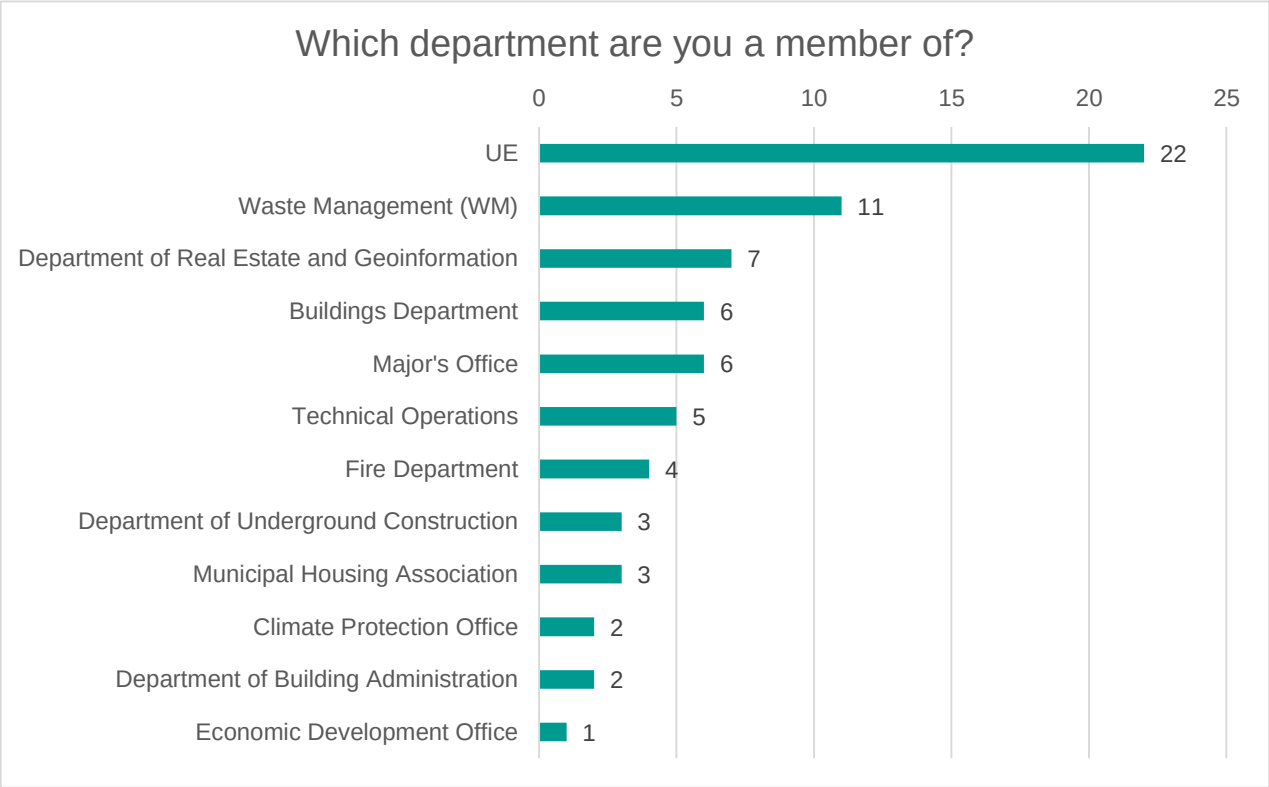

Figure 4: Assignment to the municipal offices and institutions, own illustration

To recognize the relevance of climate data in the municipal administration, the inquiry was made regarding the processes or areas of urban planning that would benefit from processed climate information and anticipated climate changes (see Figure 5). The responses highlight four areas that would particularly benefit: integration into development plans (43 mentions), the analysis of the impact of climate change (42 mentions), the consideration of climate data in strategic goals of the city (42 mentions) and climate data as an information basis for specialized planning (42 mentions).

