Driving forces and barriers for adaption strategies against the urban heat stress hazard in Berlin, Germany

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Berlin, 05.07.2018 Signature

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Abstract

Climate change is here and mitigation efforts will not be enough to stop it. We need to adapt to its unavoidable impacts. At the same time, increasing anthropogenic influence on urban climates is leading to worsening urban heat stress. Increased amounts of impervious area, dark surfaces, and the barrier effect of large buildings reduce the ability of especially dense, inner-city areas to cool themselves. The effects of climate change inside the city can vary greatly across different neighborhoods. This is due to the diverse micro- and macroclimates within a city and their unique ecological and meteorological conditions. Urban heat islands, for example, can exhibit temperatures up to four or five Kelvin (K) hotter than surrounding regions and, therefore, threaten the health and the lives of urban citizens. Three quarters of Europeans live in cities. Nevertheless, despite intensifying attention to the issues of heat stress and climate adaptation, Carbon Dioxide (CO_2) reduction remains the primary focus of public policy. Whether cities are ready to take on the challenge of responding to these threats is a significant concern for the future.

Germany is known for having numerous regulations, laws, programs, and institutions; and the situation surrounding climate change is no different. Whether and how all these legal and organizational features are used in practice and to what extent they further the success of adaptation work needs more investigation. In the framework of the German Research Foundation Research program 1736 Urban Climate and Heat Stress in mid-latitude cities in view of climate change (UCaHS), this work focuses, specifically on the treatment of these efforts in urban planning, specifically related to landscape, environmental, and land-use planning. It remains the case that planning and public policy lack an adequate body of knowledge about how to tackle urban heat stress, both legally and in the built environment. The administrative structure, legal context, and actions of major stakeholders were analyzed to help identify possible heat stress prevention and adaptation strategies, as well as the driving forces for and obstacles to their implementation. The climate adaptation plans of all German major cities and cities with a population density of 2000 residents/km^2 and a population of at least 200,000 were evaluated to help illuminate how adaptation measures for heat stress have been implemented. Results showed a clear trend: despite the advancements made through the recent adoption of so many climate-related plans and programs, the movement towards adaptation to climate change is still cutting its teeth. Mitigation is still favored over real adaptation. Among the adaptation strategies that were chosen, so called ‘no regret’ strategies like greening or unsealing were preferred, i.e., those that were economically, ecologically, and socially useful,

independent of their connection to climate change.

Our study area, Berlin, was chosen as the best city for a case study about the role of climate adaptation plans in the implementation of adaptation measures. Berlin is Germany's most populous city and is well-suited to the study because of its characteristic heterogeneity. To identify the driving forces and barriers for adaptation measures, we used Constellation Analysis and Bayesian Network methodologies. Constellation Analysis helps bridging interdisciplinary borders, incorporating all actors (persons or groups), symbols (laws or guidelines), institutions, and other elements (like green roofs or façade greening) in a system and depicting their relationships. To identify the set screws and the likelihood for the implementation of adaptation measures, we used Bayesian Networks. In order to gain the necessary knowledge for these methods, semi structured expert interviews and workshops were conducted in addition to document analysis.

In order to investigate the role of adaptation plans at the various planning levels, the City Climate Development Plan of Berlin (StEP Klima) was analyzed as an example. Constellation Analysis showed that connections between the different actors, institutions, and tools involved in adaptation planning and implementation are still inadequate. It also highlighted the individual block level as the planning stage most relevant for the implementation of adaptation measures. In a further step and in cooperation with the Research Module 3.2 and 5.1 of the Urban Climate and Heat Stress (UCaHS) Projekt, three scenarios were prepared using the constellation analysis.

1. A scenario with little political attention for the reduction of urban heat.
2. A scenario with political focus on the city center.
3. A scenario with political efforts for heat reduction for the entire city.

The aim was to develop governance storylines in order to identify possible ways of dealing with urban heat. These enable decision-makers to look into the future and, thus, to adjust their behavior.

In previous analyses, the local land-use plan level was seen as the most relevant for the implementation of adaptation measures. This leads to the question of whether adaptation concerns can successfully gain hold in urban planning and land-use plans. How will these measures be implemented? Urban and environmental planning play a vital role in this process. Bayesian Network analysis was used to explore the likelihood of the development of climate-adapted local land-use plans. This method depicts initial systems and the likelihood of certain outcomes in order to define networks of probabilities. The process relied on expert opinions gathered in numerous semi structured interviews at all levels with the Berlin stakeholders who are involved with implementation of the local land-use process. The analysis showed that the chances of the implementation of adaptation factors rely on a combination of different factors. These include the presence of investors and of an environmental assessment, as well as the individual and often very situational decisions made by the person responsible for the implementation of the plan. In order to make an environmental impact statement, and therefore the end assessment, mandatory, §13a of the German Federal Building Code (BauGB) would need to be changed. But it is important the keep in mind that the presence of rules in the Federal Building Code are not enough to drive adaptation – informed and dedicated stakeholders on all planning levels and in the population are also needed.

In Berlin, adaptation has not been a significant part of formal city and regional planning documents and processes. These administrative tools do, however, contain measures that could address adaptation, though they do not directly mention it. Unlike the formal instruments, the informal City Climate Development Plan (StEP Klima) includes many comprehensive strategies to deal with the effects of climate change. The development of informal plans like the StEP Klima KONKRET in summer 2016 which shows exact recommendations of how to implement adaptation measures, or other programs like environmental justice studies and the climate planning details map also hint at progress. Such work to expand adaptation knowledge and strategies is still young.

As long as an action is voluntarily, though, it will only be taken up by those who already understand its purpose and benefit from it. The others, who don't know about or are not interested in adaptation, need to be given concrete and binding guidelines. A new round of policies, including the Renewable Energy Sources Act, the amendments to the landscape planning programs in summer 2016, and the planned adoption of the Berlin Energy and Climate Protection Program, which are at least obligatory for the public authorities, will all show how Berlin intends to tackle urban heat stress adaptation in the future.

Zusammenfassung

Der Klimawandel ist ein Thema, das spätestens seit den aufsehenerregenden Berichten des Internationalen Klimarates IPCC im Jahre 2007 große Besorgnis auslöste. Unvermindert steigt die globale Durchschnittstemperatur, aber ebenso unvermindert wachsen auch die Emissionen der sogenannten Treibhausgase weiter, die für die Erwärmung ursächlich sind. Die Folgen des Klimawandels sind weltweit unübersehbar und fordern neben den Strategien zum Klimaschutz (Mitigation) auch eine Anpassung an dessen unvermeidbaren Folgen (Adaption).

Die in den Städten zunehmende Bebauung von Freiflächen, sowie die Zunahme von dunklen Oberflächen und die Barrierewirkung von Gebäuden führen zu einer reduzierten Durchlüftung und reduzierten Abkühlung in der schon meist sehr verdichteten Innenstadt. Auch wirkt sich der Klimawandel innerhalb der heterogenen Stadtstrukturen räumlich sehr unterschiedlich aus. Dies liegt vor allem an den groß- wie kleinräumig verschiedenen biometeorologischen Bedingungen, die innerhalb einer Stadt wirken. Die sich so in Städten bildenden Hitzeinseln gefährden durch die im Vergleich zum Umland bis zu vier bis fünf Kelvin (K) höheren Temperaturen die Gesundheit der Bevölkerung. Neben der erhöhten Sterblichkeit kommt es zur Einschränkung der Arbeitsproduktivität, die wir wirtschaftlich gar nicht beziffern können. Dreiviertel der Europäer leben in Städten – planerische Maßnahmen, um Hitzestress zu vermeiden, werden somit mehr und mehr gebraucht, um eine Entlastung der Bevölkerung zu erwirken und die Risiken und Gefahren einzugrenzen. Hierbei sind Städte wie beispielsweise Berlin gefragt, sich mit ihrer individuellen Betroffenheit auseinanderzusetzen.

In Deutschland werden zahlreiche Gesetze, Richtlinien und Programme zum Klimawandel verabschiedet. Ob diese rechtlichen und organisatorischen Instrumente in der Praxis verwendet werden und in welchem Umfang, wurde hier untersucht. Zahlreiche Veröffentlichungen zu den Folgen als auch der Anpassung an den Klimawandel mit Hilfe von Planungsinstrumenten wurden publiziert. Ob die von den Städten verabschiedeten raumspezifischen Planungen insbesondere in Bezug auf das Instrumentarium der Landschafts-, Umwelt- und Stadtplanung diesen Erkenntnissen gerecht werden, ist jedoch unklar und lag deshalb, im Rahmen des DFG Forschungsprojektes 1736 Urban Climate and Heat Stress in mid-latitude cities in view of climate change (UCaHS), im Fokus dieser Arbeit. Es stellt sich die Frage, in welcher Weise deutsche Städte Anpassungsmaßnahmen in Bezug auf den urbanen Hitzestress implementiert haben. In einer Analyse mittels eines Kriterienkataloges

wurden alle Anpassungspläne aus Städten ausgewertet, welche entweder Landeshauptstädte oder Städte mit über 200.000 Einwohnern und einer Bevölkerungsdichte ab 2000 Einwohner pro km^2 sind. Die untersuchten Städte zeigten einen klaren Trend für Maßnahmen zum Klimaschutz, gegenüber Maßnahmen zur Anpassung an den Klimawandel. Bei den Anpassungsmaßnahmen zeichnete sich eine klare Tendenz zu so genannten No-Regret-Maßnahmen ab, wie beispielsweise Entsiegelung oder die Pflanzung von Gehölzen, die unabhängig vom Klimawandel ökonomisch, ökologisch und sozial auch auf lange Sicht sinnvoll sind.

Im nächsten Schritt wurde der Stadtentwicklungsplan Klima von Berlin (StEP Klima) näher analysiert. An seinem Beispiel wurde die Rolle von Anpassungsmaßnahmen an den Klimawandel in den einzelnen Planungsebenen analysiert. Sowohl zur Analyse des Stadtentwicklungsplans Klima (StEP Klima) als auch zur Entwicklung von drei Szenarien wurde der Ansatz der Konstellationsanalyse verwendet. Die Konstellationsanalyse dient als interdisziplinäres Brückenkonzept, welches die Akteure (Personen und Gruppe etc.), Symbole (Gesetze und Leitfäden etc.), technische (Erhöhung des Albedo Wertes, Fassaden- und Dachbegrünung etc.) und natürliche Elemente (Klima und Hitzestress etc.) analytisch erfasst und in Beziehung zueinander setzt. Die Konstellationsanalyse besteht aus Beziehungen und Wechselbeziehungen zwischen den Elementen der Konstellation.

Die für die Konstellationsanalyse erforderlichen Interviews zeigten, dass in Berlin noch keine hinreichenden Verbindungen zwischen den relevanten Akteuren, Instrumenten und Kontexten wie beispielsweise ein Wissensaustausch zwischen dem Senat und den Berliner Bezirken vorhanden ist. Anders als bei den formellen Instrumenten, wie dem Bebauungsplan, beinhaltet der informelle StEP Klima umfassende Maßnahmen, um auf die Auswirkungen des Klimawandels zu reagieren. Problematisch ist jedoch, dass der Plan kaum bis keine Beachtung findet und so immer noch keine Anpassung an den urbanen Hitzestress in Berlin stattfindet. Im Rahmen der Interviews zeigte sich, dass die Bebauungsplanung als die Relevanteste angesehen wird, um Maßnahmen zur Anpassung verbindlich umzusetzen. In einem weiteren Schritt, in Zusammenarbeit mit den Research Modulen 3.2 und 5.1 des UCaHS Projektes, wurden mit Hilfe der Konstellationsanalyse drei Szenarien erstellt.

1. Ein Szenario mit wenig politischer Aufmerksamkeit auf den urbanen Hitzestress und die Initiierung von Anpassungsmaßnahmen.
2. Ein Szenario mit Fokus auf die Innenentwicklung und der Implementierung der vorgeschlagenen Anpassungsmaßnahmen aus dem Stadtentwicklungsplan Klima.
3. Ein Szenario mit politischen Bestrebungen, Anpassungsmaßnahmen gegen den urbanen Hitzestress in der gesamten Stadt mit Hilfe des Stadtentwicklungsplans Klima umzusetzen.

Hierbei war es das Ziel, politische Handlungsstränge zu entwickeln, wie beispielsweise eine gesetzliche Verpflichtung die Maßnahmen des StEP Klima umzusetzen, um so mögliche Wege aufzuzeigen, mit städtischen Hitzerisiken umzugehen. Die Ebene des Bebauungsplans wurde in den vorherigen Schritten als die für die Implementierung von Anpassungsmaßnahmen relevanteste gesehen. Hier stellt sich die Frage, ob diese Anpassungskonzepte des StEP Klima tatsächlich auf der Ebene der Bauleitplanung Eingang finden?

Um die Erfolgswahrscheinlichkeiten für einen klimaangepassten Bebauungsplan oder auch die Umsetzung von Anpassungsmaßnahmen zu ermitteln, wurde die Methodik des Bayesschen Netzwerkes verwendet. Darunter sind Wahrscheinlichkeitsnetzwerke zu verstehen, die Ausgangssysteme, wie die Erstellung eines Bebauungsplanes, analytisch abbilden und Wahrscheinlichkeiten für die Erreichung gesetzter Ziele, der Umsetzung der Anpassungsmaßnahmen des StEP Klima, abzubilden helfen. Um die Tendenzen für die Umsetzung zu ermitteln, wurden zahlreiche halbstrukturierte Interviews mit allen am Bebauungsplanverfahren beteiligten Akteuren durchgeführt. Bei der Analyse zeichnete sich ab, dass die Chance Anpassungsmaßnahmen, wie beispielsweise die Fassadenbegrünung, zu implementieren von einer Kombination aus verschiedenen Faktoren abhängig ist: Dazu zählen sowohl das Vorhandensein eines Investors der ein Bauvorhaben umsetzen möchte, die oft situativ und im Einzelfall personengebundenen Entscheidungen der Planbearbeiter, der Öffentlichkeitsbeteiligung als auch das Vorhandensein eines Umweltberichtes. Die Öffentlichkeit kann politischen Druck auf die Entscheidungsträger ausüben und verweist auf eventuelle Defizite. Der Umweltbericht bildet die Grundlage für die naturschutzfachliche Einschätzung des Gebietes. Auch können in diesem Klimamaßnahmen verankert werden.

Eine Barriere für Anpassungsmaßnahmen stellt laut den Interviews der §13a des Baugesetzbuches (BauGB) dar. Dieser hat dazu geführt, dass gesetzeskonform weniger Umweltprüfungen in der Innenstadt Berlins durchgeführt wurden. §13a BauGB soll eine Erleichterung von Planungsvorhaben für die Innenentwicklung der Städte sein. Wenn §13a greift, muss kein Umweltbericht erstellt werden. Für einen klimawandelangepassten Bebauungsplan muss dieser Paragraph bei der Novellierung des BauGB entsprechend geändert werden. Jedoch wird ein klimaangepasster Bebauungsplan nicht allein durch das Vorhandensein der Vorgaben im Baugesetzbuch erstellt, sondern bedarf wacher Akteure in den Planungsebenen als auch in der Bevölkerung.

Bisher spielt die Anpassung an den Klimawandel in den formalen Instrumenten und Abläufen der Umwelt-, Stadt- und Regionalplanung in Berlin keine große Rolle, obwohl der informelle Stadtentwicklungsplan Klima (StEP Klima) viele umfassende Strategien zur Bewältigung der Auswirkungen des Klimawandels enthält. Es zeigen sich allerdings Fortschritte in der Entwicklung von informellen Plänen, wie das Beispiel des Stadtentwicklungsplans Klima KONKRET (StEP Klima KONKRET) aus dem Sommer 2016 belegt. Dieser gibt erstmals Handlungshinweise wie eine Umsetzung von Anpassungsmaßnahmen konkret an einem Beispiel erfolgen kann. Ebenso ist die Fortführung von Planungshinweiskarten zum Thema Umweltgerechtigkeit und Klima als Fortschritt in diese Richtung zu werten.

Aber noch stehen die Bemühungen, die Anpassungen an den Klimawandel umzusetzen, in den Kinderschuhen. Um die Anpassung an den Klimawandel auf allen Ebenen umzusetzen, muss diese verbindlich werden. Das Berliner Energiewendegesetz (EWG Bln), die Novellierung des Landschaftsprogramms im Sommer 2016 oder die geplante Verabschiedung des Berliner Energie- und Klimaschutzprogramms (BEK) die zumindest behördenverbindlich sind, zeigen, welche Rolle die Anpassung in Berlin an den urbanen Hitzestress zukünftig in Berlin der Hauptstadt Deutschlands einnehmen wird.

Contents

1. Background of study

1.1. Climate change and urban heat stress

"Climate change is (...) here. It can be felt especially in cities and heavily populated areas: stormwater systems overwhelmed by heavy summer storms can cause significant financial damages and heat waves threaten the health of city-dwellers" (adapted from DWD 2009).

Climate mitigation and adaptation to the impacts of climate change are the most significant social, economic, and technological challenges of our time (UBA 2009). Among these effects are extreme heat events, which are an especially dangerous form of natural disaster (Borden and Cutter 2008; EM-DAT 2010). Its consequences threaten not only the global diversity of flora and fauna, but also humans, those responsible for these environmental changes. Therefore, climate change demands action at all levels: international, national, and regional (Riecken 2002).

There are two main strategies in the international and national discussion of climate change and its eventual outcomes: mitigation, which focuses on reduction of the threat, and adaptation, which focuses on preparation for climate change effects (IPCC 2007). A clear separation of the two terms with regard to their differences is not yet apparent in planning practice (Donner 2011; Birkmann and Fleischhauer 2009).

Problematic is that the effects of high greenhouse gas levels will not be seen for decades, due to the relatively sluggish nature of global climate systems (IPCC 2014; UBA 2009). The very drastic but predominately slow climate processes mean that climate change will play out over time at the immediate local level. The changes that we have made to our surrounding environment, especially in dense urban areas, have created a different local climate system in the lower atmosphere, called the urban climate (Oke 1988; Ward et al. 2016). Unlike rural areas, in cities the use of different building materials for various structures, varying open and shaded areas, and constants like topography and seasons lead to the development of very different microclimates. These are realized through the phenomenon of the urban heat island and its social and physical effect on humans, urban heat stress. The threat of urban heat stress is most significant at night when the urban heat island effect is at its greatest (Donner 2011; Oke 1982; Jänicke 2016; Grimmond et al. 2010; Wienert and Kuttler 2005).

Studies show that frequency and intensity of natural disasters like heat waves, floods, heavy precipitation events, strong storms, and droughts are increasing worldwide (BMUB 2008; IPCC 2014; Stern 2007; van Aalst 2006). The respectively greater impact of heat events in comparison to floods or storms is clear: though fewer people have been directly affected, fatalities are much higher for extreme heat events than for any other natural disaster (e.g., storms or floods) (EM-DAT 2010).

Several decades worth of studies have documented the effect of urban heat stress on health and comfort of urban inhabitants (Buechley et al. 1972; Clarke and Bach

1971; Clarke 1972). Furthermore, the heat wave in the summer of 2003 showed that urban heat stress must be taken seriously. Across Europe, about 70,000 people died as a result of this heat wave - in Germany alone there were about 7000 deaths (García-Herrera et al. 2010; Kinney 2012; Kovats and Ebi 2006; Robine et al. 2008). Gabriel and Endlicher (2011) also point to a correlation between mortality rate and heat events. During the 2003 heat wave in Europe, many people reported significant impacts on their well-being and the local mortality rates increased as well (e.g., Breitner et al. 2013; Guo et al. 2014; Harlan et al. 2014; Kovats and Hajat 2008; Kravchenko et al. 2013; Kjellstrom and McMichael 2013; Scherber et al. 2013). Zacharias et al. 2015 underline the increase of future heat-wave-associated mortality due to ischemic heart diseases in Germany. An individual's level of heat stress depends on various factors that can lead to different degrees of potential hazards in their interaction. These factors include age, health, socioeconomic criteria, and the built environment in which the individual is located (Kovats and Hajat 2008; Hajat et al. 2010; Schuster et al. 2014). Last but not least, an individual's recognition and estimation of the threat heat stress poses and their behaviors in response to it have a decisive influence (Adger et al. 2009). Dealing with heat stress risks poses new challenges for policy-makers, urbanists, and architects in urban development policy (Scherer et al. 2013).

Clearly, strategies to improve adaptation to climate change are required. Politicians must take the first steps to approve and implement adaptation strategies. The following section (1.2) describes the ways in which the challenges to climate change adaptation for environmental planning can be met.