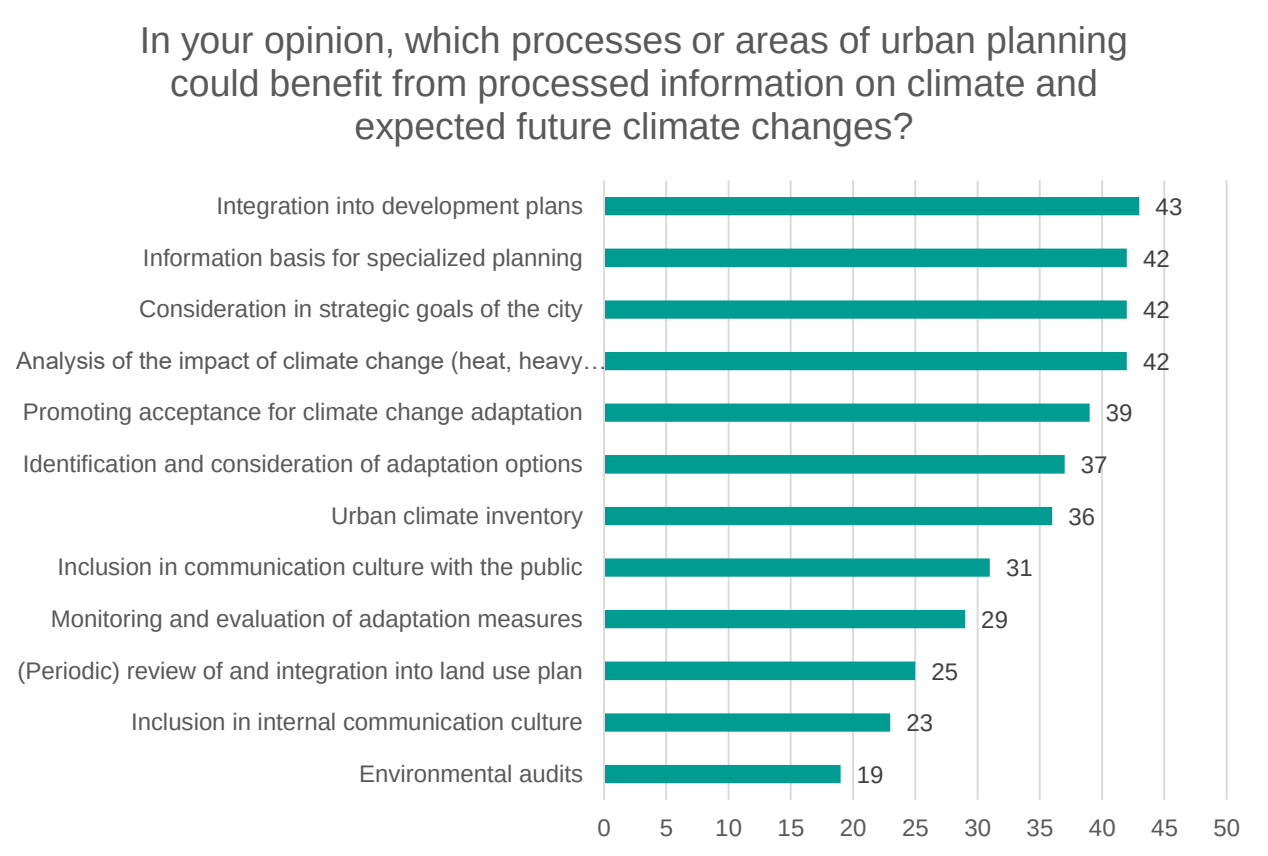

Figure 5: Processes or areas of urban planning that could benefit from processed information on climate and expected future climate changes, own illustration

In order to make administrative processes more agile, good communication between the relevant departments is a crucial requirement [59]. The following Figure 6 illustrates as a Matrix how the departments assess communication with other departments. In this representation, the red color indicates a desire for significantly increased communication, while the yellow color represents a preference for somewhat more communication. If a field is colored green, it signifies that communication is deemed sufficient. Conversely, if there is no perceived need for communication with another department, it is depicted in white.

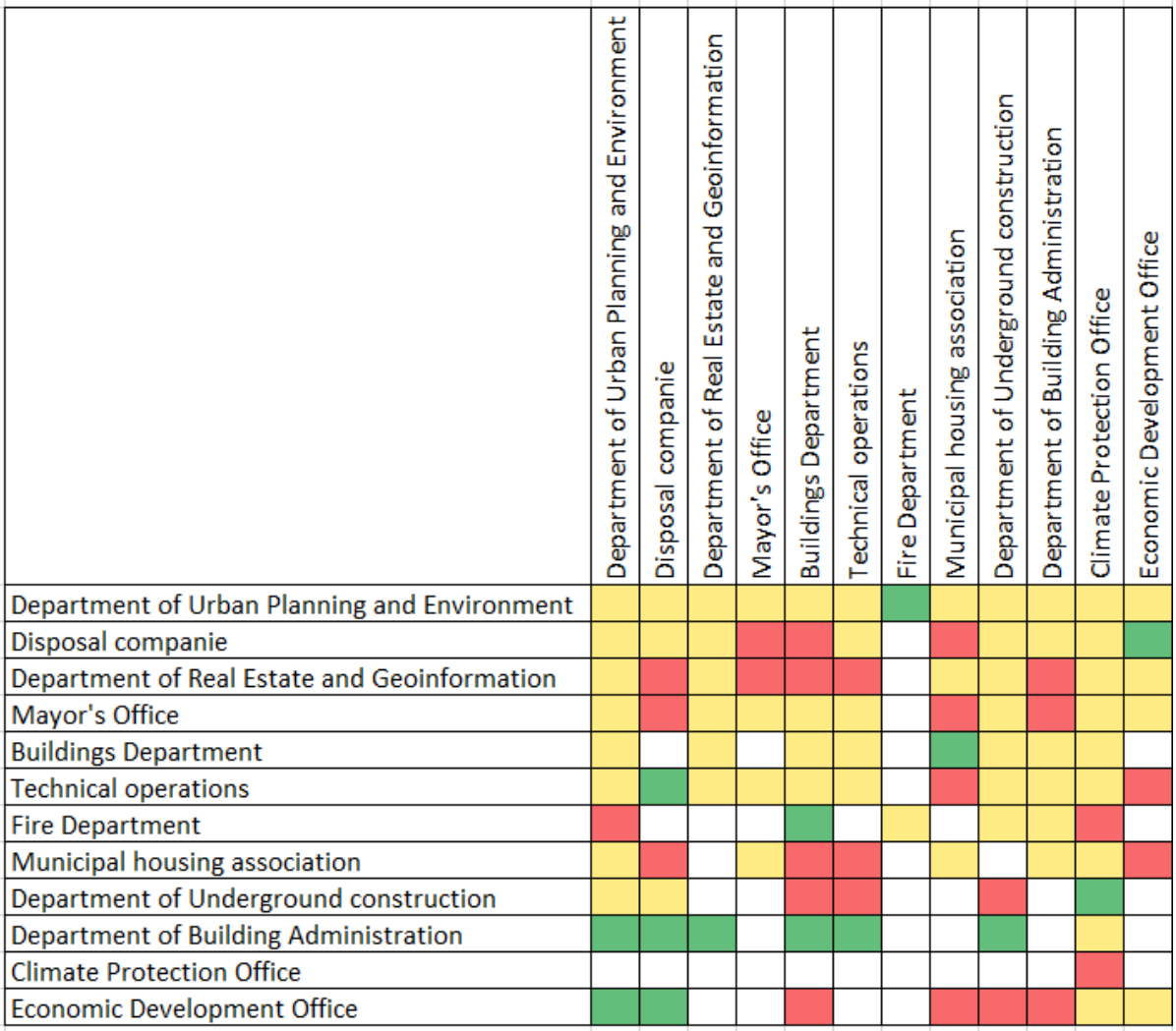

Figure 6: Communication between different Departments, own illustration

Most desired is to strengthen communication with the Buildings Department, the Municipal Housing Association, the Department of Underground Construction, the Department of Building Administration and the Climate Protection Office. It is also notable that there is not a single office that sees the communication inside the own department as sufficient.