1.2. Challenges for environmental planning

Action has been taken at all levels - global, international, European, national, regional and local (Riecken 2002). Even though climate change is a global phenomenon, its negative effects, like temperature increases, will be experienced at the regional level and felt most acutely in the urban areas where people live and work. Just as the heavily populated urban areas contribute the most to Carbon Dioxide (CO_2) production, their citizens are, at the same time, those most vulnerable to climate change (BBSR 2009). By 2050 two-thirds of world population will live in urban areas (UN 2013). Cities are growth engines and play a crucial role in addressing climate change (Betsill and Bulkeley 2007; UN 2013; UN 2014). Urban climate dynamics and the density of cities often intensify the effects of heat stress (Mahammadzahdeh et al. 2009; UN 2014). Nevertheless, not all aspects of the relationship between climate change and urban heat stress have yet been explained (Grossman-Clarke et al. 2016).

In the past years, a substantial literature on heat stress in cities has been developed, and the need for climate change adaptation strategies has been stressed in a number of plans and programs (Baker et al. 2012; Stone et al. 2010; Stone 2012; Reckien et al. 2014). If nothing else, since the Fifth Assessment Report of the IPCC 2014 was published, climate change has become an issue that must be taken seriously. It accentuates the likelihood of cities' exposure to exacerbated risks due to the globally changing climate (IPCC 2014).

Following the principle of solidarity among the regions and member states in the European Union (EU), as well as with other nations, adaptation efforts should be seen as inevitable. Climate change impacts will not stop along administrative or geographic boundaries; EU-wide strategies are needed. According to the EU, adaptation is "a question of political coherence, planning, and the resulting coordinated actions" (EC 2007, changed).

Mid-latitude cities, on the other hand, are increasingly gaining notice for their increased risk due to urban heat stress. "Unfortunately, the most effective actions for reducing heat-stress risks are based on active technologies like air conditioning causing additional greenhouse gas emissions" (UCaHS 2014). Unlike subtropical cities, air conditioning systems are not in widespread use in these areas. The risk of heat stress is, therefore, closely tied to the urban weather and climate conditions (Bouchama 2004).

There are three main urban features that impact local temperatures. These include buildings, greenspaces, and streets and sidewalks (infrastructure) (Lowry 1967). This underlines that future-focused urban planning is necessary to minimize and combat the unavoidable effects of climate change, and it requires an effectively coordinated set of policy and planning approaches (BBSR 2009). Furthermore, regionally-specific strategies must also be developed (Davoudi et al. 2009; Kleerekoper et al. 2012; Mees et al. 2014).

Some evaluations show that the impacts of climate change will be uneven: some areas will be hit harder than others (Arnfield 2003; Baklanov et al. 2016; Santamouris 2015; Souch and Grimmond 2006; Wienert and Kuttler 2005; Zhao et al. 2014). Many studies of the urban heat island effect and how governments have been creating and implementing strategies to confront it have been performed, especially in hot cities (Aaros et al. 2016; Heidrich et al. 2016).

1.3. Overview of state of the art adaption strategies and their goals

One group of articles deals with quantitative modelling and approaches for redesigning urban structures in order to make a more heat adapted city (e.g., Eum et al. 2013). Other articles also discuss, for example, the effects of ongoing development of open land and of measures such as the creation of open fresh air corridors or urban greening programs for shade or cooling (Kabisch and Haase 2014; Katzschner 2010; Kuttler

2011; Endlicher et al. 2008; Santamouris 2015; Scherer et al. 2013).

Another section of the heat risk literature focuses on urban and national heat risk plans and their approaches to hazardous events (Grewe and Blättner 2011; Martinez et al. 2011; Stone et al. 2012). These relate primarily to the results of studies of the effects on public and individual health and the potential threat to urban climates. They analyze climatology data specific to mortality and morbidity after heat waves and the associated risk for older people or patients with heart or respiratory diseases (Breitner et al. 2013; Scherber et al. 2013; SenStadtUm 2011). Also included in the research are the social dimensions of heat stress and their implication for urban planning and governance processes (e.g., Großmann et al. 2012; Ginski et al. 2013). The health of citizens is an especially significant challenge for urban and environmental planning. Because some citizens have fewer resources for individual actions, due mostly to financial inequality, environmental justice needs to be promoted though government action (Adger 2001; Fehr and Kühling 2006). This will require improved cooperation between planners and public health and health care organizations, as well as with the stakeholders who are impacted (Bhatia and Wernham 2008).

Others have investigated how planning and policy instruments can help to ensure that climate adaptation measures are taken (e.g., Baker et al. 2012; Birkmann and Fleischhauer 2009; Birkmann et al. 2014; Kumar and Geneletti 2015; Reckien et al. 2014; Stone et al. 2012). One of the key initiatives for climate change adaptation research was the risk governance approach for an effective and efficient risk management against flooding (e.g., Corfee-Morlot 2011; Renn 2006; Renn and Klinke 2013; Renn and Schweizer 2009). Condon et al. (2009) and Measham et al. (2011) lay out a broad set of tools which can be used at the local level to help implement strategies to confront climate change. They also examine to what extent various governance structures could be made more efficient with respect to climate change. In the end, though, many have found it difficult to identify the exact reasons why the implementation of mitigation and adaptation measures proves to be such a struggle (Biesbroek 2010; Biesbroek 2014; BMBF 2007; Laukkonen et al. 2009).

1.4. Initiated strategies for decision making

Numerous plans and programs, initiatives, and laws have been created to help prevent climate change. In Germany, the main goal is to reduce greenhouse gas emissions, especially CO_2, which is primarily responsible for global warming (BMUB 2008; BMUB 2014). Germany enacted the German Strategy for Adaptation to Climate Change (DAS) in 2008. The goal of this document is "to minimize vulnerability to the effects of climate change and to use all available options to maintain or increase the adaptability of natural, social, and economic systems (BMUB 2008)." With the adoption of the Adaptation Action Plan, climate adaptation finally became a stand-alone issue on the German political scene (Bubecka et al. 2016; BMUB 2008).

It did not, however, introduce any previously unknown problems.

In Germany, there are many federal requirements which reference climate change indirectly. Only three federal statutes explicitly mention climate adaptation, however. In the German Federal Building Code (BauGB) (2015), §1 (5) and from §9 (1) No. 1 to No. 26 are referenced most often. In the German Federal Water Act (WHG) (2014) and German Regional Planning Act (ROG) (2015) there are a few relevant paragraphs where climate adaptation is explicitly mentioned as well. This legal framework guides climate adaptation work in Germany (Bubecka et al. 2016). This dissertation focuses on landscape, environmental, and urban planning tools within the planning process (e.g., comprehensive land-use plan, local landscape plan and local land-use plan) (see Chapters 3, 4 and 5). The BauGB (2015) defines climate change as a spatial planning issue. Further investigation of the ROG and WHG is outside of the scope of this study.

It is important to note that adaptation measures need to be coordinated so that they can function together across local, regional, and national levels. Concepts of multi-level governance and participation are tied into these debates. Hence, planners and decision makers, especially in cities, are often uncertain how to handle the challenges of urban heat stress. In addition to this uncertainty the planners and decision makers do only have insufficient information about block level microclimates and are lacking thresholds for temperature as they exist, i.e., for noise. Accurate, high resolution analyses are required to get this data. Furthermore, so called ‘good governance’ constellations are needed to integrate effective heat stress strategies on all levels (see Chapter 3 and 5). Latour (1986) underlines this with his statement that the power to get something done lies in the relationships between the various actors in the process rather than with individuals. Furthermore, urban governance should be considered a new form of cooperation that should involve decision makers at all levels, working together to be prepared for future challenges (Betsill and Bulkeley 2007).

In this field, landscape planning “has a cross-sectional spatial planning of nature conservation” (von Haaren 2004, changed) and is of particular importance. Besides comprehensive planning for nature conservation, it is also an information and evaluation tool, e.g., for decision making for land-use planning and environmental planning (Heiland 2017; Schmidt 2017).

1.5. Study area

Berlin is the capital of Germany and, with 3.6 million citizens and an upward growth trend, also the most populous city in the country (Statistical Office Berlin-Brandenburg 2015; SenStadtUm 2016). The city covers an area of 890 km^2 and is made up of many neighborhoods with different land-use patterns and characters

(Statistical Office Berlin-Brandenburg 2014; 2015). Scenarios calculated by the regional climate model STAR2 show a clear temperature increase in the future, at an average of 2.5 °C by 2050 (Lotze-Campen et al. 2009). This will be seen in an increase in extreme high temperatures, meaning hotter, drier summers with tropical-like nights and higher temperatures especially during winter months (Lotze-Campen et al. 2009). Fenner et al. (2014) determined that the difference of the temperature in summer nights in Berlin is four to five Kelvin (K) higher in the inner city compared with the more rural outer areas. Besides heat periods, an increasing and intensifying number of extreme weather events, such as storms or heavy rainfalls, have been recorded. These are not only more frequent but are also becoming longer and more intense in their occurrence. Additionally, they are beginning to be recognized for their economic impact, on account of their high damage potential, (Revi et al. 2014; Stern 2007).

Without the direct influences of mountain ranges or seas, which might affect the formation of urban climate the city is well suited as a study area of this phenomenon (Jänicke 2016; Kabisch 2015). Berlin is one of the greenest cities in the world. More than 30% of the city's land consists of green spaces and forest areas (Kabisch 2015).

As the city continues to attract more residents, the demand for housing will also rise. About 15-20,000 new apartments will be needed each year, according to projections showing an increase of 254,000 new residents by 2030 (SenStadtUm 2016c). Along with the overall lack of housing, there is a need for renovation and renewal in many existing housing areas of the city. The main issue in the solution to the housing problems is whether (creative) re-use and infill development will be enough to satisfy the need or whether open and greenspaces must be given over to new construction. Increased urbanization and rising temperatures will only contribute further to heat stress related mortality and morbidity in the coming years (Fallmann et al. 2015; IPCC 2014). Each year in Berlin, people die from exposure to high temperatures (1600 excess deaths per year) (Scherer et al. 2013). In the course of the construction of new buildings, the life-span of the infrastructure and how it can be better adapted to future climate change should be considered (Giordano 2012).

In 1990, Berlin established two guiding principles for urban development which are still followed today: 'compact city' and 'city of short distances' (SenStadtUm 2011). Here, however, it is questionable whether densification, depending on the policies pursued, is the right approach. In the past, several environmental plans were adopted which could have an influence on the temperatures of the city. With the adoption of the informal City Climate Development Plan (StEP Klima) of Berlin (SenStadtUm 2011), the informal StEP Klima KONKRET of Berlin (SenStadtUm 2016a) and the Energy Transition Law of Berlin (SenStadtUm 2016b), the city was a forerunner in the adaptation field in Germany. Thus, further development of the city should result in a compact, urban, and livable city, with frugal use of developable land and both climate and socially compatible density. Residential areas and greenspace will be created accordingly in existing neighborhoods and new construction areas.

This is intended to improve quality of life and maintain it for future generations (SenStadtUm 2011).

1.6. Problem definition and research question

The climate is changing globally and will impact the lives and living conditions of people around the world. If the goal to keep global temperature rise below two degrees is not reached, experts warn of repercussions for the environment, economy, and society (IPCC 2014).

Even after the heat wave of 2003, which should function as a warning about the urban climate future, Germany has seen little progress towards the implementation of concrete climate adaptation measures. This is despite many formal climate-related initiatives and relevant official documents and resolutions. There are numerous laws, regulations, strategies, and programs from the international level down to the local level that are intended to combat heat stress. A large gap exists, however, between the always increasing number of publications on the topic of climate change and the actual implementation of heat stress reduction measures in the built environment (e.g., Vink et al. 2013; Wamsler et al. 2013). Among planners and politicians in moderate climate zones, there is a lack of knowledge about how to handle the problem of heat stress and how to prepare cities for it (Amundsen et al. 2010; Birkmann et al. 2013).

This dissertation consists of five articles about different governance levels and government actors. Qualitative and semi-quantitative methods were used to extract the most important influencing factors of the landscape-, environmental- and urban planning systems. This process assisted the development of promising governance approaches, which can help to combat the negative effects of heat stress. Each of the articles made use of relevant interviews (one-on-one interviews and group workshops with experts of the Urban Climate and Heat Stress (UCaHS) project) and survey results.

To identify barriers and gaps in the existing systems, Constellation Analysis (CA) (Schön et al. 2007) and Bayesian Network (BN) (Düspohl 2012) approaches were used to assess the likelihood of the use of certain implementation pathways for heat reduction measures and the probability of the integration of scientific knowledge about heat stress into urban planning and governance processes.

CA is a tool which facilitates mutual understanding of complex societal problems, focusing on questions regarding technology, sustainability, and innovation. It is often used in transdisciplinary and interdisciplinary research of societal problems to identify relationships (simple, targeted, missing, or conflicting) between the elements that characterize the problem at hand. By categorizing those elements into basically equivalent categories of actors, natural and technical elements, or signs and symbols, CA simplifies the interdisciplinary discussion and the integration of different perspectives on a problem (Schön et al. 2007) (see Chapter 3). To take a deeper look into the problem of implementation and to calculate the likelihood of implementation of adaptation measures, Bayesian Network methodology was used as well. The Bayesian Network approach is an analytical demonstration of real systems and was used here to assess the relative likelihood of the use of certain implementation pathways for heat reduction measures and for the integration of scientific knowledge on heat stress into urban planning and governance processes (see Chapter 5) (Cain 2001; Pollino et al. 2010; Hamilton and Pollino 2012; Uusilato 2007).

With this in mind, the central purpose of this work was to discover how decision makers currently deal with urban heat. Therefore, the following questions were addressed:

1. Which urban planning level is the most promising for releasing, steering, and fostering supportive interventions for the integration of urban heat stress mitigation and adaptation policies?
2. What challenges and constraints do urban planners face in their daily practice related to the integration of the concept of heat risk, and how can these be handled?
3. Do planners and policy makers have an adequate basic set of urban planning tools to make plan implementation, especially related to heat stress, successful?

1.7. Structure of the thesis

This dissertation focuses primarily on landscape and environmental planning tools to analyze how they can be used to minimize the problem of urban heat.

The paper is composed of five central chapters as well as an introduction (Chapter 1) and results and conclusion (Chapter 7) with recommendations for further research. Chapters 2 to 6 form the main part of the PhD thesis and respond to the research questions described above. Each chapter (2 to 6) is a stand-alone article, and all five central chapters have been published or have been submitted for publication in scientific journals with a peer review process. The following is an outline of the content of each section.

Chapter 1 Represents the introduction to this thesis, the main aspects of the political background, and the current state of the research.

The next two chapters offer insight into the issue of climate change and adaptation strategies in Germany. Adaptation plans were evaluated to help illuminate how adaptation measures for heat stress have been implemented. Berlin receives special attention in Chapter 3, which focuses on its City Climate Development Plan (StEP Klima).

Chapter 2 "Urban heat - towards adapted German cities?"

This chapter evaluates how German cities implement measures towards climate change adaptation via an analysis of the adaptation plans for German state capital cities and cities with at least 200,000 inhabitants and a population density of greater than 2000 residents/km^2. It serves a basis for Chapter 3.

Chapter 3 "From planning to implementation? The role of climate change adaptation plans to tackle heat stress - A case study of Berlin, Germany".

This chapter analyzes the StEP Klima of Berlin.

Chapter 4 "A constellation analysis for developing exploratory and anticipatory storylines for heat stress analysis- insights from a case study in Berlin, Germany."

This chapter lays out exploratory and anticipatory storylines for heat adaptation in urban planning using Constellation Analysis methodology. Examination of planning and governance processes allows three exploratory storylines for 2040/2050 to be presented.

Chapters 5 and 6 make use of Bayesian Network methodology to calculate the likelihood of implementation of adaptation strategies for urban heat stress.

Chapter 5 "Climate adaptation at the local level: A Bayesian Network analysis of local land-use plan implementation."

This chapter identifies the factors which play a crucial role for a climate-adapted local land-use plan.

Chapter 6 "Urban heat stress: How likely is the implementation of façade greening? Analyzed with Bayesian networks."

Most of the plans analyzed in Chapter 2 recommend greenery as a 'no regret' measure. This chapter deals specifically with the likelihood of implementation of façade greening at the building level and the factors that influence its success.

Chapter 7	This chapter consists of a summary and conclusion of the results of the preceding chapters and outlines hypotheses and questions for future research.

Chapters 2 through 6 are standalone manuscripts which have been published or submitted for publication in international peer-reviewed journals. The "Author Contribution Statement" attached in the appendix gives details about the contribution of each author.

The articles were published as follows:

Published title:	**Urban Heat: towards adapted German cities**
Version:	used in thesis: post print
Authors:	Donner, J., Müller, J.M., Köppel, J.
Journal:	Journal of Environmental Assessment Policy and Management Volume 17, Issue 02, June 2015
Year of publication:	2015
Copyright:	World Scientific Publishing Europe Ltd.
DOI:	https://doi.org/10.1142/S1464333215500209
Additional:	Electronic version of this article published as [Journal of Environmental Assessment Policy and Management, Volume 17, Issue 02, 2015, 17 Pages] [https://doi.org/10.1142/S1464333215500209] © [copyright World Scientific Publishing Company] [https://www.worldscientific.com/worldscinet/jeapm]

Published title:	**From Planning to Implementation? The Role of Climate Change Adaptation Plans to tackle Heat Stress - A Case Study of Berlin, Germany**
Version used in thesis:	post print
Authors:	Mahlkow, N., Donner, J.
Journal:	Journal of Planning Education and Research Volume 37, Issue 4, August 2016, pages 385-396
Year of publication:	2016
Copyright:	2016 SAGE Publications
DOI:	https://doi.org/10.1177/0739456X16664787
Additional:	Mahlkow, N., Donner, J., From Planning to Implementation? The Role of Climate Change Adaptation Plans to tackle Heat Stress - A Case Study of Berlin, Germany, Journal of Planning Education and Research (Volume: 37 issue: 4) pp. 385-396. Copyright © [2016] (SAGE Publications). Reprinted by permission of SAGE Publications.

Published title:	**Developing storylines for urban climate governance by using Constellation Analysis - Insights from a case study in Berlin, Germany**
Version used in thesis:	post print
Authors:	Mahlkow, N., Lakes, T., Donner, J., Köppel, J., Schreurs, M.
Journal:	Urban Climate Vol. 17, No. 17, September 2016, pages 266-283
Year of publication:	2016
Copyright:	Elsevier B.V.
DOI:	https://doi.org/10.1016/j.uclim.2016.02.006

Published title:	**Climate change adaptation at the local level: A Bayesian network analysis of local land-use plan implementation**
Version used in thesis:	post print
Authors:	Donner, J., Sprondel, N., Köppel, J.
Journal:	Journal of Environmental Assessment Policy and Management
Year of publication:	2017
Copyright:	World Scientific Publishing Europe Ltd.
DOI:	https://doi.org/10.1142/S1464333217500107
Additional:	Electronic version of this article published as [Journal of Environmental Assessment Policy and Management, Volume 19, Issue 02, 2017, 29 Pages] [https://doi.org/10.1142/S1464333217500107] © [copyright World Scientific Publishing Company] [https://www.worldscientific.com/worldscinet/jeapm]

Published title:	**Urban climate and heat stress: How likely is the implementation of adaptation measures in mid-latitude cities?** **The case of façade greening analyzed with Bayesian networks.**
Version used in thesis:	post print
Authors:	Sprondel, N., Donner, J., Mahlkow, N. Köppel, J.
Journal:	One Ecosystem Vol. 1, November 2016
Year of publication:	2016
Copyright:	Sprondel N et al. This is an open access article
DOI:	https://doi.org/10.3897/oneeco.1.e9280

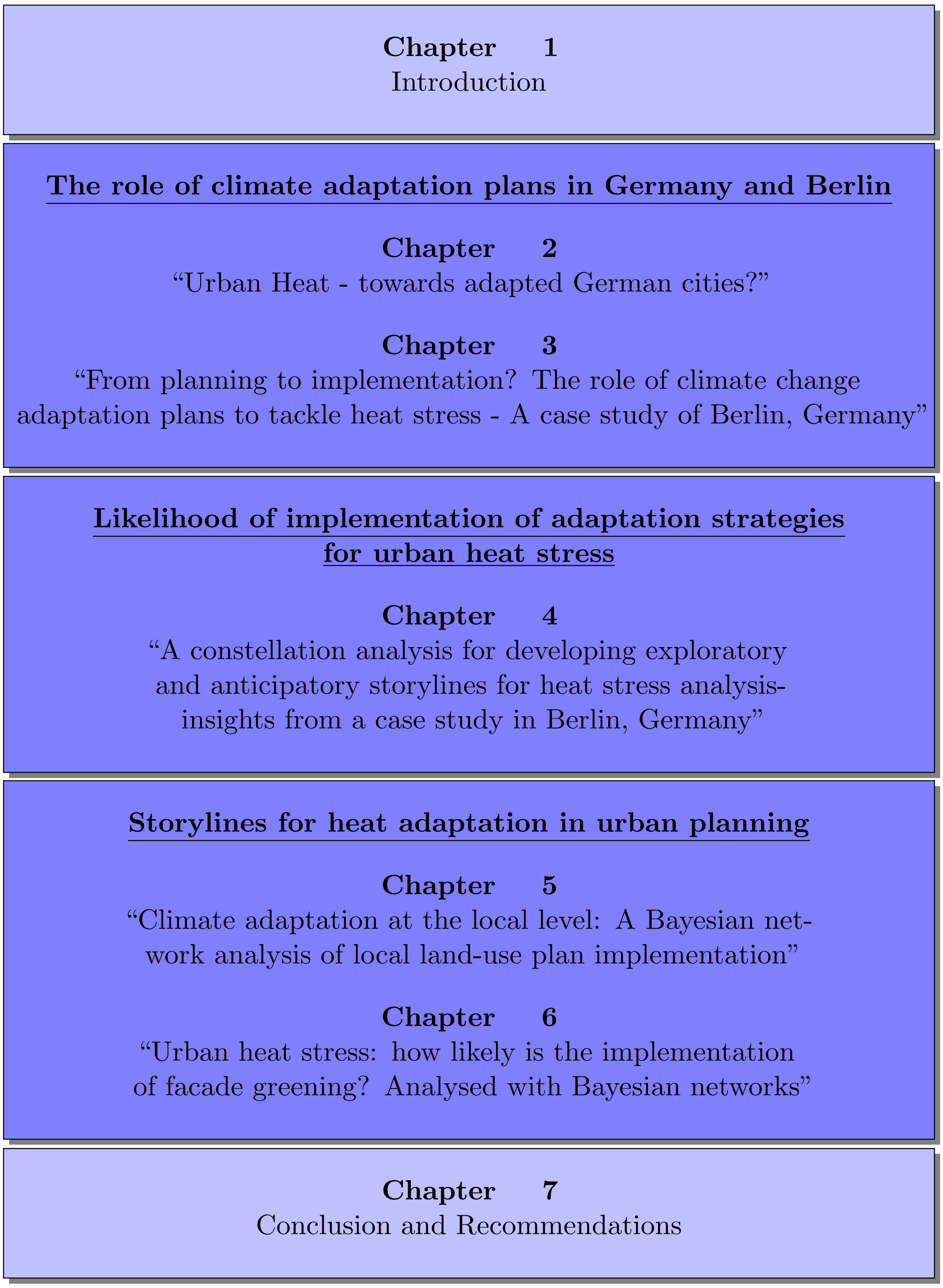

Figure 1.1.: Structure of the thesis.

1.8. Summary of the project

This research was undertaken within the German Research Foundation-supported Project #1736, Urban Climate and Heat Stress in mid-latitude cities in view of climate change (UCaHS) (www.UCaHS.org) (KO 2952/2-1). UCaHS is a multi and interdisciplinary study of potential strategies to combat urban heat stress exacerbated by climate change in mid-latitude cities. The goal is to analyze in detail the cause and effect relationships at play between urban climate influences and associated heat stress risks in outer and inner city areas (UCaHS 2014).

The UCaHS project consists of five Research Modules (RMs), with a total of ten subprojects. All focus on the risks that increasing heat will cause and on the different options to minimize or adapt to high temperatures. The five research themes are outdoor climate and heat stress hazards, indoor climate and heat stress hazard, vulnerability to heat stress, climate responsive buildings, and the urban system.

As proposed in the overall UCaHS work plan and the individual plan for RM 5.1, the researchers are Dipl.-Ing. Julie Donner and Dipl.-Pol. Nicole Mahlkow. The purpose of RM 5.1 was to identify promising government and organizational networks that can effectively tackle urban heat stress through planning and decision-making processes. To understand where institutional and governance changes are needed, it was crucial to study how heat stress is currently dealt with in planning and governance systems. Special attention was given to the actors in decision-making processes. Here, scientific work also plays a crucial role. Provided they are well integrated in existing networks, efficient methods to protect against and adapt to climate change can be established.

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2.1. Abstract

Is heat becoming a major threat to cities? Following the heat wave in Europe in 2003, which is estimated to have caused the deaths of 70,000 people, municipal authorities began to develop adaptation and mitigation plans and programs. Legal obligations to consider climate change within various development projects have been defined, e.g., by the latest amendment of the EU EIA (Environmental Impact Assessment) Directive (2014/52/EU) and the German Federal Building Code (BauGB §1a (5)). However, urban heat hazards have not yet received as much attention as, for example, carbon dioxide emissions as drivers of global warming. Dense urban structures, high buildings, dark surfaces, and high population densities trigger urban heat effects. With about 3/4 of Europeans living in cities, measures to reduce heat-related impacts are needed. This paper evaluates how German cities have implemented measures towards climate change adaptation. The results show that 24 out of 30 cities have developed mitigation and/or adaptation plans, with a majority focusing on mitigating Carbon Dioxide (CO_2), indicating less awareness of urban heat hazards. Moreover, we found elaborate and comprehensive examples which might serve as blue-prints for adaptation strategies. Based on the inhomogeneous scope of the different plans and programs, there remains a need for guidance and more knowledge exchange among the cities on mitigation/adaptation options and preferably information on their effectiveness, to further assist cities in tackling heat stress.

Keywords

Urban heat, climate change, mitigation, adaptation, urban heat stress, strategic environmental impact assessment, environmental impact assessment

2.2. Introduction

In the last decade, adaptation to climate change has become a significant political topic and a major subject to scientists. The consequences of a severe heat wave in the United States in 1980 were a motivation for this increased interest in adaptions to climate change (Jones et al. 1982). Since then, heat has been recognised in scientific research as an increasing threat to urban areas, by causing diseases (primarily affecting the respiratory system) or even deaths (Jones et al. 1982; McGeehin and Mirabelli 2001). Nevertheless, heat waves had not yet been associated with climate change (Jones et al. 1982). But since the late 1990s, heat stress in relation to rising temperatures as a consequence of climate change has been addressed in several scientific disciplines (Curriero et al. 2001). Special interest was and still is associated to medical implications as health impacts are the most recognizable effects in this research field (Haines et al. 2006). McGregor et al. (2007) describe human vulnerability to heat as a function of the degree of exposure to the heat hazard and sensitivity to changes in weather and climate and adaptive capacity. However, implementing adaptation measures for handling urban heat stress as a specific problem proves to be a challenge for governments and is as of yet understudied (Mees et al. 2014). Additional to global warming, the characteristics of cities tend to intensify the process of urban heat based on heat accumulation. Consequently, populations in urban areas worldwide are more and more affected by rising temperatures and thus by urban heat stress (Stone 2012; Stone et al. 2010; Reckien et al. 2014; Baker et al. 2012).

In the late 1960s, Lowry showed that the microclimate of a city is influenced by the materials used for façades, types of structures, and disposition of vegetation (Lowry 1967).

For example, dense building structures in combination with high buildings and dark surfaces absorb heat during daytime and emit heat during night times, thus leaving the city no chance to cool down. Furthermore, traffic and a high population density trigger heat stress and can affect people's health (Commission of the European Communities 2009; Condon et al. 2009; IPCC 2007; Stone 2012). As a result, two microclimates need to be considered. The first and more obvious one is the outdoor climate. The second, but no less important, is the interior climate, which affects the human body considerably, as we spend most of the time inside (e.g., offices, homes). Thus, heat waves in urban areas can lead to discomfort and illnesses such as Chronic Obstructive Pulmonary Disease (COPD), lung cancer, and pneumonia (Conti et al. 2005; Franck et al. 2013; Krau 2013). However, urban heat hazards have not yet received as much attention as, for example, carbon dioxide emissions. Scientists agree that heat effects need to be addressed by national policy makers and especially municipal authorities in order to develop site-specific mitigation and adaptation strategies (IPCC 2007; Oberlack and Eisenack 2013; European Commission 2009).

In our research, we focus on mitigation and adaptation strategies to tackle the effects of climate change, e.g., the reduction of greenhouse gas emissions, or increasing urban vegetation, and enhancing open spaces (Bowler et al. 2010; Solecki et al. 2005; Gill et al. 2007; Susca et al. 2011; Geo-Net 2010). Most approaches dealing with urban climate focus on mitigation (Baker et al. 2012; Reckien et al. 2014; Stone et al. 2012), as do local plans and programs, the EU White Paper (European Commission 2009), and the IPCC Fifth Assessment Report (2007). Thus, the main research focus addresses specific instruments to reduce energy consumption, for example in the cooling sector, via green façades and roofs or by planting trees for shade (Armson et al. 2012; Hall et al. 2012). The German Strategy for Adaptation to Climate Change (DAS) was set up to support German authorities to draw on an informal framework for measures to implement climate adaptation strategies (BMU 2008). To evaluate the extent to which German urban climate protection plans include measures for adaptation to urban heat stress effects, we analysed available mitigation and adaptation strategies for Germany's most densely populated cities (with more than 2000 residents/km^2). Furthermore, we examined which tools and instruments have been addressed within this sample. The analysed plans are adopted on the local level as they have been set up for the specific city, but have a rather recommendatory nature (similar to the DAS) other than, e.g., legally binding goals in a regional plan. An inclusion of climate proofing within the planning processes, e.g., in the context of the EIA, would be promising for effective handling and management (Fischer and Sykes 2007). A first step has been done by the European Union (EU) with the amendment of the EU EIA (2014), which introduced the topic of climate change to the agenda of EIA (European Commission 2014). Addressing human health issues at the same time within the amendment, it becomes at least indirectly obvious that urban heat stress matters in the field of environmental assessment ever more.

2.3. Methods

Our case study research draws on previous research from Stone et al. (2012), who developed three categories with eight management strategies (Table 2.2) to evaluate mitigation strategies in climate action plans of the 50 most populated cities in the USA. The three categories are albedo enhancement, energy efficiency (building energy efficiency, renewables programs, vehicle energy efficiency, and vehicle travel demand management), and vegetation enhancement (green roofs, regional forest management, and urban tree management).

Instead of using the total population as an indicator used by Stone et al. (2012), we chose the population density (more than 2000 residents/km^2) to identify the cities most likely to be affected by heat stress. As a prerequisite, we defined that the city should have a population of at least 200,000 or should be a federal state capital, since these are likely to be of special interest to regional policy makers (e.g., Schwerin less than 200,000 inhabitants). Applying those conditions, we identified (until November 2013) a total of 30 cities to be analysed.

Six of the 30 cities originally considered were excluded because they did not have their own management and/or adaptation plan (e.g., Munich is only covered by a management plan on climate change for the state of Bavaria). Consequently, 24 cities were included based on the number of residents, population density, and an available management and/or adaptation plan. We supplemented the criteria of Stone et al. (2012) with additional indicators due to the specific focus of this study on urban heat (Tables 2.1 and 2.1). The supplemental indicators (e.g., heat stress, heat island or fresh air corridors) were retrieved from German and international references (e.g., Armson et al. 2012; Sabler et al. 2005; Berlin Senate Department for Urban Development and Environment 2011) as well as from feedback and preliminary results gained during

UCaHS[1] project meetings. To identify and visualise the relevance of indicators, we distinguished between direct impacts on urban heat and indirect/cumulative affects which predominantly address overall climate change topics.

We based our results on categories and strategies covered in the assessed mitigation/adaptation plans. However, the results cannot be compared only based on the total score as the single scores are not equal in their potential effect on reducing urban heat. Thus, the results picture efforts and serious consideration rather than the final effectiveness. Those plans were analysed by studying the table of contents, potentially relevant chapters, and searching for keywords related to the strategy or indicator e.g., such as reflection, radiation, surface, or brightness to identify the recognition of albedo.

Table 2.1.: Categories covered within the plans.

Category	Topics Covered
A	Heat stress
B	Heat island
C	Dry periods
D	Urban floods
E	Heavy rain events
F	Water quality management
G	Fresh air corridors
H	Health
I	Vulnerable groups
J	Energy efficiency

[1]UCaHS: Urban Climate and Heat Stress in mid latitude cities in a view of climate change.
[2]Adopted by EC Directive- European Parliament 2010 and the Energy Conservation Ordinance of Germany

Table 2.2.: Strategies discussed in the climate action plans. In italics indicators developed by Stone et al. (2012).

	Categories	No.	Strategies	Explanation/function
Relevant to Urban Heat	*Heat stress*	1	*Albedo enhancement*	Increase radiation reflection, light-coloured surfaces
	Heat island *Dry periods*	2	*Green roofs*/façades	Indoor climate improvement, green roofs/façades
	Fresh air corridors	3	Green space management	Drip irrigation, changes in the design and management of green space and public spaces,
		4	*Urban tree management / Regional forest management*	More heat resistant species, planting initiatives, donation campaigns
	Health	5	Alert systems ("H" specifically for urban heat)	Newsletter, homepages
	Vulnerable groups	6	Information distribution ("H" specifically for urban heat)	Flyer, education, homepages
	Water quality management Urban floods	7	Water bodies	Small lakes, fountains
	Heavy rain events	8	Unsealing	
Relevant to Climate Change	*Energy Efficiency*	9	*Building energy efficiency*	Develop energy pass after construction, alteration, extension of buildings[2]
		10	*Renewable energy source management*	Enhance the use of renewables
		11	*Vehicle energy efficiency*	Electric cars, lower fuel consumption
		12	*Vehicle travel demand management*	Car sharing, public transport, bike lanes

2.4. Results

The 24 German mitigation and adaptation plans (Table 2.3) differed substantially in terms of scope and detail as visualised by Figure 2.1 which shall give an impression on the scope of the different plans. However since the single indicators are not equally comparable in their potential impact on urban heat the following results are to be understood as a qualitative rather than a quantitative comparison. While some plans were formulated in a rather general manner, others incorporated a majority of the indicators (Table 2.2). Some specifically address adaptation measures, such as the plans of Cologne, Stuttgart, Frankfurt/Main, Hanover, and Duisburg (Table 4). But in contrast, the majority of plans focus only on mitigation than adaptation measures, such as increasing the efficiency of public transport and/or upgrading housing insulation. We summarised our results in terms of management strategies related to (1) open spaces, (2) land cover, (3) health, and (4) emissions, energy conservation, and transport.

2.4.1. Open space management

Our results showed that 10 of the cities addressed green space management within the mitigation and/or adaptation plans. Of the 24 plans, 17 mentioned the importance of fresh air corridors that safeguard an air exchange between cooler air from the outskirt areas and the warmer urban air. The importance of fresh air supply has been highlighted, for example, in the City Climate Development Plan of Berlin within a specific chapter on bio-climate (Berlin Senate Department for Urban Development and Environment 2011). Efficient adaptation strategies such as albedo enhancement were only included in eight plans. Implementing effective measures can lead to healthier living conditions without the necessity of installed air conditioning.

2.4.2. Land cover management

Heat accumulation on surfaces such as bare soil, dark asphalt, or others that store solar radiation can be reduced significantly by deliberate management strategies (e.g., open water bodies, unsealing, green pace). Open water bodies deliver an appreciable cooling effect on a local scale due to evaporation (plus transpiration of adjacent plants); this is covered by about a third of the plans we examined.

Table 2.3.: Analysis of the management and adaptation plans regarding direct (white) and indirect indicators (grey) on urban heat.

City	Climate Adaptation/Action Plans	Topics covered										Management Strategy												Pop. density in ppl./km^2 [3]	Pop. in 1000	Area in km^2
		A	B	C	D	E	F	G	H	I	J	1	2	3	4	5	6	7	8	9	10	11	12			
Berlin	StEP Klima; 2011	x	x	x	x	x	x	x	H	X	x	x	x	x	x		x		x	x	x	x	x	3,927	3,502	891.75
Bochum	Energie- und Klimaschutzkonzept für die Stadt Bochum bis 2020										x									x	x	x	x	2,567	374	145.66
Brunswick	integriertes Klimaschutzkonzept für Braunschweig								(x)		x				(x)					x	x	x	x	1,285	251	192.13
Bremen	KLAS (Klimaanpassung-sstrategie)	(x)		(x)	(x)	x																		1,685	548	325.42
Cologne	Klimawandelgerechte Metropole Köln	x	x	x	x	x	x	x	x	x	x	x	x	x	x	H	H	x	x	x	x	x	x	2,510	1,017	405.17
Dortmund	Handlungsprogramm Klimaschutz 2020			x	x	x	x	x	(x)		x		x	x	x		x			x	x	x	x	2,070	581	280.71
Dresden	REGKLAM (Energie- und Klimaschutzkonzept)	(x)	x	x	x	x	x	x	x			x		x			H	x						1,614	530	328.31
Duisburg	Klimawandelanpassungs-strategie für Duisburg	(x)	x	x	x	x	(x)	x	H	x	(x)		x	x	x	(H)			x	x		x	x	2,096	488	232.83
Düsseldorf	Klimabericht			(x)				x	x		x				(x)		x			x	x	x	x	2,725	592	217.41
Erfurt	Integriertes Klimaschutzkonzept der Landeshauptstadt Erfurt										x									x	x	x	x	767	206	269.14
Essen	Integriertes Energie- und Klimakonzept der Stadt Essen			x	x	x		x	x		x		x	x	x		(x)		x	x	x	x	x	2,726	573	210.34
Frankfurt am Main	Frankfurter Anpassungsstrategie	x		x	x	x	x	x	H	H	(x)	x	x	x	x	x	x	(x)	x	x	x		x	2,785	692	248.31
Gelsenkirchen	Integriertes Klimaschutzkonzept Gelsenkirchen 2020	(x)			x	x	x	x	x		x		x	x			x			x	x	x	x	2,446	257	104.94
Hamburg	Aktionsplan Anpassung an den Klimawandel	(x)		x	x	x		x	H	x	x		x	x	x	x	H	(x)	x	x	x	x	x	2,382	1,799	755.30
Hanover	Anpassungsstrategie zum Klimawandel	x	x	x	x	x	x	x	x	(x)	(x)	x	x	x	x	(x)		(x)	x	x			(x)	2,576	526	204.14
Kiel	Kieler Energie- und Klimaschutzkonzept			H			x		H		(x)									x	x		x	2,040	242	118.65
		A	B	C	D	E	F	G	H	I	J	1	2	3	4	5	6	7	8	9	10	11	12			

continued on next page

Table 2.3 – continued from previous page –

City	Climate Adaptation/Action Plans	Topics covered										Management Strategy												Pop. density in ppl./km^2 [3]	Pop. in 1000	Area in km^2
		A	B	C	D	E	F	G	H	I	J	1	2	3	4	5	6	7	8	9	10	11	12			
Leipzig	Klimaschutzprogramm der Stadt Leipzig							x	(x)		x		x		x				x	x	x	x	x	1,788	532	297.37
Magdeburg	Energie-und Klimaschutzprogramm 2013-2015							(x)			(x)										(x)	x		1,156	232	200.99
Nuremberg	Handbuch Klimaanpassung	x	x	x		x	x	x	x	x	(x)	x	x	x	x	(x)	x	x	x	x	x		x	2,740	511	186.37
Oberhausen	Energie- und Klimaschutzkonzept für die Stadt Oberhausen		x	H					x		x		x	x			x		x	x	x	x	x	2,757	213	77.10
Potsdam	Integriertes Klimaschutzkonzept 2010	x	x	x	x	x	x	x	x		x		x	x	x	(x)	x		x	x	x	x	x	847	159	187.52
Saarbrücken	Urbane Strategien zum Klimawandel	x	x		x	x		x	x	x	(x)	x		x	x			x	x				x	1,054	176	167.09
Schwerin	Klimaschutzkonzept Schwerin					x					x		x	x	x	x		x	x	x	x	x	x	730	95	130.53
Stuttgart	Klimaanpassungskonzept Stuttgart, KLIMAKS	x	x	x	x	x	x	x	H	x	(x)	x	x	x	x	x	x		x	x			(x)	2,958	613	207.35
	Sum	10	10	15	13.	16	11.5	16.5	17.5	8.5	18	8	15	16	15	5.5	12.5	6.5	14	20	17.	16	20			
		A	B	C	D	E	F	G	H	I	J	1	2	3	4	5	6	7	8	9	10	11	12			

[3] According to the German Federal Statistical Office; Stand: 31.12.2011

Heavy rain events and urban floods are widely known effects of climate change which impact cities even more significantly compared to rural areas. This is due to the sealed areas where precipitation cannot drain but also the construction design (only narrow runoff routes).