To ensure the future integration of climate data into administrative workflows, it is crucial to determine which departments are currently utilizing climate data. The survey revealed that only 23.6% of the surveyed municipal employees are currently using climate data, with no specific department showing a significant increase in its usage (see Figure 7).

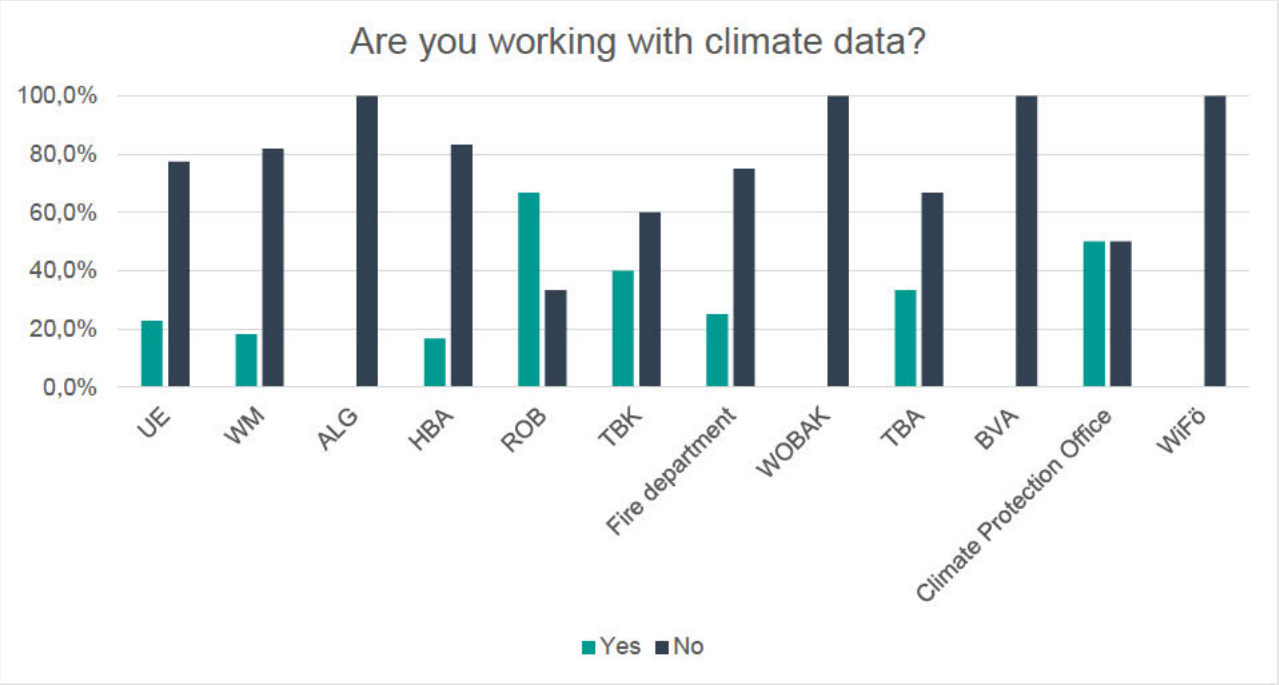

Figure 7: City administration working with climate data, own illustration

However, 41.8% of the respondents expressed a desire to work with climate data, with the Department of Urban Planning and Environment showing particularly high interest compared to other departments (see Figure 8).

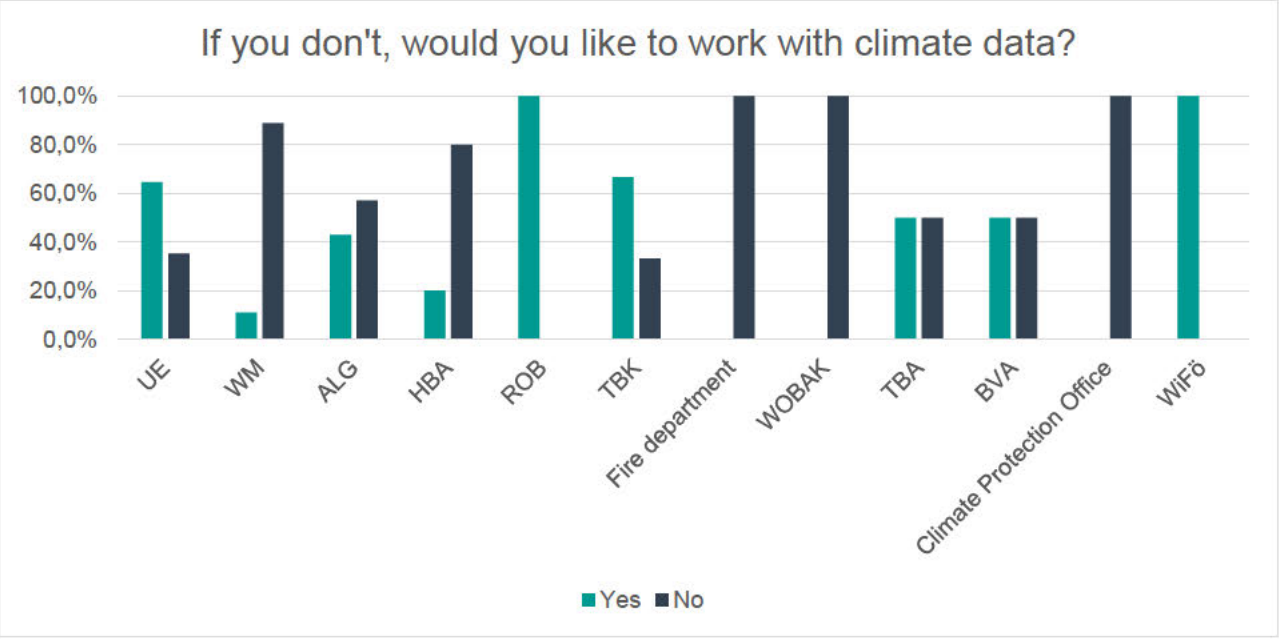

Figure 8: Willingness to work with climate data in the future, own illustration

In the context of digitalization and data integration in existing administrative processes, several challenges were identified (see Figure 9). These include a lack of employee know-how, increased work volume due to digitalization, and resource constraints or high investment costs. These

findings align with the latest report from the Intergovernmental Panel on Climate Change (IPCC) [31] and [60].