Researchers agree that unsealing, addressed by almost half of the analysed German urban action plans, can provide greater benefits to urban climate than CO_2 reductions. This is due to the cooling effect by soil transpiration and avoided accumulation of heat by sealing materials such as asphalt or concrete (Stone et al. 2012; European Environment Agency 2012).

The evaporation of sealed surfaces is decreased, which leads to less humidity and thus, the microclimate changes. Furthermore, sealing leads to a loss of soil as a natural filter for dust and pollution (Osman 2013), as a habitat for animals and plants, and as a recreational and nature experience area for citizens. Especially during summers, unsealed surfaces with woods offer welcoming space and cool down areas (Ali-Toudert and Mayer 2007). The heating of yard space and surfaces can be reduced by unsealing, accomplished by exchanging asphalt by lawns, tree planting, setting up shading elements (canopies, pagodas), and light paving (Ali-Toudert and Mayer 2007).

2.4.3. Health management

The groups of residents, which are affected more intensely by urban heat stress than other residents, are children, are those above 65 years and those in bad physical condition (i.e., due to illness). They are likely to face direct impacts on their everyday life due to heat island effects (European Environment Agency (EEA) 2012). Thus, there is a significant and realised need to implement health management strategies. This is underlined by the fact that in 19 plans, climateinduced health problems were mentioned in general and 12 of these addressed heat stress specifically. Within the analysed plans, health threats were mostly related to rainstorms causing urban floods. Heat alert systems[5] were only found in nine of the plans. Most plans referred to the warning system of the German Meteorological Service (DWD) which is already in place (German Meteorological Service 2010; Koppe 2012). This tool automatically sends digital heat warning messages to hospitals and other institutions. However, five city mitigation and/or adaptation plans did not address health issues at all.

Only a few tools and strategies were identified to provide essential information for specific target groups. Cologne, for example, addresses health risks for vulnerable groups (children, over-65, and ill people), proposing communication campaigns via press, flyers, Internet, and other media about risks and ways to reduce impacts from

[4] The individual scores are not equally comparable in their potential effect on reducing urban heat.

[5] DWD provides a newsletter that sends heat warnings in case the wind chill factor at 2 days in a row is above 32 °C or it is above 38 °C

urban heat. The Cologne plan suggests considering heat aspects when planning buildings for vulnerable groups such as e.g., hospitals, retirement homes, and childcare centres. Furthermore, it points out the need for emergency plans for congested urban areas where a great number of people or vehicles converge. The climate adaptation concept of Stuttgart includes a monitoring system focusing on illnesses caused by climate conditions. This shall help the cities' health scientists to retrieve substantial knowledge on the impact of heat on the human body.

2.4.4. Emissions, energy conservation and transport management

Besides the global warming potential of emissions such as CO_2, temperatures can also be increased by Particulate Matter (PM) that is predominantly emitted by the transport and energy sector. Traffic jams are a common event in bigger cities, impacting the air quality and share of airborne PM. Hence, managing these sectors offers additional potential for enhancing urban climate. Of the 24 plans assessed, energy efficiency of buildings (84%) and a well-organized and sustainable local public transport sector (88%) was covered by the majority. In order to adapt to urban heat, Frankfurt's adaptation plan aims at analysing whether heat waves lead to certain diurnal traffic patterns. Increased public transport provision at peak times could reduce pressure on certain travel routes. The possibility of schedule adaptations to heat waves remains a particular challenge. Providing public transport shelters offering shade and lower temperatures are mentioned as measures to adapt to urban heat burden.

2.4.5. Excluded cities

Six cities, which would have been included on the basis of their population density, did not provide any city-specific plan or information on strategies and concepts to reduce urban heat impacts. These were: Wuppertal and Bonn, where adaptation and mitigation plans only exist on the state level where Bonn has developed an integrated concept for climate protection but is not accessible for the public; Mainz, which has a climate initiative and climate change reports but as of yet no plan; Munich, is covered by the Bavarian climate program 2020; Wiesbaden, is part of a "100 local authorities campaign for climate protection" ('Hessen aktiv') and has an adaption plan on a state level as well; and Mannheim city, where the administration provides only a summary of the overall city concept of climate protection and follows a state level climate mitigation law.

Figure 2.1.: Analysis of management and adaptation plans including information of the analysed management and adaptation plans. For each city we illustrated the number of regarded management strategies (Table 2.2: e.g., Albedo enhancement, green space management or unsealing) as well as the number of topics addressed (Table 2.1: e.g., heat stress, heat island or health) by means of a bar chart[4].

2.5. Discussion and Conclusions

The analysis of 24 German city mitigation and adaptation plans reveals that climate change is proven to be an important topic to urban policy-making. Nevertheless, even ten years after the European heat wave which caused 70,000 deaths, the importance of heat adaptation strategies is still underestimated in many German cities' policies. The results illustrate that capital cities of all the 16 German federal states are acting to respond to climate change by developing mitigation and/or adaptation plans. The six cities not providing any plan did all mention initiatives or projects on a federal state or regional level however. Although urban heat stress leads to significant impacts on urban environments and human health, it has not been given sufficient consideration. The scopes of the various plans differ significantly in terms of the certain topics addressed and the related measures that should be taken. In general, the cities focus their attention predominantly on the reduction of greenhouse gas emissions, specifically on CO_2 emissions, in context of climate change mitigation. Nevertheless, plans do also address an implementation of measures to reduce urban heat stress and by that, promote healthier living conditions without a higher necessity to use air conditioning. The issue with air conditioning is that it would in turn lead to increased energy demands which is dependent upon the energy mix to additional emissions and thus gives a potential rise in temperature (due to emissions global warming potential and the presence of PM) (Bernard et al. 2001; Jacob and Winner 2009; Karl and Trenberth 2003; Landsberg 1981). This issue is gaining in consideration as more than half of the plans address green space management as a beneficial measure to reduce urban heat stress. However, less than half of the cities recognised the option of surface unsealing to reduce heat accumulation and increase surface percolation. Moreover, about three-quarters of the cities did not consider the cooling potential of water bodies to improve the urban climate.

Local impacts such as urban heat fuelled by climate change are addressed only in a negligible manner by Environmental Assessments (WTO 2009). However, climate protection as well as adaptation to climate change are formulated as goals within the German Federal Building Code (BauGB §1a (5)), which is part of the legislative basis for conducting an EIA and/or Strategic Environmental Assessment (SEA). With the latest amendment of the European EIA Directive (2014/52/EU) the subject of climate change has been introduced. As soon as member states have ratified this amendment, they are obliged to consider climate change as an important element regarding decision-making processes and within project development assessments (European Commission 2014, 2015).

An applicable and effective option to prevent the accumulation of heat is, e.g., the siting of constructions (whether they are located within fresh air corridors, the distance to other buildings and streets, etc.) and height of buildings. Such issues are laid down by the local land-use plan. The potential to improve the cities' climate at this planning level are most promising. It is the small-sized urban planning unit which reveals the challenges for urban planners to deal with heat stress on an operational level. Informal incentives such as an online platform for local authorities to share their experiences with adaptation and mitigation measures may help to improve consideration of urban heat.

Such a commonly accessible platform for the public, administration and planning agencies which includes the different plans might support the development of adaptation and mitigation plans, since this would include a wide range of measures and instruments. A forerunner like Cologne could function as a benchmark reference, since it addresses all relevant indicators identified in our analysis. However, addressing a range of indicators covered by mitigation and/or adaptation plans does not necessarily imply that a city will be able to realise its aims in terms of heat stress. Without guidance by regulations or incentives, there is no guarantee that measures will be implemented either on a national or a local level. Moreover, there is still a lack of awareness on the importance of tackling heat stress. There are good examples that address both management and adaptation strategies against urban heat such, as the policies and plans of Cologne, Stuttgart, Frankfurt/Main, Hanover, and Duisburg. However, further research is needed regarding the impacts of such plans and to investigate the reasons why all these five cities are located in western Germany. The overall question for further research is whether there is a measurable positive impact on climate in cities who have implemented mitigation and adaptation plans.

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3. From Planning to Implementation? The Role of Climate Change Adaptation Plans to tackle Heat Stress - A Case Study of Berlin, Germany

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3.1. Abstract

Global climate change increases the necessity for mid-latitude cities to tackle urban heat. Climate change adaptation plans are common policy mechanisms to approach the issue. This paper studies the City Climate Development Plan (StEP Klima) of Berlin, Germany, by using Constellation Analysis (CA). We analyzed to what extent StEP Klima might trigger planning and governance processes for the implementation of heat stress measures. Berlin's plan brought attention to the local risks of urban heat and possible strategies. To translate its aims into decision-makers' everyday governance and planning practices institutionalized guidance and an activation of policy instruments is needed.

Keywords

Berlin, climate change adaptation, Constellation Analysis, policy instruments, urban heat

3.2. Introduction

Following scientific advice and political statements declaring that the regional and local level is of high priority in adapting to climate change (e.g., Carter et al. 2015; Dannevig et al. 2012; Frommer 2009), a huge number of cities have created adaptation plans. The question remains whether these plans indeed trigger actions concerning local adaptation to climate change or if they remain tokenism.

Several scholars have assessed local adaptation plans and strategies (e.g., Reckien et al. 2014; Baker et al. 2012; Lehmann et al. 2015). Reckien et al.'s (2014) survey highlights the distribution of climate change mitigation and adaptation plans across European cities. It includes a broad analysis of adaptation plans, but does not capture the complexity of the policy processes involved in various cities' adaptation to climate change (Baker et al. 2012). The authors call for studies that "investigate potential drivers and barriers of plan development as well as of the implementation of planned actions (. . .)" (Reckien et al. 2014: 339). Baker et al. (2012) developed an evaluation framework to assess seven local climate change adaptation plans in Southeast Queensland, Australia. The study provides an insight into structural, procedural, and contextual factors that pose limits to a comprehensive adaptation process. However, it does not pay much attention to the interplay of factors inhibiting the implementation of a plan's goals. Lehmann et al. (2015) compare four cities in developing and developed countries concerning barriers and opportunities for effective climate change adaptation planning. They focus exclusively on the preparation and adoption of adaptation strategies and action plans, and identify a similar set of barriers in developing and developed countries. The authors stress the importance of the institutional context, participation, and multi-level governance to mainstream adaptation.

Only recently has the scientific community given more attention to the way planners and policy-makers perceive and deal with the particular climate change adaptation issue of urban heat (Runhaar et al. 2012; Mees et al. 2015; Carter et al. 2015; Kleerekoper et al. 2012). Wilby (2007) identified urban heat as a risk factor aggravated by the global greenhouse effect due to an intensification of urban heat islands (Oke 1982) and a higher frequency of extreme weather events such as heat waves. Heat stress has been associated with a significantly lower human well-being, as well as higher mortality and morbidity rates (e.g., Kravchenko et al. 2013; Scherber et al. 2013; Harlan et al. 2014). In causing tremendous numbers of excess deaths, heat waves have had the strongest impact of all natural disasters on human health in Europe between 1998 and 2009 (EEA 2010). In particular, the 2003 heat wave with app. 70,000 fatalities throughout Europe (Robine et al. 2008) proved the high health risks for populations who do not commonly experience extreme temperatures.

Knowledge about policy instruments guiding urban development in tackling heat health risks is still scarce. Stone et al. (2012) reviewed 50 municipal and state level action plans in the US regarding their emission control and heat management strategies. They found that the plans lack heat management strategies, which potentially puts human health and welfare in the covered areas at risk. The study of Donner et al. (2015) examines the importance German climate change plans assign to heat-related risk factors and prevention measures. While many German cities adopted climate change adaptation plans, the reduction of urban heat risks still receives insufficient attention. Berlin has been one of the forerunners and addressed most, but not all, relevant heat-related indicators (e.g., albedo enhancement, green roofs/façades or unsealing).

Thus, current research has reviewed outputs of adaptation plans regarding preferred heat stress measures. An in-depth analysis of the adaptation plans' performance and outcome before and after the implementation of proposed measures is missing. We investigate how a local climate change adaptation plan can lead urban development governance and planning towards the implementation of heat stress measures.

The Berlin City Climate Development Plan (StEP Klima) fulfilled a pioneering role in Germany for urban climate change adaptation planning. It was acclaimed for its methodological approach, which should serve as an example for other cities (SenStadtUm 2010). The aim is to systematically integrate the StEP Klima's goals into administrative processes (BBSR 2015). Studying the Berlin City Climate Development Plan (StEP Klima) we identify challenges to use climate change adaptation plans as a guiding policy instrument for the implementation of heat stress measures.

3.3. Method

3.3.1. Study site

Berlin is the largest city and capital of Germany. It covers an area of 892 km^2 with, as of 2014, about 3.46 million inhabitants (Statistical Office Berlin-Brandenburg 2014) and is expected to grow substantially in the next decade (SenStadtUm 2016). Berlin infamously suffers from a precarious economic situation (INSM 2012). The city has two tiers of public administration; the Senate and its Departments set the general policy guidelines for the entire city and execute tasks of city-wide importance. All other tasks, including local land-use planning, are to be taken over by the twelve districts (Musil and Kirchner 2012).

Berlin's humid continental mid-latitude climate is characterized by warm to hot summers and cold winters (Peel et al. 2007). Daily mean temperatures of 19.0 °C have been observed for the two warmest months in summer during 2000 to 2010 (Dugord et al. 2014). Climate change projections for the city of Berlin imply a rise in temperatures of 2.5 °C degrees by 2050 with more hot days and tropical nights as well as more extreme weather events (Lotze-Campen et al. 2009).

Gabriel and Endlicher (2011) showed a positive correlation between heat and mortality in Berlin, particularly for the most densely built-up districts during the two main heat waves within their study period. Scherber (2014) identified spatial clusters with elevated relative risks of summer mortality and morbidity, especially for respiratory system diseases, in the north-western and south-eastern parts of Berlin's city center. In their statistical study for the city, Scherer et al. (2014) estimate an average heat stress related death rate of about 1600 people per year (app. 5% of all annual deaths).

Research approach: Constellation Analysis

To support interdisciplinary research, the Center for Technology and Society at the Berlin Institute of Technology (TU Berlin) developed the CA approach. Inter- and transdisciplinary research often faces the challenge of balancing different disciplines with specific methods and theories, while at the same time ensuring a comprehensive problem orientation. CA is a tool to facilitate mutual understanding of complex societal problems focusing on questions regarding technology, sustainability, and innovation.

Societal processes are characterized by heterogeneous influence factors, which CA intends to consider equivalently. The various factors relate to each other and form constellations. A graphical illustration and an explanatory description of the identified network of factors provide a multi-perspective appraisal of the problem at hand (Schön et al. 2007). Visualization and explanation support each other and remedy the deficits and difficulties of the other medium of presentation, allowing different disciplines to relate to the analysis (ibid).

Various interdisciplinary research projects have successfully applied this approach to explore and analyze complex research objects, to structure discourses, and to develop strategies and new projects (Bruns et al. 2011; Mohajeri and Dierich 2009).

Application of the CA for the given research objective

From February 2014 to May 2015, twelve semi-structured, problem-centered expert interviews (cf. Meuser and Nagel 1991) were conducted with Berlin administrative officials. The interviewed officials were either involved in the creation of the City Climate Development Plan or apply the instrument in their daily work routine. Moreover, we examined gray literature and policy and planning documents on the City Climate Development Plan. The empirical material was analyzed using Content Analysis (Mayring and Fenzl 2014).

For the subsequent CA, all main influences on the studied subject, derived from the empirical material, are categorized into four equal element groups:

- Actors: Individuals and groups of actors (e.g., human beings, organizations, social movements)
- Natural elements: Materials, resources, plants and animals, the landscape, or a natural phenomenon
- Technical elements: Strategies and measures
- Symbolic elements: Policies, institutional, legal, or economic factors (Ohlhorst and Schön 2015; Ohlhorst and Kröger 2015; Schön et al. 2007).

Furthermore, CA displays the interplay of the elements, classifying relations according to their frequency and state of occurrence within the analyzed empirical material. Relations between the elements can be simple, directed, conflicting, oppositional, or simply missing (Ohlhorst and Kröger 2015). Conflicting relations occur between elements that intentionally act against each other or multiple other elements. If an element resists unintentionally to the expectation or attribution of others the relation is called 'oppositional' (Ohlhorst and Kröger 2015). Ohlhorst and Schön (2015) point out that the relations between elements can be undetermined or missing. Spatial proximity or distance mapped in the constellation show how close or loose the connections between some elements are. The most important elements are arranged in the center of the constellation. Less central elements for the analytical problem are assembled further away from the core of the CA.

The StEP Klima proposes strategies and actors to implement heat stress measures. The constellation described in the following paragraphs classifies these strategies and actors as CA elements (Figure 3.1). Furthermore, it shows their relation to the climate change adaptation plan, revealing challenges for the plan in the existing urban development governance and planning system.

The corresponding text explains the diverse components of the CA element groups - natural, technical, symbolic elements, and actors. The discussion of 'symbolic elements' refers predominantly to the planning instruments, whereas the paragraph on 'actors' focuses on important urban development actors and explicitly relates to governance oriented strategies. Assuming that all elements have varying potentials to influence the main variable of heat stress, they are not explained in any hierarchical order. Rather, the following paragraphs first of all study the policy mechanisms at the city level, followed by the ones that mainly target the building and parcel level.

3.4. Results

Implementing heat stress measures under the guidance of a climate change adaptation plan - the Berlin example Content and purpose of the City Climate Development Plan. After being adopted by the Senate of Berlin in 2010, the City Climate Development Plan (StEP Klima) was published in May 2011 by the Berlin Senate Department for Urban Development and the Environment (SenStadtUm 2011). The StEP Klima is the first policy instrument that spatially differentiates the climate change adaptation needs for a German city focusing on urban development (SenStadtUm 2011).

StEP Klima contains a "set of weighing-up and control tasks rather than a detailed set of instructions. It outlines prospects rather than making rigid regulations" (SenStadtUm 2011: 8). Nevertheless, to ensure that the informal instrument is considered in every planning process, it was passed in the legal form of an urban development plan.

The plan covers three different aspects:

A) It provides spatially differentiated analyses of the areas of adverse climatic impacts within the period of 2001 to 2010. Moreover, the areas that are projected to be affected in 2046 to 2055 and prioritized action zones are mapped.

B) It introduces measures and strategies that aim at improving the urban design to reduce adverse impacts on the local climate. The city's existing built environment and green and open spaces are the focal points in the four main action fields of "bioclimate", "green and open spaces", "water quality and precipitation", and "climate change mitigation".

C) It outlines governance and planning strategies on how to achieve the implementation of proposed measures (SenStadtUm 2010) and presents an action plan that includes model projects to develop a climate-proof city.

3.4.1. Constellation Analysis - Explanatory text

Natural element. The 'natural element' of heat is represented in StEP Klima's analysis of risks and the proposed measures (Aspect A and B of the plan). The constellation element of urban heat stress is depicted primarily by the StEP Klima action field of "bioclimate". This action field focuses on the strains on human health due to climatic conditions. StEP Klima highlights seniors and those with medical conditions as the most vulnerable, affected severely by a degradation of the urban "bioclimate". Even though the term "bioclimate" also covers extreme heat events, StEP Klima's analysis of local heat prioritizes gradually rising temperatures and corresponding risks and measures. To react to extreme heat events, adaptation approaches need to go beyond anticipatory urban development measures. They demand strategies that allow for concurrent reaction to the risk such as the installation of cooling centers or drinking fountains that are not outlined in the plan.

Technical elements. StEP Klima emphasizes the urban structure, in particular the building density, to be an important factor influencing the "bioclimate". In order to make the city's building stock more heat-resistant, the instrument recommends using trees to provide shading, increasing albedo values of buildings, greening façades, and rooftops. To make use of the cooling potential of green spaces, StEP Klima endorses the effects of planting and preserving trees and creating other neighborhood green and open spaces, unsealing courtyards and other suitable spaces, installing open water bodies, as well as preserving and developing cool air corridors.

As part of the plan, the heat load is modeled in a spatially explicit way for day and nighttime for the current and future situation. Interviewed experts appreciate the modeling approach that identifies areas of high risks for urban heat to lead priorities for action. They nevertheless point out difficulties to apply the risk maps in planning practice due to their low resolution. Current modeling approaches of urban heat load also provide only a risk approximation, as personal heat exposure varies with location, sun-exposure, personal characteristics, psychological and physiological factors, and individual time-activity patterns (Chan et al. 2001; Chen and Ng 2012; Middel et al. 2016). Without strong political support for the adaptation to climate change, planners find it difficult to implement measures in a legally incontestable way.