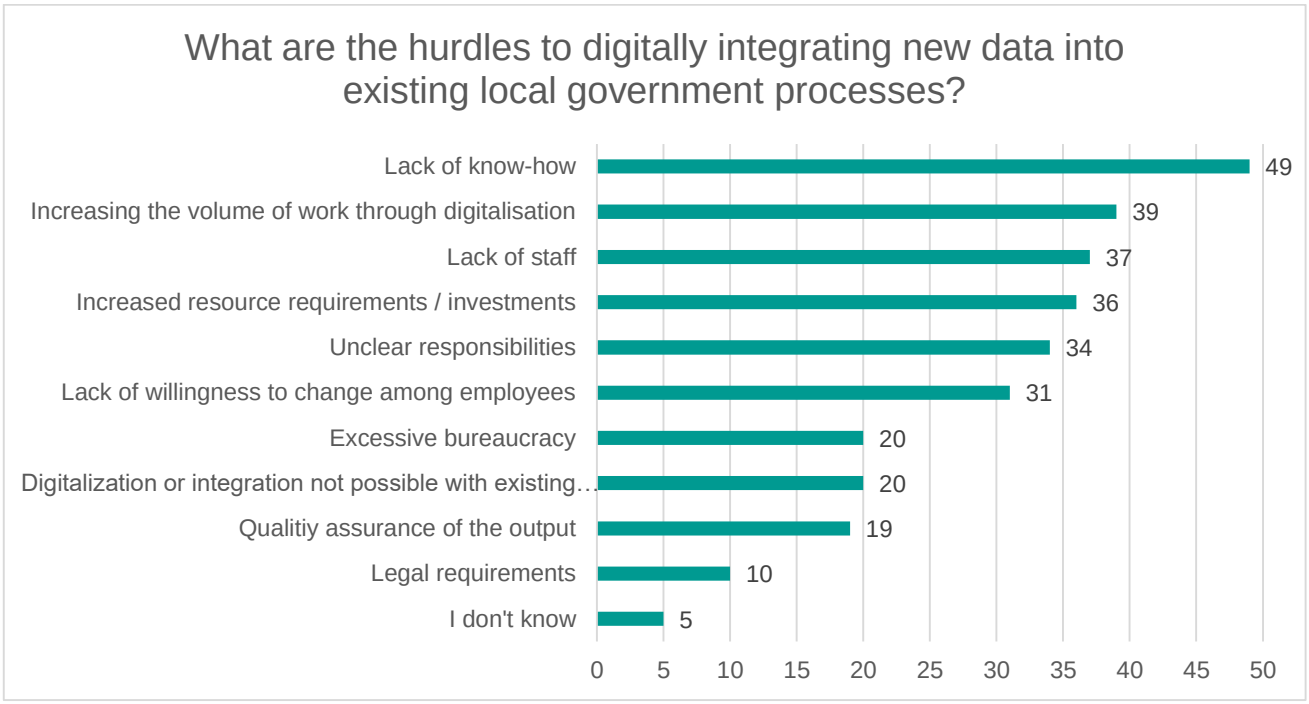

Figure 9: Hurdles in integrating data into existing processes, own illustration

This survey laid the basis for a deeper literature review on management methods and the legal situation of spatial planning in Baden-Württemberg to develop an exemplary workflow afterwards.

4. Development of an agile data workflow for the city of Constance

Taking into account the aforementioned stakeholders' concerns and previous research on leading practices some more investigation was done on the topics of agile management especially in municipal administrations and the structure of spatial planning in Baden-Württemberg. Afterwards an illustrative workflow was developed to demonstrate the agile integration of climate data into the administrative process of urban land use planning, using the city of Constance as an example.

4.1. Agile management in municipal administration

Due to the hierarchical structure of municipal administrations in Germany (monocratic administrative organization), work is carried out according to the classic waterfall project management approach [61]. This approach is siutable for Day-to-day business but has clear limitations when it comes to reacting to changes and adapting to new conditions. This is due to the structure of this management approach: the goal here is to have planned the entire project from start to finish and to implement it according to these steps [62]. Municipal administrations face profound governance and management challenges in dealing with climate change and adaptation. The urgency of climate change demands flexible and rapid actions. Aligning with the goals of the 2015 Paris Agreement (COP21) to limit warming to 1.5°C and adapt to existing impacts necessitates critical reflection and a transformation of administrative structures [63]. One way to overcome the slow and bureoctatic monocratic administrative organization is through agile management methods.

Agile management has its origins in software development [59, 64, 65]. In 2001, 17 experts elaborated a manifesto on agile management based on the following principles:

- “Individuals and interactions are more important than processes and tools
- A software that works well is more important than extensive documentation
- The cooperation with project stakeholders is more important than contract negotiations
- Responding to change is more important than sticking to a rigid plan” [66].

Agile management has extended its application beyond software development, encompassing transformation projects and organizational development in various sectors [64]. As Morisio et al. (2020) emphasize, "Traditional Organizations Cannot Cope with New Demands" [65, p. 13], a sentiment that resonates even more in current times and emergent disasters. Particularly in time-critical projects, traditional project management methods encounter limitations, and the integration of flexibility and reduction of bureaucracy pose significant challenges [65]. An agile framework tailored to public administration should cater to the specific needs of individual departments while maintaining a holistic organizational perspective. The objective is to enhance efficiency, adaptability, and communication through digital administrative processes and streamlined information and data flows. Agile structures enable swift adjustments through continuous solution elicitation. Key elements of agile management include a willingness to experiment, embrace feedback, and iterate early and regularly [59].
The essence of agile management lies in transcending traditional delineations of responsibilities and subject areas. When responsible employees from relevant offices convene regularly to