Moreover, StEP Klima gives a rather implicit qualitative definition for its aim of ensuring a healthy urban climate. It neither contains information on adverse health effects induced by bioclimatic conditions that should be avoided, nor does it include benchmarks or normative goals to achieve a healthy climate.

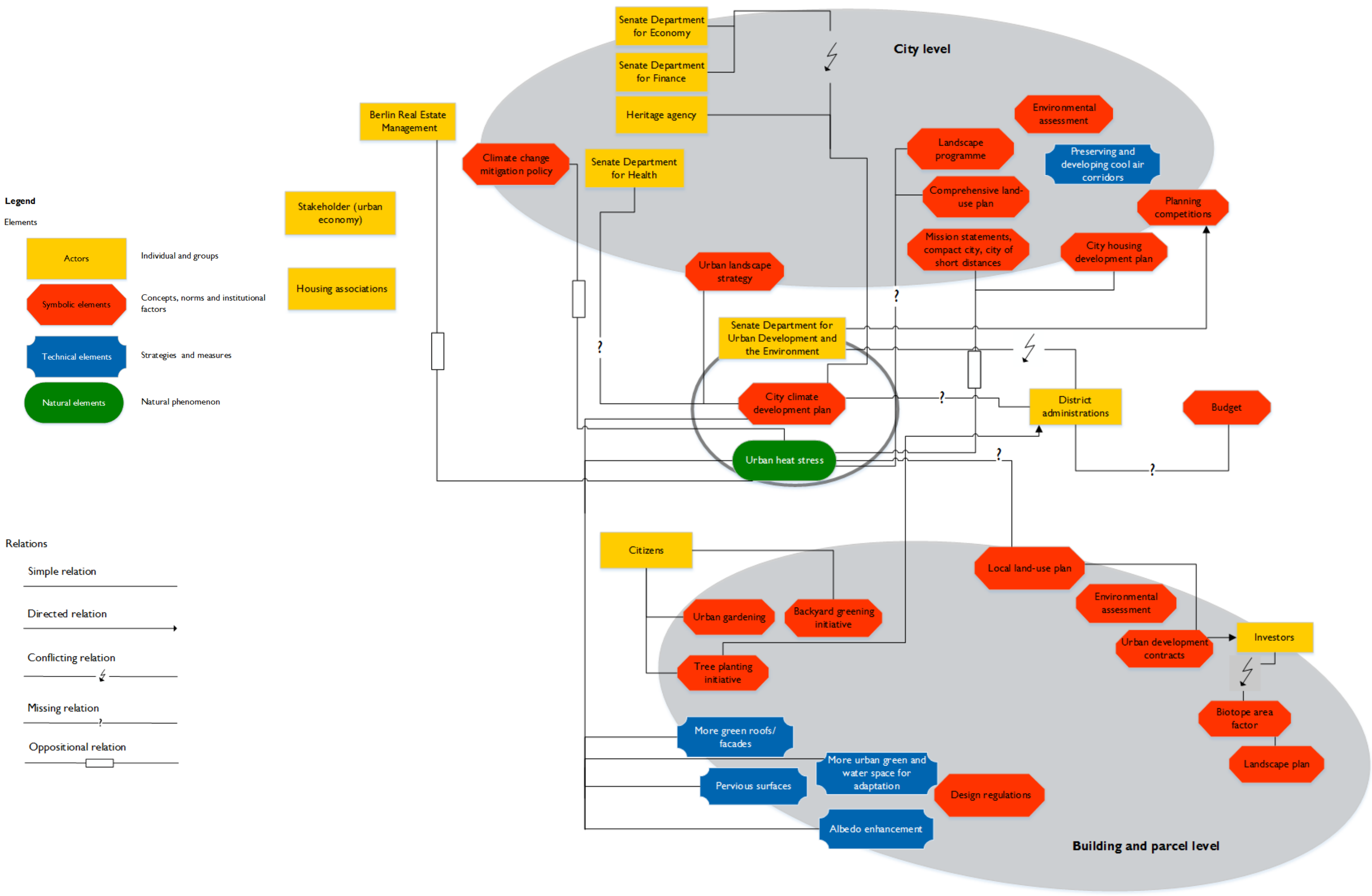

Figure 3.1.: Constellation Analysis: Integration of heat stress measures into urban development planning and governance according to StEP Klima.

3.4.2. Symbolic elements

Mission statements for the urban development. For the Senate Department for Urban Development and the Environment, the StEP Klima is just one of many, sometimes contradictory, policies it pursues for Berlin's urban development. The plan proclaims a climate change adaptation in conjunction with Berlin's long term guidelines of urban development. Since the 1980s, the city has been following the mission statement of realizing a "city of short distances" and in this context the concept of a "compact city". The outer city development shall follow the inner one to guarantee short distances and to prevent space consumption in uninhabited areas (SenStadtUm 2011).

With Berlin growing, the need for housing space is a pressing political issue. Berlin documents its housing policy aims, similarly to the policy goals for the adaptation to climate change, in an urban development plan. The different urban development plans need to be acknowledged equally, but according to the interviewees, creating new residential property is a topic that currently overshadows all others in the city administration. However, expanded urban building activities imply impacts on the local climate now and in the future. Denser urban forms do not necessarily have a negative effect on the urban "bioclimate"; several studies have shown that dense urban forms, especially in hot urban environments, can create local "cool islands" during the day (Oke 1987; Pearlmutter et al. 1999; Ali-Toudert et al. 2007; Georgescu et al. 2011; Middel et al. 2014). While shading from buildings has a positive impact on thermal comfort at daytime, buildings store heat during the day and slowly release it at night (Ali-Toudert 2007; Chen et al. 2012). Even though general evaluations of heat risks of dense urban forms cannot reflect the complexity of heat generation, a single assessment of the impact of every new building or the evaluation of suitable heat risk measures for new buildings does not seem feasible in daily planning practice. Interviewees confirmed that combining new housing and climate change adaptation for a long term sustainable city has not yet been pursued explicitly in urban planning and politics.

The aims of StEP Klima were further defined and politically backed in another conceptual framework - the Urban Landscape Strategy - expressing a focus on greening measures to tackle high temperatures. However, with the political focus on the provision of new housing the preservation of green and open space is often compromised for new building projects.

Mission statements for urban development sometimes complement, but also at times compete with the agenda and objectives of climate change adaptation (see Knieling et al. 2012). Interviewed planners feel overwhelmed by many concepts and frameworks that are too vague - one reason why the informal instrument of StEP Klima gets neglected and does not have much influence on urban planning. Currently the ranking of various development plans undermines climate change adaptation and causes non-integration rather than mainstreaming into administrative practice.

Planning competitions. The Senate Department of Urban Development and the Environment sets the framework for urban planning competitions for the city of Berlin. Since adopting StEP Klima, all 'calls for proposals' also need to take climate change adaptation demands into account (SenStadtUm 2014a).

However, according to interviewees, these directives collide with standards and ideas of competing architects who usually prioritize the architecture rather than hiding it under a green façade or roof. Planning competitions inspire actual building processes, but the realization of heat stress prevention measures included in architectural concepts might also be compromised due to budgetary restrictions.

Environmental assessment. Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) are methods to identify the effects of a program, project, or plan on the environment and humans at an early stage in the planning process. In a StEP Klima communication workshop, district planners recommended the introduction of an obligatory climate impact assessment for every local land-use plan (SenStadtUm 2012a). Interviewed Berlin planners also stress the difficulties to handle the complexity involved in assessing climatic effects in planning processes. Interviewees state that they do not have the capacity and lack strategies to operationalize measures suggested by StEP Klima on a local planning level. They plead for binding city-wide strategies that can be integrated easily into the workflow.

Comprehensive land-use plan and landscape program. In Germany, the formal planning instruments of comprehensive land-use plans and their supplementing landscape programs, which add environmental objectives, regulate city-wide urban development. In Berlin, both documents were amended comprehensively for the last time in 1994 (SenStadtUm 1994a; SenStadtUm 1994b). Accordingly, the more recent demands of a growing city and a changing climate have not been integrated into the plan but acknowledged only by an additional report. Considering current findings on the interplay of urban development and local climate at the level of the city-wide comprehensive land-use plan would set a distinct guideline for all subordinate zoning plans. By including climate change projections into the comprehensive land-use plans, it could fulfill a longer term planning function, rather than being an instrument displaying urban development in Berlin reactively. Several scholars suggest ways to consider changing urban heat risks adequately in comprehensive land-use plans (Greiving 2009; Greiving 2010; Othengrafen 2014), for example by displaying a change in land-use over time.

Urban heat risk prevention needs the integrative perspective of comprehensive land-use plans for informed decision-making (Wamsler et al. 2013). Cooling measures such as air corridors provided by a distinctive positioning of green and open space can only be planned and preserved by taking the setup of the entire city (resp. metropolitan area) into account. The status quo displays no coordination between neither the comprehensive land-use plan nor the landscape program and the recommendations of StEP Klima. Thus, a translation of the policy objectives of the StEP Klima into a mandatory city-wide planning instrument is missing.

Local land-use plan. According to the German Federal Building Code, local land-use plans are key planning instruments that should ensure sustainable urban development and foster climate change mitigation as well as adaptation. The interviewees confirmed the importance of land-use plans as instruments to tackle heat stress. Heat adaptation and mitigation measures not only need to be implemented at the neighborhood or parcel level in the existing built-up area, but also in new building projects planned to serve the needs of the growing city.

In fact, the StEP Klima encourages using the local land-use plan for climate change adaptation. In terms of reducing heat load, local land-use plans can determine which parts of an estate can be built upon or need to remain unsealed. They can regulate the location of buildings, green and open spaces as well as open air corridors, and even façade greening and other measures (Birkmann 2012; Kumar and Geneletti 2015; SenStadtUm 2011).

Nevertheless, according to the interviewees neither the informal planning instrument of StEP Klima nor an amendment of the German Federal Building Code, which should enforce a climate-friendly development in cities (§1 (5) German Federal Building Code (BauGB)), have had a profound impact on their planning routines. When issuing a local land-use plan, public and private interests have to be considered and well balanced (§1 (5 &7) BauGB). The interviewed experts at the district level stated that in an economically challenged city such as Berlin (Berlin.de 2015; INSA 2012), serving investors and creating tax income has been an important, politically backed up argument in the land-use planning process that often outweighs climate considerations (SenStadtUm 2014c).

Planning experts declared that local land-use plans are overloaded with environmental concerns such as biodiversity requirements, a reduction of land consumption, etc., which makes it difficult to prioritize urban climate. Noise prevention is assigned an outstanding role in Berlin planning practice, but respective measures often conflict with those recommended to reduce climatic risks. The temporary nature of high temperatures, unlike ongoing noise exposure, makes it difficult to legally enforce the implementation of heat reduction measures. Guidelines and orientation thresholds are available for noise prevention, which help planning officials to define binding standards in a local land-use plan.

The biotope area factor of the landscape plan. Local landscape plans (concretizing the aforementioned city-wide landscape programme) serve the mitigation of heat stress by fixing Biotope Area Factor (BAF) (e.g., Carter et al. 2015; resp. "green area ratio": Stone 2012; Othengrafen 2014). BAFs assess the surface area which is covered by biomass and shall create a balance of green spaces and other land-use forms. Yet, needs and measures of nature conservation and landscape management in city states, such as Berlin, are defined in city-wide landscape programs. Landscape plans for each district are optional; they are therefore only sporadically used in the current planning practice, limiting also the application of BAFs (SenStadtUm 2011). According to the interviewees, StEP Klima could not resolve this issue and they plead for enhancing the BAF's scope by including climatic considerations as well as integrating it into other planning instruments.

Urban development contracts. Urban development contracts represent a special form of public service contract, binding public authorities and investors. They can assure a climate adapted layout of properties or a binding land-use. The configuration of buildings by demanding roof or façade greening or a façade design with an increased albedo value can be specified (e.g., BMVBS 2013).

In the context of tight budgets for public authorities and limited options to enforce the implementation of measures in local land-use planning, urban development contracts can be instruments to implement heat stress measures. Yet, Berlin planning officials can only secure the application of measures negotiating with investors if they can offer something in return. For example, authorities allow building more extensively than average, if extra greenery is added to the site. However, even if investors offer to install greening measures, standards recommended by the officials are not always followed (e.g., plant species composition). District level planning authorities therefore demand Berlin-wide guidelines and training on how to assess and handle the climate impact of certain operations to apply urban development contracts with regards to climate risk reduction (SenStadtUm 2014c).

Design regulations. Design regulations aim at preserving, protecting, and developing the building stock and surrounding area, its specific architecture and other characteristic features, by defining standards for building materials and layout. These instruments could protect existing garden areas, trees and façade greening, or regulate the color of building faces in order to increase albedo values.

To date, design regulations are often used for cultural preservation, sometimes to explicitly prevent the application of climate change mitigation measures such as façade insulation or solar panels. Even though there have been considerations to apply the instrument for climate change adaptation (Frankfurter Rundschau 2015), StEP Klima could not yet stimulate its use for that purpose.

3.4.3. Actors

Coordination of StEP Klima's aims within the Senate Department in charge. The StEP Klima was set up as a policy instrument by the Senate Department of Urban Development and the Environment (SenStadtUm), one of nine Berlin Senate Departments. As the department is also the main actor to promote the StEP Klima, it takes a prominent position in our constellation. Responsibilities assigned to climate change adaptation lie within the authority of that department. Consequently, the intention of the climate change adaptation plan was to systematically address sector specific needs of urban development actors. Nevertheless, even within the Senate Department for Urban Development and the Environment there are difficulties to mainstream climate change adaptation into the work logic of different subunits. In the Heritage Agency, for example, strategies are still missing of how to apply heat related measures, such as green roofs or façades, to the currently 10% of the building stock with heritage conservation requirements (LUGV Brandenburg 2014).

Coordination of StEP Klima aims across different departments. An urban development policy that takes the risks of urban heat stress into account needs to be multi-dimensional. Nevertheless, aspects that overlap with other Senate departments, such as the departments concerned with health issues or the local economy, are only marginally involved in the climate change adaptation plan. This creates problems when it comes to the implementation of measures; a necessary prerequisite for further action would be to financially back up the plan by the Department of Finance. To tackle urban heat stress in the long run includes harmonizing actions against increasing temperatures, in a precautionary manner with pro- and reactive strategies for extreme events. The Senate Department for Health pursues some strategies, such as precautionary and self-help information campaigns addressing especially elderly people, health care personnel, as well as employers and employees. As of yet, interviewees miss an exchange of health and urban development authorities on the cross-over of heat-health and urban development issues, especially with regard to disaster risk reduction.

Local multi-level coordination between the district departments and the Senate Department. The Senate Department for Urban Development and the Environment assigns the responsibility for the implementation of proposed measures of StEP Klima to a range of different actors, among them the twelve Berlin districts. After the plan's adoption, a workshop addressed the district planners to discuss their role in local climate change adaptation (SenStadtUm 2012a). However, a continuous participatory process has not been established. Lehmann et al. (2015) consider this "a weakness of assigning climate change to a single department that selected relevant fields of action in a top-down approach". Interviews revealed that a missing involvement in the process of creating the climate change adaptation plan contributes to its general lack of acceptance amongst decision-makers at the district level.

Coordination of StEP Klima's aims with local stakeholders. To raise awareness for the new urban development plan and to discuss possible measures another workshop was held with local stakeholders from the housing economy, environmental associations, banks, insurances and water economy in November 2011. One conclusion of the workshop was a need for an ongoing communication and discussion of what climate change adaptation means. However, to date a permanent and institutionalized stakeholder involvement in the climate change adaptation process has not been realized.

As some of the main stakeholders to support the implementation of its heat stress aims, the plan mentions the real estate and housing economy. One important actor in that respect is the Berlin Real Estate Management (BIM); an institution that administers, rents out, and sells the city-owned real estate. With app. 4,500 estates in its repertoire, a commitment of the BIM to foster the implementation of heat adaptation measures would be highly influential. There are efforts to design the company's processes in an environmentally friendly and sustainable way, but StEP Klima's goals still need to be incorporated. As part of a "Climate Change Mitigation Contract" with the City of Berlin the BIM committed to reducing Carbon Dioxide (CO_2) emissions as well as to setting up an environmental management system. With regards to reducing waste heat generation, energy efficiency measures and combined heat and power generation are promoted for the administrative buildings under BIM management (BIM 2016). BIM, as well as predecessor Real Estate Funds, sells property mainly considering fiscal aspects, not yet taking regulations to promote StEP Klima aims into account (Berlin House of Representatives 2012).

Especially the efforts of the major housing associations, subsidiaries of the federal state of Berlin, reflect the success of the local government and administration to mainstream climate change adaptation goals. Over 85% of the Berlin citizens live in apartments (SenStadtUm 2014b). Urban housing associations, often landlords with a large building stock, are pivotal players tackling heat stress in- and outdoors. Measures such as green roofs, façade planting or a higher albedo value have hardly been applied yet. Housing associations focus on climate change mitigation strategies, e.g., energy standards for buildings (e.g., DGNB 2009). Home insulation to improve the energy efficiency of buildings can also increase thermal comfort- especially indoors (Harlan and Ruddell 2011). Housing associations focus on the reduction of greenhouse gas emissions for financial reasons as measures have to be profitable for them. Implementing the heat stress strategies recommended in StEP Klima, such as green roofs or façades, demand long-term financial commitment. They may lead to potential conflicts with residents concerning rising rents and health concerns such as allergies or insects (SenStadtUm 2014a).

Involvement of citizens to coordinate StEP Klima's heat prevention aims. Citizens constitute an important element of the CA as they are the objects of protection from heat stress; but the StEP Klima plan also acknowledges their role in realizing its goals. Civic engagement, taking up a few of the StEP Klima greening objectives, is in various ways supported by the authorities. Urban or guerilla gardening as well as tree planting or backyard greening initiatives create new green spaces and mitigate heat stress. An example for projects that realize ecological aims in the building stock in cooperation with residents is the “Backyard Greening Initiative”. By providing minimal funding for plants, other material, and consultancy, the program sets incentives for residents to ’green’ their backyards (SenStadtUm 2012a). The Tree Planting Initiative, a public-private co-funding of street trees, is used to replace dead trees, but young trees cannot provide enough shade for effective heat mitigation. Interviewees demand a better protection of existing green space by the city.

Recent scientific findings suggest that the positioning of greening measures can be decisive for its effectiveness to reduce heat stress (see Hagen et al. 2014). Therefore, even though private initiatives are crucial to achieve the goals set by the government, especially on private plots, they can only be an addition to a publicly planned comprehensive approach to realize a heat adapted urban design.

3.5. Discussion and Conclusion

In Berlin, heat stress mitigation through smart urban design remains pioneer work even in the presence of a climate change adaptation plan. The StEP Klima example showed that CA can identify challenges of climate planning and governance. The approach of CA provides new insights into the impacts of planning instruments, a field in need for more empirical work (Millard-Ball 2012). CA discloses deficits of the plan itself in dealing with the risk of urban heat as well as the governance and planning system it is embedded in. While the CA shows whether the plan’s regulatory decisions conform with other urban policies, it also sheds light on the plan’s performance by analyzing its potential role in decision situations.

Millard-Ball (2012) sees little evidence that climate change mitigation planning leads to outcomes that would not be realized otherwise. Our CA suggests that this also applies to the Berlin StEP Klima plan. However, the challenges to integrate a climate change adaptation plan into practice are different to the ones faced for mitigation.

In the Berlin case, the climate change adaptation plan constitutes an attempt to gather knowledge on the various impacts a changing climate can have on a city. As impacts and solutions have a local character, raising awareness might not necessarily take place through “media coverage, peer effects, and other channels” like it is the case with climate change mitigation processes (Millard-Ball 2012). The planning instrument of StEP Klima represents an important step to bring attention to relevant local actors and available instruments and spatially defined hot spots of risks. By creating a specific local problem perception of heat risks and coping strategies, the plan is an instrument that influences perceptions and preferences while giving recipients orientation of how to handle the subject (Dupuis and Knoepfel 2011). It addresses relevant actors and possible means by explicitly assigning responsibilities to act.

However, the CA points to the plan's limitations to have an impact on outcomes and shows that its approach inhibits a mainstreaming of urban heat reduction strategies into urban planning and governance. For instance, StEP Klima and related policies prioritize greening strategies to reduce heat stress. Political discourses claim that Berlin is already a "green city" (SenStadtUm 2012a; SenStadtUm 2012b; Kabisch and Haase 2012), which hampers to give local climate issues higher political priority. The Berlin StEP Klima constellation also showed that main challenges are similar to the ones faced by planning and governance in dealing with other climate change adaptation problems. Among those barriers are ill-equipped policy and planning instruments, a lack of participation in the plan creation, competing policy agendas, financial and information deficits, and coordination problems within the urban institutional setting (see e.g., Measham et al. 2011; Lehmann et al. 2015; Runhaar et al. 2012; Baker et al. 2012).

Policy and planning instruments to implement StEP Klima heat stress measures, in the CA represented as symbolic elements, exhibit a gap between their legal potentials and the actual planning practice. Analyzing the various constellation elements illustrated that the goals of the Berlin climate change adaptation plan often conform to other policies on a theoretical level. However, in the weighting process, climatic aspects cannot compete against other environmental and social claims. In the case of Berlin, climate change adaptation considerations are often overpowered by social or economic interests and not framed as part of those interests. Investigating the efforts of various cities to implement climate change mitigation programs, Sharp et al. (2011: 1) conclude that "while financially strapped cities may adopt climate mitigation programs to advance co-benefits or cost savings, fiscal stress also impedes program implementation". Similar observations can be made for the Berlin climate change adaptation plan. It can be considered a strategic instrument to position the city in an international climate change adaptation discourse. Financial strains, affecting staff or funding, restrict further promotion of its heat stress reduction aims.

Most prevalent difficulties to improve the performance of StEP Klima are coordination deficits within the urban institutional setting. Results derived from the StEP Klima governance and planning constellation bear similarities to Langeland et al.'s (2013) findings for the city of Bergen, Norway: One challenge of urban climate change adaptation is to coordinate the complex interplay between many different actors and activities and the attached distribution of responsibilities. Our study confirms the requirement of integrated approaches that include multi-actor and multi-level governance to tackle this complexity (Langeland et al. 2013). In this respect, the CA shows a need for a more action-driven, normative document: Getting backed with quality goals for urban climate and health could expand the function and performance of the plan by committing all the diverse actors towards common aims.

Actors need to participate in the strategy development right from the beginning to avoid fragmented climate-governance (Romero-Lankao 2011) and discuss procedures on how to integrate heat reduction measures into planning projects. A careful translation of climate change adaptation objectives into daily planning practices requires constant communication between urban government levels and different sectoral units. Precise knowledge can thus be gathered on how heat adaptation works on various urban scales (cf. Carter et al. 2015; Adger 2005) and how the formal and informal planning and governance instruments at different levels can be linked. Information gained in different cases and projects in the city needs to be bundled, and consultation made available regarding common city-wide standards as well as possible pathways to implementation. This understanding of climate change adaptation transcends the provision of planning documents. It calls for a long term institutionalized strategy to coordinate activities across all government levels as well as the perennial participation and exchange of local stakeholders. Ultimately, political backup and public support is needed to elevate the StEP Klima from a policy instrument in a rather conceptual and informative stage to a tool that truly changes planning practices and sets incentives for implementation.

Our analysis is an example how to study the performance of a climate change adaptation plan. Further research is needed to assess quantitatively how many climate change adaptation projects the plan triggered and how these projects contribute to reducing urban heat stress. An adaptation plan, especially when it is set up as a flexible planning instrument, needs constant updating and integration of new knowledge. It can only be the very beginning of a process to integrate climate change adaptation into local political and administrative work. Berlin is about to approach the challenges and is currently working on an additional document that will provide more details on how to apply heat measures in urban development and instruments facilitating the implementation.

3.6. List of Interviewees

Interviews

- Author 2 (December 6, 2013). Interview with Senate Department of Urban Development and the Environment (SenStadtUm). Berlin.
- Author 2 (December 19, 2013). Interview with Senate Department of Urban Development and the Environment (SenStadtUm). Berlin.
- Author 2 (January 16, 2014). Interview with Senate Department of Urban Development and the Environment (SenStadtUm). Berlin.
- Author 1 (March 28, 2014). Interview with district official, Berlin.
- Author 1 and 2 (April 8, 2014). Interview with district officials. Berlin.
- Author 1 (April 30, 2014). Interview with district official. Berlin.
- Author 1 (May 14, 2014). Interview with Climate Protection Agency, Berlin.
- Author 1 (May 30, 2014). Interview with district official, Berlin.
- Author 1 & 2 (July 7, 2014). Interview with district official. Berlin.
- Author 1 & 2 (July 16, 2014). Interview with district official. Berlin
- Author 1 (March 24, 2015). Interview with district official. Berlin
- Author 1 (April 30, 2015). Interview with Senate Department of Urban Development and the Environment (SenStadtUm). Berlin

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3.10. Notes

1. While definitions for heat waves vary, the World Meteorological Organization and the Met Office (UK) refer to Frich et al.’s (2002) Heat Wave Duration Index defining a weather event a heat wave “when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5 °C, the normal period being 1961-1990.”
2. There are trade-offs as planning recommendations for building positions, for example, are different for both risks.
3. StEP Klima KONKRET is going to be published by early summer 2016.

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4. Developing storylines for urban climate governance by using Constellation Analysis - insights from a case study in Berlin, Germany

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4.1. Highlights

- Vulnerability to urban heat is linked to governance strategies for urban development
- Urban governance constellations are place and time specific relations between actors and natural, technical and symbolic elements
- Constellations for urban development reveal barriers to urban heat risk reduction
- Current governance barriers hint at different storylines related to future vulnerability to urban heat

4.2. Abstract

Urban populations are at large risk from climate change and particularly extreme heat events. While there are various studies about heat risks, including those based on modeling experiments examining hazards and vulnerability related to heat (exposure, sensitivity and adaptive capacity), methods to develop urban heat scenarios built upon in-depth knowledge on urban governance are missing. The aim of this paper is to create exploratory and anticipatory storylines for heat adaptation in urban planning using the method of Constellation Analysis. Focusing on the case of Berlin, Germany, the complex sets of urban governance measures that exist on different spatial levels are introduced. From the analyzed governance and planning processes three exploratory storylines for 2040/2050 are derived. Additionally, the paper presents an anticipatory storyline of a "heat adapted city". The limitations and benefits of these perspectives and the need for quantitative and spatially explicit scenarios are discussed. Systematic approaches to identifying urban heat governance constellations and deriving respective storylines are of utmost importance for discussing possible urban development paths with different stakeholders.

Keywords

climate change adaptation, urban heat, urban governance strategies, urban development, storylines, Constellation Analysis

4.3. Introduction

As a result of urbanization increasingly large shares of the world population are living in cities. Cities are merging points of economic, political, social and cultural life, and as such face a higher risk of damages from climate hazards (e.g., Carter 2011; Revi et al. 2014), including the urban heat island effect (e.g., Rizwan et al. 2008). Limited vegetation and resulting evapotranspiration, large shares of dark surfaces with low albedo, building configurations that trap heat, and the concentrated generation of heat from anthropogenic activities lead to higher temperatures in cities than in the surrounding countryside (Oke 1982). Distinctive microclimates are known to create hotspots of urban heat risk within cities (Lowry 1967) and global warming from greenhouse gas emissions is intensifying heat in cities (Wilby 2007).

Heat events put urban infrastructure systems and especially inhabitants at risk. They have been associated with higher mortality and morbidity rates and a significant lowering of the well-being of urban populations (e.g., Breitner et al. 2013; Harlan et al. 2014; Kravchenko et al. 2013; Scherber et al. 2013). Many studies on urban heat risks have been undertaken in hot climates, for instance in Phoenix, Arizona, (e.g., Baker et al. 2002; Harlan et al. 2006), Houston, Texas (e.g., Hitchcock 2011) and Seoul, South Korea (e.g., Eum 2013). Mid-latitude cities in temperate climate zones, such as Berlin, Germany, are only beginning to get attention. A statistical analysis by Scherer et al. (2014) identified a mortality risk of about 1600 excess deaths per year associated with heat in Berlin. The authors concluded that dealing with heat risks poses increasing challenges for policy makers, urban planners and architects in mid-latitude cities.

Referring to the IPCC framework on climate change risk and vulnerability (IPCC 2000). McGregor et al. (2007) describe human vulnerability to heat as a function of the degree of exposure to heat hazards, the sensitivity to changes in weather and climate and adaptive capacity. Age, income, gender, health status and exposure are factors influencing individuals' sensitivity (Harlan et al. 2006; Schuster et al. 2014). Individual vulnerability is also defined by the specific spatiotemporal exposure to heat. Adaptive capacity encompasses the available means of a society to target the risks induced by a hazard and reduce respective vulnerability (IPCC 2000 in Carter et al. 2015). Assessing vulnerabilities to urban heat requires consideration of a complex set of factors linked to hazards and their impacts as well as their spatial and temporal patterns. It is also necessary to study various policy and decision-making strategies.

Urban development is a policy field of specific importance for the reduction of vulnerability to heat. It covers governing the materiality of the urban fabric and at the same time involves social, ecological and economic aspects of spatial development (Koch 2010). According to Stone (2012) changing land-use and urban growth are powerful means to alter local climate and to counteract the risks expected from global warming due to greenhouse gas emissions over the next half century. Land-based heat mitigation can lead to a measurable decrease of local temperatures.

There is considerable research on urban governance and climate change. The literature addresses adaptation (see e.g., Carter 2011; Winsvold et al. 2009), heat as an urban development challenge (see Carter et al. 2015; Kleerekoper et al. 2012), and approaches to urban development which can contribute to city cooling, like the arrangement and design of buildings and the quality of their surroundings (e.g., Jänicke et al. 2014; Schwarz et al. 2011; Stone and Rodgers 2001). There has, however, not yet been research on how urban governance influences possible pathways of urban development with regards to reducing vulnerability to heat. Different strategies and their interplay may hinder or result in synergies which can contribute to sustainable urban development. To study the complex sets of factors influencing societal problems, Constellation Analysis, an interdisciplinary approach to research was developed (Schön et al. 2007). The approach allows analysis of the multiple co-existing governance strategies for urban development and climate. Bulkeley and Kern (2006) identify various governance strategies: self-governing, governing through enabling, governing by provision and governing by regulation. These are relevant for understanding urban governance constellations.

Also important is to recognize that policies are dynamic and can be altered in the light of experience. Policy makers can react proactively or reactively to changes in their surroundings, like a changing climate. Social agency and reflexivity, however, make forecasting socio-economic trends a challenging task (Berkhout et al. 2002).

Scenario analysis is an important method for testing different adaptation strategies and to support decision-making processes (Hagemeier-Klose et al. 2013). Capable of capturing a broad range of possible futures, scenarios can include uncertainties inherent in a variety of potential developments and are a popular method used in climate change and land-use change studies (Hagemeier-Klose et al. 2013; Mahmoud et al. 2009; Quay 2010). As they allow for testing different perspectives of interest and their implications, scenarios play an important role for urban planning (Schwedes and Kollosche 2011).

Exploratory scenario techniques use the present as their basis of study. Trends or causal dynamics are extrapolated and implications for future developments beyond these known trends are examined. Anticipatory scenario methods initially outline a preliminary view of a possible (often desired) future or set of futures that are of particular Interest. They analyze how these futures may be achieved or can be avoided taking present restrictions, resources and technology into account (Sterner et al. 2012).

For climate change related scenarios the IPCC has introduced an approach to facilitate the process of describing alternative future developments combining qualitative and quantitative data (IPCC 2000). The IPCC's socio-economic narrative or "storyline" approach was an inspiration for our scenario research. However, here the decisive role of future narratives on governance for local vulnerability assessments is stressed.

While several climate change scenarios have been developed for the global and regional levels, only a few scenarios on urban heat exist (e.g., Aguejdad et al. 2012; Masson et al. 2014). Scenarios will become increasingly important for mid-latitude cities in the temperate climate zone which will likely experience future increases in temperatures. This makes it important to examine and understand urban governance constellations and configurations and how they could shape future urban development paths with regards to reducing vulnerability to urban heat. Hence, the overall aim of this paper is to develop exploratory and anticipatory storylines. This is done using Berlin's current governance constellations as the basis for a case study. The storyline creation presented here serves as a first step to building overall "scenario families" (IPCC 2000). More specifically, the research questions addressed are:

1) What is the city's governance constellation for urban development? And how do governance processes address urban heat on multiple spatial scales?
2) What governance conflicts does the constellation reveal concerning urban development for reducing urban heat?
3) What are plausible exploratory and anticipatory storylines of urban climate governance? And how do they relate to urban development pathways and vulnerability to heat?

4.4. Methods and analytical framing

4.4.1. Case study

Berlin is the largest city and capital of Germany. It covers an area of 892 km^2 and has a population of about 3.5 million inhabitants (Statistical Office Berlin-Brandenburg 2012). Berlin is characterized by a humid continental mid-latitude climate with warm to hot summers and cold winters (Peel et al. 2007). Daily mean temperatures of 19.0 °C were observed during the two warmest summer months of the year from 2000 to 2010 (Dugord et al. 2014). Scientific studies show the heat risks for Berlin on a small spatial scale (e.g., Dugord et al. 2014; Schuster et al. 2014). Dugord et al. (2014) propose a potential heat risk map based on simulated air temperatures and the concentration of infant and elderly population. The analysis associates the inner city area with high risks. Other studies have presented heat mortality risk maps that reveal mortality patterns of great spatial variety with potential risk hubs also lying outside of the inner city ring (Schuster et al. 2014). Urban development of the city state of Berlin is determined at two different levels of authority. The Senate sets the general policy guidelines for the entire city and has, like the Berlin parliament, legislative competencies. The Senate's departments execute tasks of citywide importance. The districts are dependent subdivisions of the central level (Hoffmann and Schwenker 2010; Musil and Kirchner 2012)[1].

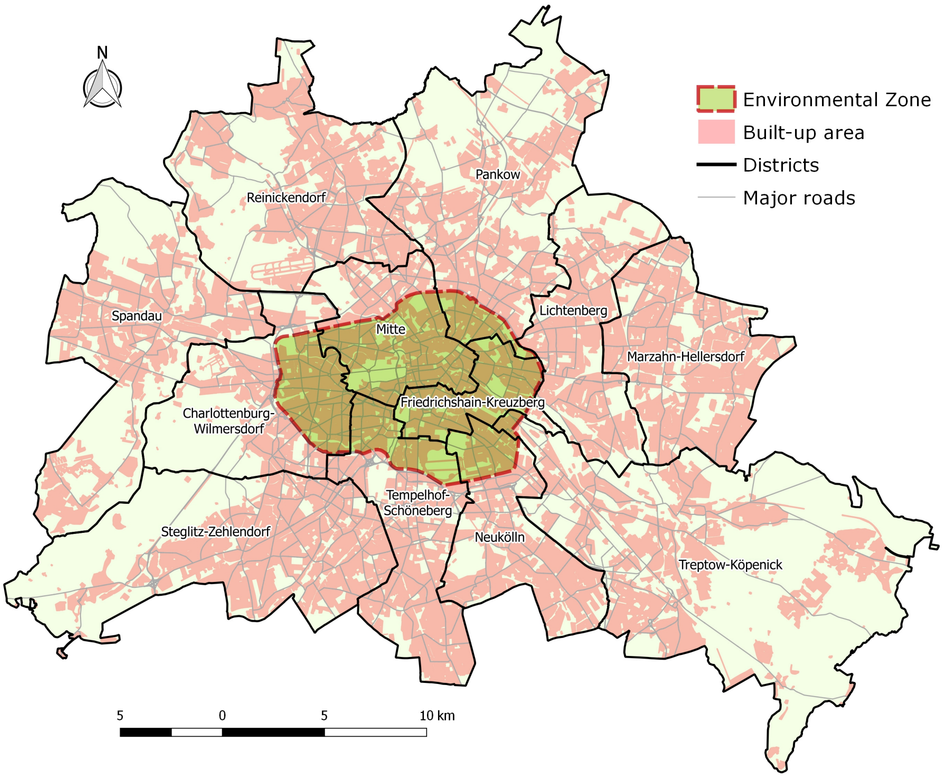

Figure 4.1.: The case study area of Berlin[2]

4.4.2. Constellation Analysis

Constellation Analysis (CA) (Ohlhorst and Kröger 2015; Ohlhorst and Schön 2015; Schön et al. 2007) has been employed to study urban governance capacities to adapt to and mitigate urban heat, with a special focus on urban development. Following Berkhout et al. (2002) we understand urban governance to refer to the level and manner in which power and authority is exercised in cities by governmental as well as non-governmental actors. The presented CA is based on results gathered through expert interviews, expert workshops, and literature review.

[1] Districts have the right to issue local land-use and landscape plans. It can be taken away in case an area of city-wide importance is affected.

[2] The environmental zone characterizes the inner city area which is the most densely populated area of Berlin.

From February to July 2014, 10 semi-structured, problem-centered expert interviews (cf. Witzel 2000) with Berlin administrative officials were conducted. Officials who have a broad knowledge of the local climate policy and planning culture and represent the different urban policy levels were interviewed. The interviewees were asked about their perceptions of urban heat risks, urban development and related governance strategies. The interviews were transcribed and analyzed using the method of content analysis (Mayring 2004).

Between February and July 2014 Constellation Analysis workshops were conducted with researchers from the "Urban Climate and Heat Stress in mid-latitude cities in view of climate change" (UCaHS) project team in order to integrate interdisciplinary scientific knowledge. In four sessions, environmental planners, social scientists, climatologists, urban geographers, hydrologists and physics discussed the interrelations of heat and urban development. In the different meetings researchers developed constellations of how urban heat is and should be dealt with from their disciplinary perspectives. The results of the two constellations were tied together under the urban development governance perspective. In addition grey literature and policy documents on climate governance and urban development were examined.

4.4.2.1. Description of constellation elements and relations

For Constellation Analyses the following elements are identified:

- Actors: individual and groups of actors (e.g., human beings, organizations, social movements)
- Natural elements: materials, resources, plants and animals, landscape, and natural phenomena
- Technical elements: artefacts (e.g., technical elements, procedures)
- Symbolic elements: concepts, ideologies, standards, laws, discourses, institutional, legal or economic factors (Ohlhorst and Kröger 2015; Ohlhorst and Schön 2015).

Subsequently, the interplay of the elements is assessed. Constellation Analysis classifies relations between the elements as: simple, directed, conflicting, missing and oppositional[3] (Ohlhorst and Kröger 2015). Graphical illustration and a description of the identified network of elements provide a multi-perspective appraisal of how a problem can be structured (Schön et al. 2007).

[3]Ohlhorst and Schön (2015) point out that the relations between elements can be undetermined or completely missing. Spatial proximity or distance mapped in the constellation shows how close or lose the relation between some elements is. Elements that explicitly and intentionally act against one or multiple other elements are conflicting. If an element resists unintentionally to the expectation or attribution of others the relation is called oppositional (Ohlhorst and Schön 2015).

For the Berlin Constellation Analysis dominant elements and relations were derived from expert interviews, expert workshops and literature. Dominant elements and relations are categories that repeatedly occurred within the empirical material.

4.4.2.2. Analysis of the constellation

The constellation elements display urban governance processes and strategies that we arranged according to Bulkeley and Kern's (2006) framework of urban climate governance. The framework distinguishes modes of *self-governing*, *governing through enabling*, *governing by provision* and *governing by regulation*. It was designed to categorize the processes through which urban governing is orchestrated and the institutional arrangements within which it takes place. As our analysis focuses especially on governance constellations, the framework of urban climate governance structured the variety of arrangements that exist.

Table 4.1.: Framework of urban climate governance analysis (Bulkeley and Kern 2006; Kern 2008)

Mode of governance	**Characteristics**
Self-governing	Capacity of local government to govern its own activities
Governing by provision	Shaping of practices through the delivery of particular forms of services and resource
Governing by authority/regulation	Use of traditional forms of authority such as regulation and direction, use of control and sanctions
Governing by enabling	Role of local government in facilitating, co-ordinating and encouraging action through partnership with private and voluntary sector agencies and various forms of community engagement

In addition, the concept of heat vulnerability (McGregor et al. 2007) was applied for the Constellation Analysis. Urban development (governance) strategies are categorized according to their aim of reducing exposure or sensitivity to heat.

4.4.2.3. Developing exploratory and anticipatory storylines

Three main governance conflicts were derived from the interactions of constellation elements. We conceptualized the conflicts as arising from the different frames, values and beliefs of actors that are embedded in complex, sometimes constraining institutional environments (Biesbroek et al. 2014).