exchange ideas, flexible and agile work becomes possible [67]. The IPCC aswell as the United Nations Environment Programme (UNEP Adaptation Gap Report (2022)) see the need for system change in order to face the challenges of CCA [13, 68].
Although agile administrations are not yet pervasive, the Swedish city of Ängelholm stands as a notable example of implementing agile administrative management in 2015. Traditional administrative practices have not been entirely supplanted by agile methodologies; instead, the two approaches complement each other [69]. The agile approach is implemented through so-called arenas, very concrete problems are discussed. This brings together everyone who can contribute to the issue. These are employees of the relevant offices, external experts if necessary, but also affected citizens, associations and businesses. An arena is accompanied by process controllers, who are also employees of the administration and carry out this task in addition to their daily business. Through this structure, communication is strengthened, thinking beyond one's own departmental boundaries takes place and the affected citizens are included [70]. The arenas focus on citizen-oriented topics that should be solved in no more than five sessions. Before convening an arena, consideration is always given to whether a conservative or agile approach will bring the better solution to the current problem. The agile approach is chosen when the administration is not able to solve a citizen's problem in a conservative way, the level of service is not sufficient or it is a time-critical project (e.g. threat to public safety) [71].

4.2. Structure of spatial planning in Baden-Württemberg

The following subchapter provides an overview of the hierarchy and structure of spatial planning in Baden-Württemberg. It serves as a classification and shows the position of the development plan in spatial planning as preparation for the implementation of the agile data workflow in the process of development plan creation.
The structure and hierarchies of the various spatial planning plans in Germany differ significantly from each other due to the principle of subsidiarity [72]. The focus of the master thesis is on the federal state of Baden-Württemberg, since the use case, the city of Constance, is located there.
In Baden-Württemberg, the model of regional planning by associations of municipalities is used. This divides the state into 12 regions. In addition to Baden-Württemberg, Brandenburg, Saxony and Saxony-Anhalt follow this model [72]. Figure 10 shows hierarchical levels of the different plans, the scale development and the relevant laws.

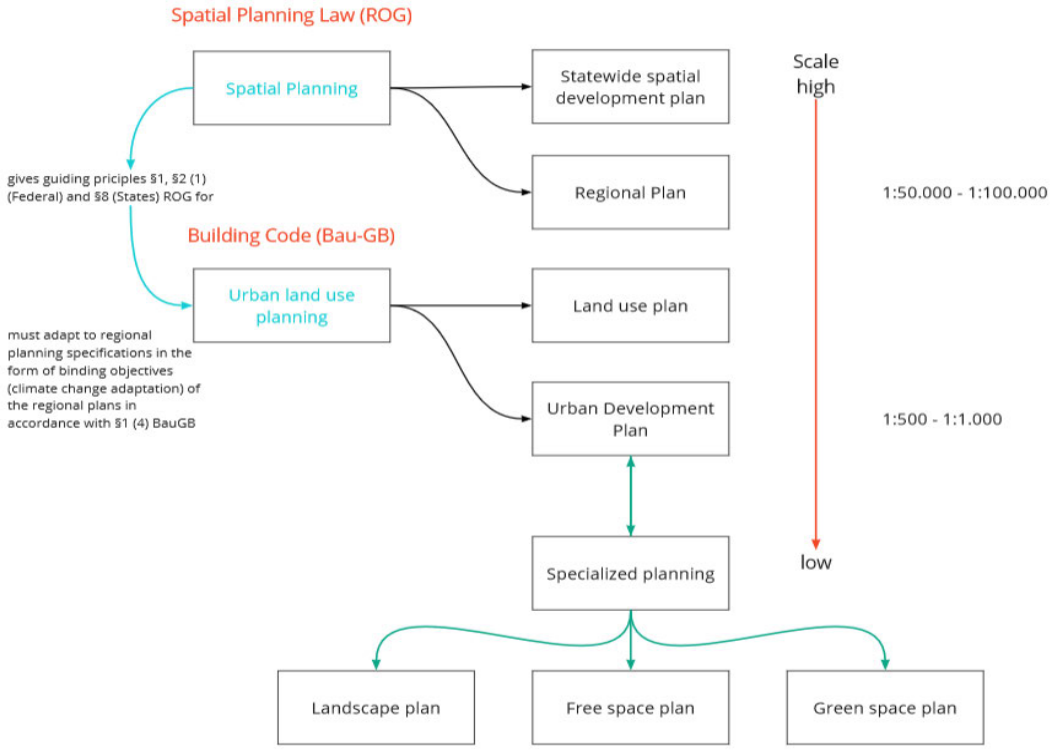

Figure 10: Hierarchy of planning levels in Baden-Württemberg, own illustration, based on ROG and BauGB

In the process of creating the regional planning plans, public and private concerns must be weighed against each other, but also among each other. Since the amendment of the national wide binding Building Code in 2011, the concerns of climate protection and climate change adaptation must be weighed equally with all other concerns [73, 74]. A detailed description on how an urban development plan is implemented is part of the following chapter 4.3.

4.3. Implementation of the agile data workflow

Considering the mentioned concerns of the stakeholders (see chapter 3.2.2) and the preceding research, an exemplary workflow for an agile integration of climate data into the administrative process of urban land use planning was created using the example of the city of Constance (Figure 11). The abbreviation TBA stands for the Department of Underground Construction and HBA for the Buildings Department.