The conflict dimensions characterizing urban development governance strategies underlay the assumptions of the three exploratory storylines described in Table 4.2. The storylines depict urban development paths up to 2040/2050 and what these paths mean for vulnerability to heat should present conflicting dimensions get solved. The exploratory storylines incorporate dynamic elements, like an increase in temperature of 2.5 degrees in Berlin by 2050 (Lotze- Campen et al. 2009) as well as projections for an increase in population from 3.59 to 3.74 million (SenStadtUm 2012).

The assumption underlying the exploratory storylines is that resolving the conflicting dimensions makes the implementation of measures more likely. To find ways to implement policies involves the identification of factors that reduce the identified conflict dimensions- a problem that is focused on by the anticipatory storyline. The anticipatory storyline (Table 4.3) reverses the analytic focus. It shows factors to achieve the defined aim of "the heat adapted city" that are derived from our empiric results. We define a "heat adapted city", as a city that provides an urban governance system able to integrate the topic of heat, which raises awareness for the risks and facilitates the implementation of effective and efficient measures.

4.5. Results

4.5.1. Mapping the urban development constellation

Of the set of *symbolic elements* outlined by Ohlhorst and Schön (2015) we focus on concepts, norms and institutional factors that structure governance processes. Central to our constellation are policy and planning instruments guiding urban development on different spatial scales. Their relations with other elements and interplay with each other characterize urban adaptive capacity to urban heat.

We define urban heat and other environmental subjects of protection like soil and noise as *natural elements* for our constellation. Urban heat as the main independent variable is the focal element of the constellation. *Technical elements* in the depicted constellation are tools for urban design to diminish the accumulation of heat. Ohlhorst and Schön (2015) point out that an unambiguous designation of natural or technical elements cannot always be achieved. In our case the elements of "Air circulation" or "Increase of vegetation" abstract from a distinct classification. We also characterize the urban configurations of building stock and new buildings as technical elements.

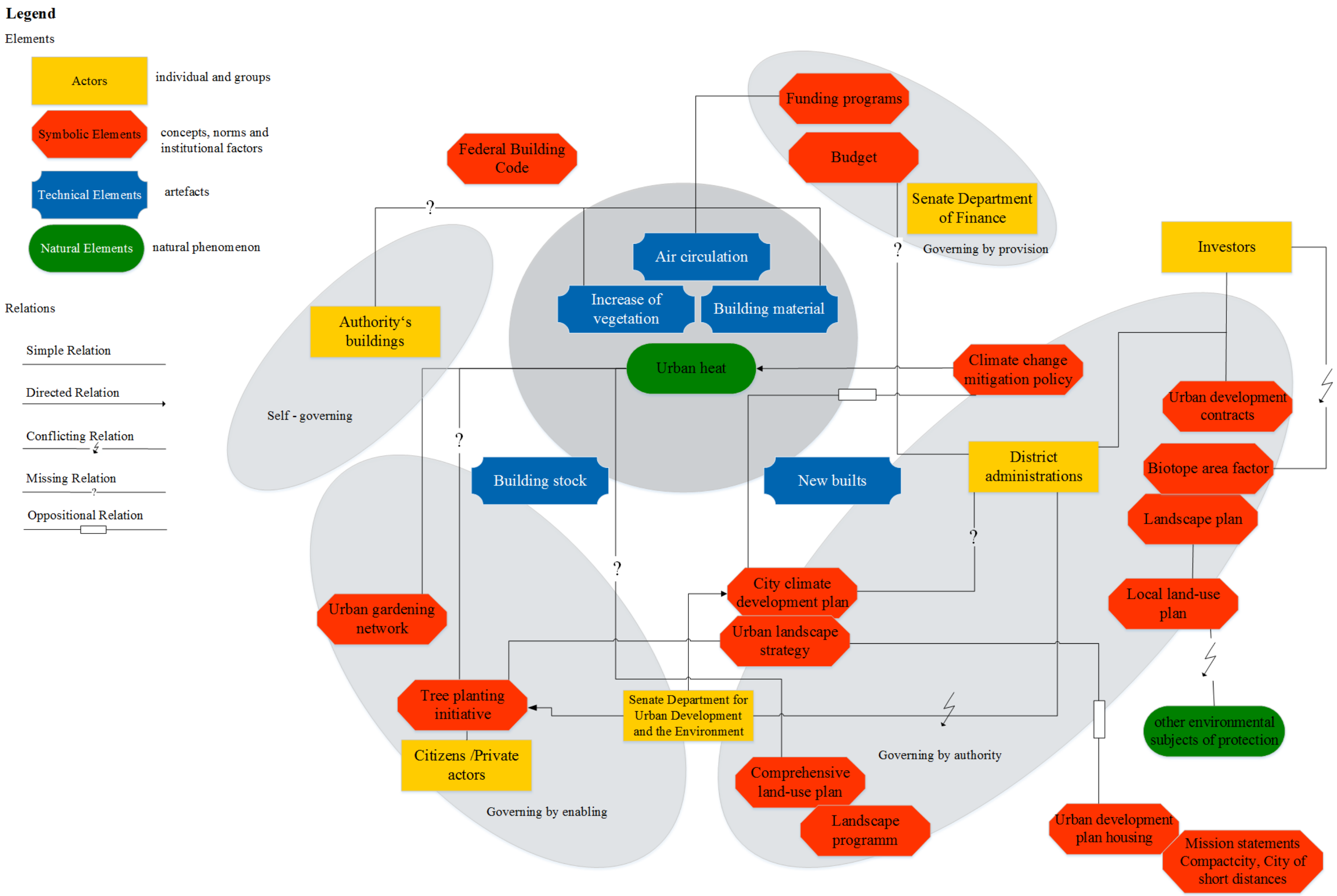

Figure 4.2.: Constellation Analysis of the urban adaptive capacity to heat in Berlin (barriers and potentials)

Finally, *actors* play a vital role in the Berlin constellation. They handle policy and planning instruments and are addressed by them.

The mapped constellation displays an overview of current urban development governance that may appear static. It is a socially constructed network that needs to be understood as place and time specific. Nevertheless, the constellation is the product of a pathdependent history of institutional settings and cultures. It therefore indicates a dynamic range of futures but also displays certain institutional limitations of these pathways.

4.5.2. Urban development governance and urban heat - a detailed description of the Berlin constellation

At the center of the constellation, urban heat and the different urban development measures that target heat risk can be found. These technical elements have been derived from a review of the literature and discussions in the constellation workshops. Kleerekoper et al. (2012) categorize elements into groups: vegetation (urban forests/parks, street trees, private green in gardens and green roofs or façades), water (fountains etc.), built forms (building density/geometry) and material (albedo increase, permeable materials, thermal admittance of materials). Stone (2012) points out the influence of "carbon cooling strategies" (energy efficiency measures, changes in transport systems) to reduce waste heat. These measures influence the level of heat human beings are exposed to in urban settings. Some of them have been shown to also exert a positive influence on sensitivity to heat. Green spaces can improve the urban microclimate and human health. Nature experience advances health conditions resulting from and leading to higher stress levels like diseases of the respiratory system (e.g., Lafortezza et al. 2009; Lee and Maheswaran 2011). A recent study suggests a strong connection between health, fitness and individual heat stress providing evidence that urban development governance which increases activity levels of citizens could reduce the sensitivity to urban heat stress proactively (Schuster et al. in preparation). Heat prevention measures can be applied at the building stock as well as new building sites. Both are targeted by different governance and planning instruments with the aim of urban heat reduction.

4.5.2.1. Governing through authority/regulation

The symbolic elements, available policy and planning instruments and their capacity to influence heat risk reduction play a central role in shaping the city. Urban planning is the traditional mode of *governing* urban development itthrough authority/regulation. Planning instruments target different spatial scales. Various instruments take account of the local climate as one of numerous aspects to be considered in planning processes. However, there are many uncertainties as to how to operationalize this claim.

Federal Building Code Since 2011 the German Federal Building Code states that the mandatory instruments of urban planning, that is the comprehensive and local land-use plans, need to foster climate change mitigation and adaptation in urban development and secure a humane environment (§1(5) German Federal Building Code). The federal legislator expanded the legal framework beyond current risks arising from local climatic conditions. Urban planning is asked to handle risks specific to climate change.

Greiving (2009- 2010) points to one of the central difficulties arising from the difference between new planning requirements for climate change and traditional conceptions of urban planning. Planning used to refer to experiences made in the past relying on the statistical reoccurrence of weather and climate. Finding ways to integrate uncertainty concerning future climatic conditions challenges established planning routines (Greiving 2009- 2010). Patterns of heat exposure and sensitivity of people and infrastructure are highly spatially and temporally diverse. Urban heat is therefore especially difficult to take into account in the planning process (i.a. Carter 2011; Klok and Klueck 2015).

Comprehensive land-use plan Mandatory concepts of land-use for every German city are fixed in the comprehensive land-use plans, supplemented with landscape programs which integrate environmental objectives. In Berlin both planning instruments were amended systematically for the last time in 1994 (SenStadtUm 1994a; SenStadtUm 1994b). In the meantime, the documents have been further modified, making comprehensive land-use planning an instrument displaying short-term or immediate urban development. This practice erodes the functions of the instrument as a guide for longer term planning. Not systematically including new knowledge concerning the urban climate in connection with demographic developments into mandatory planning instruments misses out on chances to ensure the adequate consideration of climate related impacts on lower planning scales.

Local land-use plan As the main mandatory planning instrument the local land-use plan, which is mainly issued by the district administrations[4] , regulates the possible ways of building in the city. Local land-use plans can influence small-scale heat exposure by determining which parts of an estate can be built upon or need to remain unsealed, the location of buildings, the establishment or preservation of green and open spaces as well as open air corridors, and even obligations for façade greening and other measures (SenStadtUm 2011). When issuing a local land-use plan public and private interests have to be considered and well balanced (§1(5&7) German Federal Building Code). Cost intense heat reduction measures can easily be outweighed by

[4]Exceptions: developments that are of interest for the whole of the city or of exceptional significance as well as planning and measures related to Berlin's function as the German capital are withdrawn from the district's authority and transferred to the Senate's.

investors' interests (SenStadtUm 2014a). Local climate is just one of many different legally protected environmental goods that should be considered in the planning process. Local land-use plans are overloaded with requests tied to noise prevention, biodiversity protection, and many other issues, which makes it difficult for the topic of climate to gain ground. Traditionally planning practice in Berlin is characterized by a dominance of concern for noise prevention. The subject of noise prevention is characterized by guidelines and orientation thresholds (e.g., DIN 18005-1) which makes it easier for planning officials to define binding noise standards in a local land-use plan.

Biotope area factor Another instrument to regulate urban development in Berlin is the internationally much referenced Biotope Area Factor (BAF) (e.g., Carter et al. 2015, resp. "green area ratio": Lakes and Kim 2012; Stone 2012). The BAF can be included in the local landscape plan, a supplement to the local land-use plan. It assesses the surface area covered by biomass and it serves to create a balance among current land-use forms like residential areas, business and industrial sites, infrastructure and green spaces (Lakes and Kim 2012). By using the instrument, ecological standards can be fixed when an urban site is being developed or modified. Acknowledging the effects of urban green on health, an application of the BAF can reduce citizens' sensitivity to heat in addition to potentially reducing their heat exposure. Yet, landscape plans are instruments that are only sporadically employed in current planning practices as their use is optional (SenStadtUm 2011). Even if a BAF is part of a landscape plan, its inclusion in the mandatory local land-use plan is not required. The investor's inclination to accept such regulations and the district authorities' willingness to bind the investor are decisive prerequisites for an effective application of such an instrument.

Urban development contract Urban development contracts do not entirely represent *regulatory* approaches, but modes of *governing by enabling* play a role. They are special forms of public service contracts which bind public authorities and investors as well as landowners. Fixing the layout of properties or a binding land-use for heat reduction are possible applications of the instrument. Urban development contracts could demand roof or façade greening or an increased albedo (e.g., BMVBS 2013). In contexts were public authorities face tight budgets, urban development contracts could ensure the inclusion of measures against heat in the building process by the investor[5]. However, in Berlin executive urban planning officials on the district level point out that due to economic competitiveness between the districts, officially recommended standards have been compromised in negotiations with investors (e.g., plant species composition).

[5]See the Statistical Report of the Statistical Office Berlin-Brandenburg (2013)

City Climate Development Plan (StEP Klima) As a means of *governing by authority* the Berlin City Climate Development Plan (StEP Klima) is the strategic document combining political objectives of climate change adaptation and urban development (SenStadtUm 2011). It takes heat reduction explicitly into account and puts a focus on the risks identified within the city-center ring. The StEP Klima currently only plays a marginal role in Berlin's urban development. Intended as a strategic, informal planning instrument by the Senate Department for Urban Development and the Environment, StEP Klima operates without substantial financial support for the implementation of aspired measures from the Department of Finance. Being a non-mandatory instrument, which maps risks at a relatively low spatial resolution, officials on the district level consider StEP Klima unable to exert much influence on the actual planning practice. Furthermore, officials emphasize the lack of reconciliation between different urban planning objectives as an impediment to StEP Klima's ability to play a more central role in planning processes. Urban development on all Berlin governance levels is dominated by the political objective to provide more dwelling space. Strategic aims for the provision of new housing are documented in the "Urban Development Plan Housing". So far this instrument does not enforce the concurrent consideration of climate change adaptation needs, but backs up building projects even if these projects compromise green and open space. In dense cities the exposure of citizens to urban heat is believed to be higher. However, dense urban forms have also been shown to exert cooling effects due to shading (e.g., Ali-Toudert and Mayer 2007). Stone (2012) also stresses that the quantity of excess heat generated per person in lower density settings is more than in higher density urban cores. Sensitivity to heat may also be reduced in a positive way as compact cities could enable a more active lifestyle leading to heat stress reduction (Schuster et al. in preparation), an argument not acknowledged by StEP Klima and current planning practices. To reconcile Berlin's mission statement goals for a "compact city" and "city of short distances" with the requirements of climate change adaptation would still demand an assessment of the urban heat impacts of urban development projects currently considered unrealistic by urban planners. Climate change mitigation measures have also been included in the StEP Klima. They are considered as means to tackle global warming. Their potentials to reduce local exposure to heat are not acknowledged. Stone (2012) points out that applying energy efficiency measures for example in power generation and reducing vehicle transport are effective means for decreasing waste heat in cities. Currently more than 50% of electricity in Berlin is gained by combined heat and power generation[6]. Air-conditioning is not widely in use in Berlin (Buchin et al. 2015). Nevertheless, officials point out that regulations aimed at improving the energy efficiency of buildings are not widely executed.

Heat adaptation strategies, like designing climate responsive buildings by applying green roofs or façades, are also not yet recognized as effective strategies for decreasing greenhouse gas emissions (Buchin et al. 2015). Climate change mitigation dominates

[6]http://www.stadtentwicklung.berlin.de/umwelt/energie/kwk/de/berlin.shtml, accessed 20.11.2015

administrative discourses and practices on climatic issues, marginalizing instead of integrating the topic of local adaptation to climate change.

4.5.2.2. Governing by enabling

Even though the informal StEP Klima planning instrument has not exerted much influence on mandatory planning, other governance mechanisms emerged in the background and promoted some of its aims for the building stock. The “City Climate Development Plan” is supplemented with the so-called “Urban Landscape Strategy”, a strategic document putting greening measures in the center of the Berlin adaptation strategy. In sharp contrast to citywide strategic goals, district officials point out that maintaining green space is difficult due to budgetary restrictions. Campaigns like the urban tree planting initiative are part of the greening strategy. As a means of *governing by enabling* the campaign seeks to encourage citizens and local companies to fund the re-planting of lost trees on streets. Companies also invest in the initiative as a compensation measure for building elsewhere. The public authority takes the role as enabling institution, but also gives additional financial support, once a fixed amount of money has been donated. It should be noted that recently planted trees cannot provide adequate shade to reduce heat exposure. Systematic urban heat reduction implies a consideration of scientific recommendations for locating greenery (see Stiles et al. 2014). Public authorities often fail to steer urban development leaving it to private economic or civil society actors. The Berlin authorities are thus *enabling institutions* for civil engagement within urban development. Urban gardening initiatives, for example, transform most often derelict land into green spaces serving the reduction of urban heat exposure as well as reducing sensitivity by *enforcing active engagement of citizens*. The Berlin administration encourages these projects indirectly by mediating conflicts, establishing supportive conditions and helping with building a network of initiatives (Berlin House of Representatives 2013).

4.5.2.3. Self-governing

Self-governing mechanisms for the authorities’ building stock are currently limited to the application of energy efficiency measures, a source of reducing waste heat. It is not yet on the political agenda to install green roofs, façade planting or a higher albedo value on public buildings to set an example for private owners. These measures are potentially subject to rejection as they are perceived as unprofitable and potential causes of conflicts with tenants (SenStadtUm 2014b).

4.5.2.4. Governing by provision

Funding instruments for urban climate issues are often provided by supra-local governance levels, like the Berlin Program for Sustainable Development derived from the European ERDF funds (SenStadtUm, n.d.). Reverting to upper governance level's financial support programs contradicts with challenges posed by local climate risk: financial support is often just short term and project-based whereas heat prevention measures need long term commitment (maintenance of green, climate change adaptation projects). On the district level officials with knowledge to make use of funding opportunities are often missing.

4.6. Urban development storylines of future urban heat

4.6.1. Conflict dimensions for the governance of heat in urban development

The Constellation Analysis revealed conflicting governance dimensions that hinder a systematic implementation of heat reduction measures. These conflicts work as analytical focal points to derive the exploratory storylines for urban development. The main conflicting dimensions are:

1. *Competing policy objectives*
   Urban governance is dominated by the goals of creating new dwellings and providing space for investors. These aims are currently implemented in a way that does not consider heat reduction. There are also other environmental risks competing with climatic aspects for acknowledgement in the planning process. Political awareness of the problem is low.

2. *Conflicting spatial risk perception*
   Risk perception is guided by the climate change adaptation plan StEP Klima, which focuses on urban heat risk in the city center area. In so doing the spatial diversity of heat risks is denied and potential vulnerabilities are not tackled.

3. *Competing objectives of scales of governance and coordination barriers*
   Conflicting notions of responsibilities and respective endowment with resources between the district and city level as well as other actors lead to an overall loss of potential for strategic risk reduction action.

4.6.2. Exploratory storylines of future urban heat

The baseline storyline shows urban development and possible implications for vulnerability to heat in 2040/2050 assuming current conflict dimensions remain stable.

Storyline 2 depicts the progression of vulnerability to heat if the coordination problems between urban governance levels are solved. Present planning instruments are applied for heat reduction in the city center - a spatial distribution of precautionary measures suggested by the adaptation strategy StEP Klima. Storyline 3 explores the question of how vulnerability to heat would change if all conflict dimensions were to be solved. All districts and the city work in a coordinated manner on the policy goal of heat reduction. The policy aim is harmonized with other, currently competing goals of urban development. Planning and policy instruments handle the reduction of potential vulnerabilities to heat for the whole of Berlin acknowledging the diverse spatial distribution of sensitivity and exposure. The storylines are differentiated into three spatial levels of the block, the district as well as the city. They highlight the various strategies that the resolution of each governance conflict brings about on different governance levels.

The policies found in the different storylines represent the state of urban capacity to heat in 2040/2050. The policies are not static. Heat reduction measures are likely to be implemented in a proactively (storyline 2, 3), but also reactively as temperatures continue to climb (likely storyline 1). Quay (2010) shows that urban governments can use decision frameworks that break up urban adaptation to climate change into incremental steps.

“Signposts” are indicators that assist governments to anticipate when action needs to be taken in order to respond effectively to achieve the aims of a specific storyline (Quay 2010). These indicators are usually based on monitoring quantitative data and represent defined, but flexible thresholds for action. Defining “signposts” requires scientific knowledge and political negotiation processes. Possible indicators for urban heat risks could involve monitoring urban temperature change and setting a threshold similar to the global 2 degree target. The frequency of heat wave periods, but also social factors like hospital admissions or a combination of risk dimensions could also serve as “signposts” for action. Furthermore Quay (2010) speaks of “trigger points” for urban governance action. These triggers are not necessarily climatic changes. Local public opinion, external socio-economic and political factors or the availability of new technologies can also set off a change in urban development practices.

The Constellation Analysis showed that political awareness about the risks of urban heat in Berlin has been triggered. Interviewees pointed to the 2007 IPCC Fourth Assessment Report and a report of the Berlin Climate Protection Council, a policy advisory board, as trigger points that resulted in climate change adaptation gaining political attention. There has not, however, been much strategic action related to implementation.