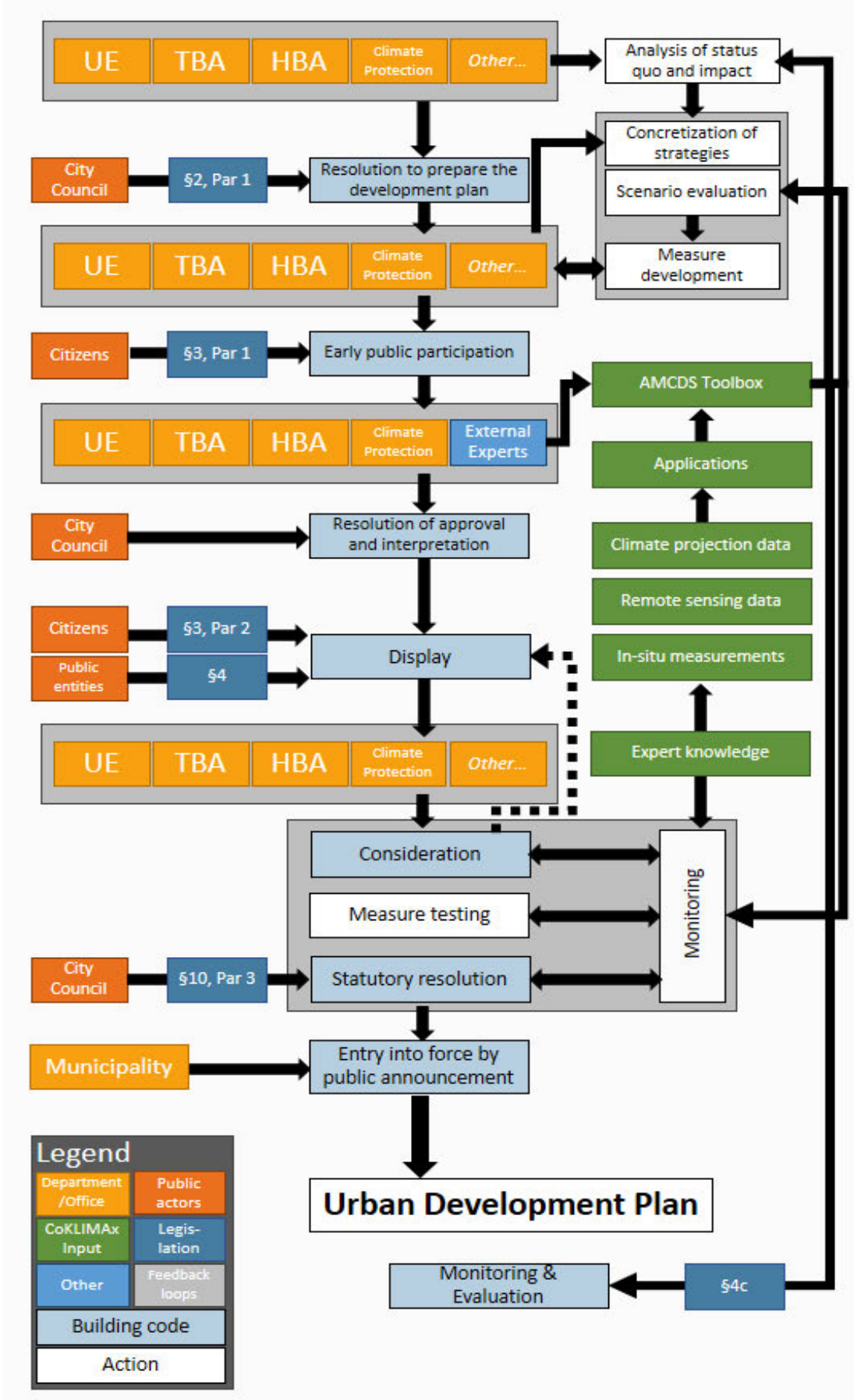

Figure 11: Agile data workflow for the implementation of an Urban Development Plan, own illustration

The survey results (Figure 6) indicate the crucial involvement of specific departments and offices in communication, forming an integral part of the agile data workflow. Constant feedback loops among these parties are represented by grey boxes, while the arrows depict the direction of communication, with double-sided arrows indicating ongoing exchange during a particular phase. The light blue boxes encompass established procedures of urban land use planning as dictated by the binding building code, substantiated by the relevant paragraphs. These legally binding processes offer multiple opportunities for the integration of the AMCDS Toolbox.

The building code is the basis for all construction projects in Germany [74]. The initial section of the law explains the fundamentals of urban land use planning, encompassing general regulations, the preparatory urban land use plan (land use plan), the binding urban land use plan (development plan), and cooperation with private entities. This workflow focuses on the first part of the building code. The subsequent six steps are necessary for the final approval of the development plan: (1) Preparation of the development plan, (2) Implementation by the city municipality after approval by the City Council, (3) Early public participation through the public display of the plan, (4) Involvement of external experts for the preparation of environmental and noise protection reports, among others, (5) Consideration of early public comments leading to a resolution of approval and interpretation by the City Council, followed by a second display for citizens and public interest entities. If the consideration of all balances results in significant changes, it is necessary to revise and repeat the application (6a, dotted arrow). If no serious changes are made, the City Council decides to establish the development plan through the statutory resolution (6b). The statutory resolution marks the stage where the final development plan is approved and becomes enforceable through public announcement by the city of Constance administration. Throughout this proposed workflow, the resources within the AMCDS Toolbox can be utilized in all stages, from informing the public about data-driven climate information regarding their immediate environment and planned changes to demonstrating and evaluating the impacts of the proposed measures.

After analyzing the survey data, four primary processes (Actions) have been identified as highly advantageous for the utilization and integration of climate data: (I) Assessment of the current situation and its impact, (II) Formulation of measures, (III) Adaptation and testing of measures, and (IV) Ongoing monitoring and evaluation. To facilitate these processes with data-driven information and applications, the AMCDS Toolbox is seamlessly incorporated into the proposed agile data workflow.

Once an urban development plan is entered into force, continuous monitoring and evaluation are legally mandated. These processes generate feedback data that can be utilized by the AMCDS Toolbox, empowering data experts to assess and refine the execution of the development plan. This reciprocal data flow contributes to the continual enhancement of data reliability and the ability to make future predictions for the city. The implementation of such a process necessitates either training and dedication from existing municipal employees or constant oversight from AMCDS Toolbox scientists. The feasibility of establishing such a process is thoroughly discussed in the subsequent section.

Given that the proposed workflow hinges on the involvement of the entire city and demands broad support from citizens and elected representatives, the participation of the City Council is of paramount importance. Garnering acceptance and backing for urban projects and achieving timely

outcomes can only be accomplished through the active engagement of all stakeholders. Consequently, raising awareness among citizens becomes a crucial task, as evidenced by successful practices adopted worldwide.

4.4. Feedback-Loop

During a workshop (online) on April 26. with nine employees of the administration of the city of Constance and the regional office, who had expressed their interest and willingness for further cooperation in the previous survey, the workflow was presented and feedback was gathered. After the event, a survey was sent to the participants of the workshop to ask precise questions and to give the employees the opportunity to deal with the topic in peace. The following questions were asked:

1. Is there an office that has been forgotten within the workflow but takes on a significant role? At which position?
2. Does one or more office(s) in the process not play a role (anymore) at one point? Or is positioned in the wrong place?
3. Is the integration of climate data at the presented points in the exemplary workflow comprehensible/feasible/meaningful? If not, why not?
4. What other processes can you think of (preferably from the topics of heat, water, and vegetation) that would benefit from such a workflow?

Unfortunately, the survey was completed by only one person. Since this employee is the head of the Urban Development Staff Office, he brings a lot of experience to the table and therefore his comments were taken into account and the workflow has been adjusted.

4.5. Workflow adaptation

One comment has refered about the section on the top right side of the workflow. The analysis of status quo and impact, the concretization of strategies and the scenario evaluation can be summarized in a vulnerability analysis which the city administration with the help of an external planning office is currently developing. It was suggested that this citywide vulnerability analysis should be used as the basis for developing measures rather than developing new ones for each development plan. This would save valuable time. This was taken into account in the workflow by moving this area slightly away from the rest of the process and clearly delineating it with a dashed line.
Regarding the offices involved into the preparation of a development plan, the necessity of the climate protection office was questioned. The employee pointed out, that the buildings department (HBA) would only be integrated into this process when the development plan concerns municipal projects. The waste management (EBK) and the technical operations (TBK) should be more involved into the process. In the workflow these comments were considered by exchanging the climate protection office with the waste management (EBK) and the technical operations (TBK) and by giving the buildings department (HBA) less meaning by giving this stakeholder a more faded color. The person who answered the survey also mentioned the integration of external experts (light blue, white letters in the workflow). For the development plan especially the

environmental report is of high importance. Taking into account the building code of Germany an environmental assessment must be done and an environmental report must be written (§2, Par 4) [74]. Annex one of the building code provides information about the structure of the environmental report. The following section should be highlighted:

2. “Part of the environmental report: a description and assessment of the significant environmental impacts identified in the environmental assessment (...), including the following information:”

b) “a forecast of the development of the state of the environment during the implementation of the planning; for this purpose, (...) in particular the possible significant effects during the construction and operation phases (...) are to be described, among other things as a result of”

gg) “the problems resulting from the impact of the planned projects on the climate (...) and the vulnerability of the planned projects to the consequences of climate change” [74]

At this point the usage of the AMCDS toolbox can support the external experts with important and valid information. In the workflow this was taken into account by adding the environmental report as a separate box and linking it to the AMCDS toolbox.

The following Figure 12 shows the evaluated and adapted agile data workflow for the process of an urban development plan.

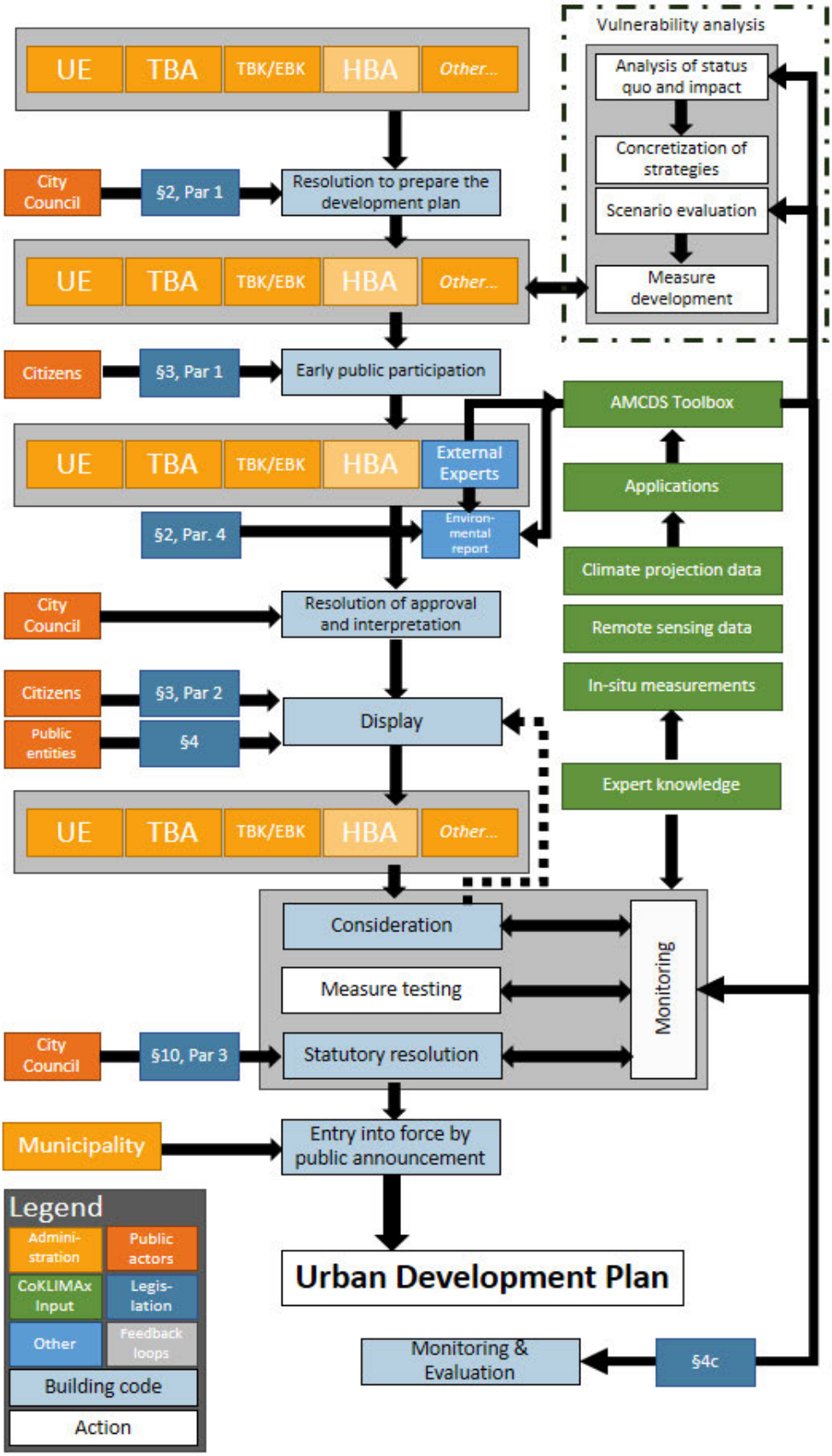

Figure 12: Adapted agile data workflow for the implementation of an Urban Development Plan, own illustration

5. Links and outlook

Data and governance are the two complexities facing the implementation of climate data in urban planning processes [5]. Firstly, currently there is a lack of incorporation of climate data into urban planning processes. Secondly, there is a deficiency in structure and agility within city governance to integrate climate data into existing established processes. At the local governance level, there has been a recent acknowledgment of the importance of active climate change adaptation, but sufficient attention and significance have yet to be given to this issue through the establishment of appropriate processes and procedures.

The case study conducted in the city of Constance, which included an analysis of a survey among administrative staff and literature research, revealed, that climate change adaptation at the municipal level is not solely a technical matter but also a socio-political one. Existing laws have identified three key stakeholders in the municipal structures: The City Council, responsible for commissioning administration and making decisions on financial and human resources, the municipal employees, who prioritize and implement measures, and the citizens, who form the foundation of society and support these measures. By encouraging the “city government to be an integrating force, fostering communications and mutually beneficial partnerships among experts and stakeholders at multiple levels” [7, p. 23] and by incorporating climate data into the planning and decision-making process, the long-term objective of building a climate-resilient city can be achieved, while avoiding maladaptation [5, 7, 13].

In Constance, the City Council consists of 40 elected citizens who serve on a voluntary basis, meaning that professional politicians are not members of the council [75]. Each council's term lasts five years [76]. However, climate change adaptation measures take time to demonstrate direct effects, and their outcomes are often not immediately visible (e.g., installation of storage sewers in the sewer system) or may appear restrictive to citizens, as observed in other cities worldwide (e.g., nature-based solutions in Remiseparken in Copenhagen, Rotterdam, and New York City, where lowered sports fields function as retention areas during heavy rainfall events [15, 77]). Furthermore, climate change mitigation pursues the overarching and quantifiable goal of reducing greenhouse gas emissions. CCA, on the other hand, pursues the less sharply defined, long-term goal of reducing the vulnerability of natural, social and economic systems [38]. Consequently, adaptation to climate change does not enjoy widespread popularity among politicians and citizens. According to the survey, the greatest challenge in integrating climate data is still perceived at the administrative level. Additionally, a concerning finding from the survey is that none of the offices felt that communication within their own office was sufficient (see Figure 6). This opinion is also shared by the Federal Environment Agency: The focus group of the survey on the effectiveness of the DAS concluded that prerequisites for the preparation and implementation of adaptation measures are integrated planning and action and suitable internal administrative structures. Above all, the municipalities lack suitable instruments such as interdepartmental working groups or coordination and organizational structures [10].

A shift toward a more agile administration is only possible through constant communication within and beyond the offices, involving other stakeholders.

Based on the results of the survey and the research, it is concluded that the agile data workflow and the AMCDS toolbox can work in theory. However, a significant challenge lies in making such a digital tool permanent [78]. As indicated in Figure 9, the main obstacle to integrating new data into existing local government processes is a lack of know-how. Overcoming these hurdles can be achieved through the use of an intuitive AMCDS toolbox, providing a detailed introduction to its utilization, and ensuring continuous review and further development. Another approach for

continuity would involve supervision by the scientists who created the toolbox. However, this approach presents systematic difficulties as it requires stabilizing personnel structures after the CoKLIMAx project's duration to ensure consistent support. On the other hand, this approach offers the flexibility to respond to changes and make prompt adjustments. A successful example of continuity is demonstrated in the state of Victoria, Australia, where the local council collaborates closely with residents to implement a Heatwave Plan and conduct ongoing evaluations [23, 24] (see Section 2).

The proposed workflow represents a potential solution for the city of Constance. Transferability of the workflow to other municipalities in the state of Baden-Württemberg is feasible by considering local structures and context. However, for the integration of climate data into municipal governance structures throughout Germany, a case-by-case examination of various legal standards and binding codes, such as state building codes (LBO), which vary among the 16 federated states, is necessary. The state of Baden-Württemberg has already enacted the latest law on climate protection and adaptation, as mentioned in Section 3.1. A concern arises from the fact that the only paragraph addressing climate change adaptation requires the creation of an adaptation strategy, which has already been in place since 2015 [42, 43].
Climate change and its adaptation are not solely national challenges but global ones. Considering climatic, geographic, political, and structural differences, a thoughtful approach that takes into account local circumstances is essential [13, 31, 68, 79]. Furthermore, it is important to acknowledge that the financial resources available to municipalities vary significantly globally and within Germany [31, 80].
To avoid maladaptation and ensure the effectiveness of climate adaptation measures, local decision-makers require a reliable system based on climate data that facilitates the transition toward informed and climate-resilient urban planning. This system should also provide a framework for measuring progress and making scenario predictions [13, 15]. In the post-workshop survey, participants were asked about other administrative processes related to heat, water, and vegetation that would benefit from an agile workflow. The response highlighted that the determination of compensation measures under the aspect of climate change would benefit from an agile approach and workflow development. Another research avenue could involve the creation of an agile workflow specifically for this area. By empowering local decision-makers, the municipality, and citizens through the provision of necessary tools and resources, agile data workflows have the potential to unlock climate resilience in urban areas.

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