Table 4.2.: Exploratory storylines of adaptive capacity to urban heat in Berlin 2040/2050

	Baseline Storyline 1	City center Storyline 2	Comprehensive city Storyline 3
Dominant conflict dimensions	Competing policy objectives		
	Conflicting spatial risk perception		
	Competing scales of governance		
Characteristics of governance strategies for urban development	Urban governance according to existing political and planning instruments	Measures implemented proactively according to the scope of current planning and governance capacities	Measures implemented incrementally and proactively according to advanced planning and governance capacities
	Low political attention for heat reduction	Political attention focused on the city center	Political attention for heat reduction for the *entire* city
City-wide	StEP Klima marginalized by other development objectives	*Implementation* of measures according to StEP Klima	*Short-term* implementation of measures relates to StEP Klima assumptions and therefore *focuses on the city center*
			Long-term implementation goals to tackle exposure and sensitivity to heat risks *throughout the entire city*
	Higher density urban development throughout the entire city *without* implementation of heat reduction measures	Paradigms of *compact city* and *city of short distances* linked with the implementation of heat mitigation and adaptation aims	
			Incentives for *building higher* rather than disperse building
City-wide	Comprehensive land-use plan adapted and updated following trends in current urban development in the city		Comprehensive land-use plan includes short-term and long-term land-use possibilities considering projections of climatic and demographic development

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Table 4.2 – continued from previous page –

	Baseline Storyline 1	**City center Storyline 2**	**Comprehensive city Storyline 3**
	Climate change mitigation measures and adaptation measures *compete against* instead of complement each other		Climate change adaptation and mitigation measures checked on *mutual benefits*, e.g., energy efficiency measures applied explicitly to reduce urban waste heat
Districts			Prioritizing the center districts in the *short term*
	Prioritization of *other* urban development concerns	*Inner city districts* follow strategy of urban climate protection, focusing on greening measures	In the long term all districts follow strategy of urban climate protection
	Districts *lack their own strategies*	No district strategies	Priority action analysis according to *sensitivity and exposure maps* on the district level
	Local land-use plans issued mostly *without* considerable implementation incentives for heat measures	Local climate issues play an *influential* role in mandatory planning (Albedo increase, green space enhancement, air corridors), especially *within the city center ring*	Local land-use plans deliberately *increase open space ratio* instead of building development *Temporal* building permits
	BAF *not commonly* used in planning	BAF and urban development contracts used strategically to ensure urban heat reduction in the *city center*	*Short-term* enhanced BAF ratios
Districts	Civic engagement in *urban gardening* initiatives supported by urban planning administration, but less and *less space* available	*Sealing ground* in city center only possible with climate adapted *green space compensation* located in heat affected areas of *the city center*	*Sealing ground* is restricted to a *limited amount of space* in the different districts following strict assessment of climate impacts

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Table 4.2 – continued from previous page –

	Baseline Storyline 1	**City center Storyline 2**	**Comprehensive city Storyline 3**
	Mature trees planted by tree planting initiative, but planted in a way that is *not necessarily optimal* for shading purposes		Extension of *untouchable green and open spaces*
	Authorities' building stock equipped with *energy efficiency* measures	Authorities' building stock adapted in the *short-term* to heat by applying green roof and green façades to *set an example for private* investors	
	No politically encouraged use of urban facilities like swimming pools or libraries for reactive heat protection		Urban facilities as *"cooling centers"* and public drinking fountains
Building/block	Heat reduction measures in buildings applied according to *market demands* High costs of measures like palisades/roof and façade greening Extended city-wide use of *air-conditioning*	Heat reduction measures in new buildings, like palisades/roof or façade greening applied *mandatorily in the city center*	Heat reduction measures like palisades/roof or façade greening applied *mandatorily at new buildings and building stock throughout the entire city*
	Reducing *sensitivity* to urban heat by means of urban development *not politically enforced*		Proactive reduction of *sensitivity* due to short distances to important facilities: expansion of *cycling/walking facilities encouraged*
Implications for population vulnerability to heat	Selectively protected city; not necessarily the most sensitive are reached by measures; exposure reduced for those who can afford it. Vulnerabilities not strategically targeted by urban development	Urban planning measures aim at the amount of people that are vulnerable through exposure in a dense city center; vulnerabilities induced by sensitivity are not explicitly targeted	Reducing vulnerabilities induced by exposure as well as sensitivity are approached by means of urban planning and policy

The baseline storyline assumes that means of adaptive capacity to heat will develop as byproducts of other urban development targets. The implementation of strategic measures targeting the risks of urban heat explicitly is not politically enforced, but might happen voluntarily. This strategy implies a potential increase in the vulnerability to urban heat.

The trend in storyline 2 shows a state that might occur if current planning instruments are applied for the purpose of heat risk reduction. Enhanced implementation action represented by this storyline needs a trigger point to be put into force. Its implications for the vulnerability to heat are spatially limited to decreasing exposure in the city center.

As shown in storyline 3 substantial influence on risk and vulnerability can be taken if the spatial risk perception induced by the climate change adaptation strategy (StEP Klima) is extended. Storyline 3 demonstrates how flexible heat policies incrementally lead to an adapted city by 2040/2050. Like in storyline 2 implementation is triggered by specific events or conditions. But heat adaptation and mitigation decisions are broken into different steps, targeting spatial hot spots in an incremental way before they occur. As instruments are flexible, it gives decision-makers the opportunity to react to new “signposts” signaling the need for action as temperatures are rising. Governance actively tries to reduce exposure and identifies areas with a population of high sensitivity.

4.6.3. Anticipatory storyline “The heat adapted city”

The anticipatory storyline shows urban governance strategies that would be prerequisites to achieving a “heat-adapted city”, an ideal city where conflicting governance dimensions are solved.

We consider prerequisites to achieve the heat adapted city as the integration of heat policy into the governance and planning system and the commitment of actors to implementing the policy. The anticipatory storyline shows the importance of communicating the risks and possible coping strategies at and between all governance levels. Initiating public debates also seems to have a decisive impact. Communicating risks and strategies resolves the conflict dimensions that keep current governance processes from acknowledging urban heat in development planning and action.

Table 4.3.: Anticipatory storyline "The heat adapted city of Berlin in 2040/2050", conflict dimensions targeted shown by the numbers in brackets

	Anticipatory storyline
City-wide	Promote a public debate about heat risks and what to invest to reduce them involving relevant actors from all governance levels, stakeholders and citizens (1,2,3)
	Define orientation goals/ trigger points/ signposts of acceptable levels of heat in different urban structures (1,2)
	Pass legal agreements like a Climate Act to enforce aims of non-mandatory instruments like the adaptation plan (StEP Klima) and expand budgets to (co-) finance heat reduction measures to show a strong political commitment (1)
	Clear allocation of respective responsibilities of private and public actors, make competences known to them and accepted by them (3)
	Provision of communication channels for actors involved in dealing with local climate (3)
Districts	Climate commissioner as integrative figure to coordinate mainstreaming of topics in all kinds of district urban development departments and between districts and city-wide governance levels (3)
	Strengthen link between urban development officials and scientific actors, constant exchange of knowledge concerning spatially diverse risks and possible administrative coping strategies (2)
	Training for planners to handle heat by means of urban planning and to acquire funding sources provided by different governance levels (3)
Building/block	Counseling of investors/architects how to invest in heat reduction measures by taking advantage of public funding (1,2)

4.7. Discussion

There are many benefits to a systematic Constellation Analysis of urban development governance and local climate. Taking the example of Berlin, this study has identified relevant actors, and technical, natural and symbolic elements and as well as their capacity to contribute to urban heat reduction.

The Constellation Analysis is a useful tool for examining the barriers to and potentials for reducing vulnerability to heat that lie within societal and political processes. Our results complement the findings of Stone et al. (2012) on available urban governance instruments with an analysis of their actual use for heat reduction purposes.

To analyze the potentials for reducing urban heat vulnerability in urban development policy, we distinguish adaptive policy action into instruments that target sensitivity and those that decrease the exposure to heat. The Constellation Analysis showed that current urban development policy instruments predominantly concentrate on greening measures as means to adapt the urban system to the impacts of climate change. Reducing exposure and sensitivity are inseparable properties of greening measures (Smit and Wandel 2006). Only recently, studies point out the decisive influence of the population's fitness and its sensitivity to heat (Schuster et al. in preparation). This opens up new perspectives for heat and urban development governance. Precautionary strategies focus on raising activity levels of the population to tackle their sensitivity to heat. Urban development policy instruments intended to increase the numbers of pedestrians, bicycle use or other sports activities should be considered by policy-makers. They are not yet present in current urban development discourses and therefore have not been included into this Constellation Analysis. Future studies could give attention to this aspect.

The Constellation Analysis displays only a broad overview of Berlin's urban development governance for heat mitigation and adaptation. We reduced the complexity of the Berlin governance constellation to the most dominant relations revealed by our interviews, the workshops as well as relevant policy and planning documents. This was a necessary prerequisite for building future storylines. By taking a perspective that goes beyond the analysis of the present, the study took on a different perspective than previous ones in that field. Extending the view to possible future development paths and how to achieve them advances Constellation Analysis. Socio-economic scenarios and their narrative parts are value-laden, subjective assumptions that need to involve the perspectives of the users of the scenario outputs (Berkhout et al. 2002). Constellation Analysis is a suitable approach to realizing that demand as it integrates a broad range of expert perspectives.

Berkhout et al. (2002: 93f.) stress the importance of including socio-economic scenarios, especially governance storylines, into climate change assessments. The authors emphasize that one aim of using storyline approaches must be to "simplify and clarify to create archetypes of commonly held narratives that can help reorient collective action" (Berkhout et al. 2002: 87). Our storylines were reduced to the most dominant characteristics of urban development derived from the constellation and only give a very broad overview of urban climate governance measures for the city.

To provide a rich texture to the future narratives a threefold scalar approach was taken that aims at the city-wide, district and block level and the governance measures and respective exploratory storylines. This approach led to simplified but differentiated future perspectives on the subject. Deepening this approach could include further downscaling to assess governance measures targeting different urban structure types and different governance storylines about adaptation to urban heat.

The storylines also display simplified developments that are characterized by continuity. The underlying assumption is a steady increase in temperatures due to climate change and a resulting aggravation of the urban heat island effect. Governance measures on urban development are not designed to take preventive action against weather extremes like heat waves even though temperature extremes may be a common characteristic of the climate in the future (SenGUV 2009; Solomon et al. 2007).

Using storylines is a way to take account of difficulties in introducing climate change adaptation measures. Among the challenges that scenario processes can address are the uncertainty, spatial diversity, social controversy and complexity (Mees. et al. 2014) related to the impacts of a changing local climate. We believe that Constellation Analysis which provides a basis for developing storylines can be useful in finding ways to react in a locally specific and fitting way to climate-induced challenges.

4.8. Conclusion

Urbanization processes result in distinct urban fabrics, ecosystems, climates, societies, economies and governance systems. These features of the city are mutually influencing. Accordingly when trying to determine the relationship between heat risks, the city and respective vulnerabilities ideally all of these components will be considered (Wamsler et al. 2013).

Constellation Analysis and storylines can serve as first steps in building scenarios tied to urban heat vulnerability. Qualitatively identifying the locally available means to adaptive capacity allows the building of storylines and makes it possible to comprehend the features of local vulnerability. It would be very difficult to do so quantitatively, as the quantitative primary data that would be needed to comprehensively grasp the spatially, temporally and socially diffuse distribution of vulnerability to urban heat is typically not available (Zaidi and Pelling 2013).

Nevertheless, a combination with quantitative modeling could add further insights into the spatial distribution of urban heat risks, as well as exposure and sensitivity patterns. Thereby, the methodological benefits of both in-depth Constellation Analysis for developing storylines and quantitative spatially explicit modeling of possible future scenarios could be combined to gain a broader analysis of urban heat vulnerabilities. For a model-based scenario analysis for urban heat risk an inclusion of trigger points that might change policy action could add valuable insights into the development of risks.

These comprehensive scenarios can provide shared pictures of possible futures that enable decision-makers to collectively change their behavior (Berkhout et al. 2002). They open up new opportunities to discuss available governance measures with regards to vulnerability and might encourage learning processes to heat-proof the city.

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5. Climate change adaptation to heat risk at the local level: A Bayesian network analysis of local land-use plan implementation

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5.1. Abstract

Urban and environmental planning plays an important role in climate change adaptation. In this area, most German cities have developed adaptation strategies, i.a. tackling growing urban heat effects. Still in question, however, is how these measures will be implemented at the local level. The goal of this paper is to assess the implementation probability of climate change adaptation measures via local land-use plans using a Bayesian Network approach. Six plans were analyzed in-depth. We used expert interviews to estimate the likelihood of implementing climate-adapted measures. Whether a local land-use plan stimulates climate change adaptation depends on a combination of different factors e.g., the setting of the borough councilor in exchange with an investor, in a next step the willingness of the plans' creator to implement adaptation strategies as well as an existing environmental report.

Keywords

Bayesian Network, climate change adaptation, urban heat, urban governance strategies

5.2. Introduction

Hand in hand with its growth as a major research topic, climate change mitigation has become a significant political topic in the last decade (McGeehin and Mirabelli 2001). Rooftop solar arrays and wind farms are highly visible components of low carbon energy production: these steps towards combating climate change are recognizable to everyone. Furthermore, the effectiveness of mitigating greenhouse gas emissions is quantifiable (Ford and Berrang-Ford 2016). Measures to accompany common mitigation policies and enable adaptation to climate change impacts (here after referred to as adaptation strategies) are also essential. Even though general objectives and guidelines for adaptation measures have been identified (Keskitalo 2010), implementation rarely occurs to a sufficient degree (Biesbroek et al. 2010; Berrang-Ford et al. 2011; Knoepfel et al. 2011). Clearly, adaptation is not a barrier free process (Biesbroek et al. 2014). Although these barriers are not yet fully understood, there is a dedicated body of research on their causes (Biesbroek et al. 2013; Biesbroek et al. 2014). One of the many constraints to implementation identified in adaptation research is the failure to translate broad adaptation objectives into concrete frameworks to guide the day-to-day actions of administrative staff involved with the issue (Greiving and Fleischhauer 2012; Carmin et al. 2012; Wamsler et al. 2012).

Dealing with urban heat is a major challenge for local governments and is generally understudied as part of climate change adaptation (Mees et al. 2015). City residents have a significantly lower well-being during heat waves and many researchers highlight an association between higher temperatures and increased mortality (see, for example, Breitner et al. 2013; Kravchenko et al. 2013; Scherer et al. 2013; Scherber et al. 2013; Harlan et al. 2014; McGeehin and Mirabelli 2001).

The latest IPCC report (2014) emphasizes the likelihood that cities will face higher levels of exposure to the risks posed by changing global climate. Stone et al. (2012) and others (Koomen and Diogo 2015; Kleerekoper et al. 2012; Oke 1982) have shown that, as a result of the land-use patterns they create, cities also induce higher temperatures than the surrounding countryside. The loss of vegetation and related evapotranspiration, dark surfaces with low albedo which absorb and then radiate heat, building configurations that trap heat, and the concentrated generation of heat from anthropogenic activities all contribute to higher temperatures in cities (Oke 1982). Also within the city, distinctive microclimates evolve due to different surface structures which can create small scale hot spots of urban heat risks (Lowry 1967). Internationally climate scenarios especially for indoor heat stress do not play an important role yet. The German research unit Urban Climate and Heat Stress (UCaHS) try to address the complex scientific questions under the topic of heat stress in mid-latitude cities. Therefore, climate modifications especially for indoor heat stress as well as different heat stress scenarios got analyzed (Jänicke et al. 2015; Jänicke et al. 2016; Mahlkow et al. 2016; Walikewitz et al. 2015). They figured out that indoor heat stress is especially dangerous for the citizens but further research is needed (Jänicke et al. 2015; Walikewitz et al. 2015).

Several German cities have developed plans for climate adaptation and mitigation (Donner et al. 2015). Nevertheless, in Germany studies are lacking, however, as to what extent the measures outlined in these plans are implemented and how they are considered at the local government level.

5.2.1. Research Question

It has been identified in the literature that local land-use plans are well suited to implement adaptation measures (Battis et al. 2010; Birkmann et al. 2012; Kumar and Geneletti 2015; Mahlkow and Donner 2016; Measham et al. 2011). Local land-use plans can determine which parts of a land parcel can be built upon or needs to remain unsealed. It can also regulate the position of buildings, open air corridors, and green spaces such as those used for façade greening (Birkmann et al. 2012; Kumar and Geneletti 2015; SenStadtUm 2011) (see Table 5.1). The level of the local land-use plan can consist of different types of urban uses and as building structures, any number of individual measures could be applied. Importantly, existing private buildings and courtyards pose difficulties for official access and action. Paragraph 1

(5) German Federal Building Code (2013) indicates that development planning needs to ensure a human environment, to protect natural resources and to develop in a manner which is responsible as regards the general climate.

The aim of this paper was to explore important process points where adaptation measures against the heat section can be best integrated into the planning process and which steps must be taken to implement them. To figure out how much "weight" and how much influence the individual instruments have, we analyzed which planning instruments facilitate the implementation of heat risk strategies in the course of local land-use planning in Berlin, Germany.

5.2.2. Study site

The city of Berlin, Germany, is a typical example of a mid-latitude city facing urban heat risks and the problem of developing policy and planning strategies to handle them. Berlin is the capital city and the largest and most populated city in Germany, with an area of 892 km^2 and around 3.5 million inhabitants (Statistical Office Berlin-Brandenburg 2015). One of the main problems faced by the city is a strong pressure on open spaces, as numerous new projects are being realized (SenStadtUm 2016b). This will only be exacerbated in the next decade, as the population is expected to increase (SenStadtUm 2015a): current studies estimate that by 2030 Berlin's population will exceed 3.8 million (Berlin.de 2016a). The city has a humid continental mid-latitude climate that is characterized by cold winters and warm mild summers (Berlin.de 2016b; Peel et al. 2007). With 56% of its surface area taken up by buildings (e.g., residential uses) and transport or infrastructural facilities, Berlin is also affected by the urban heat island effect. Climate change projections calculate an increase in temperatures of 2.5 °C for Berlin by 2050, with warmer nights as well as more extreme heat events (Lotze-Campen et al. 2009). Scherer et al. (2013) have estimated a conservative average heat stress related death rate at about 1600 people per year (app. 5% of all annual deaths) for the city. Gabriel and Endlicher (2011) highlight the positive correlation between the mortality rate and heat events in Berlin.

Berlin has two tiers of public administration: the Senate and its districts. The Senate defines the general policy guidelines for the whole city and explicates tasks of city-wide importance (Mahlkow and Donner 2016). Other tasks, such as the local land-use plans, are to be handled by the 12 districts of Berlin (Hoffmann and Schwenker 2010; Musil and Kirchner 2012).

In 2011, the city of Berlin set up its adaptation strategy to tackle the local impacts of climate change (SenStadtUm 2011). The City Climate Development Plan is an informal planning instrument that addresses Berlin's objectives concerning climate change adaptation related to urban development. The City Climate Development Plan focuses on adaptation to climate change and protecting the climate (mitigation) with particular concern for spatial and urban planning. Its goals aim to tackle rising temperatures primarily at the neighborhood level: from an increase in albedo to securing the provision of green space close to residential areas (SenStadtUm 2011).

After the recommended actions for land-use planning were developed in the City Climate Development Plan in 2011, the Berlin Senate proposed the creation of a Comprehensive Adaptation Framework Berlin (AFOK) in the middle of 2016 for all urban infrastructures and areas of urban life likely to be affected by climate change. As part of the AFOK, the establishment of adaptation steps spanning different timelines was developed (SenStadtUm 2015). We will not examine the Berlin Energy and Climate Mitigation Program and Comprehensive Adaptation Framework Berlin (AFOK) in depth. It is however important to note that these programs also shape the discourse of the Senate Department regarding climate change adaptation.

In June 2016, the Senate Department adopted a more concrete form of the City Climate Development Plan and created the City Climate Development Plan KONKRET (SenStadtUm 2016a). It's is similar to the City Climate Development Plan in that it is an informal tool, but it also provides practical and concrete recommendations for adaptation in Berlin.

5.2.3. The planning system of Berlin

This section provides an overview of Environmental Assessment in urban land-use planning in Berlin and explains which instruments can play a role in the climate adaptation process.

Environmental Assessment (EA)

An EA is described in an environmental report if a project may affect humans (including human health), animals, plants, biodiversity, soil, water, air, climate, landscape or cultural assets. Not all local land-use plans require an EA. The annex to the EA Law lists all cases in which an EA has to be carried out. This pertains to very large potentially dangerous plants or projects for people and the environment. The fact is that local land-use plans which have been created under §13a German Federal Building Code (2013) do not need to be subject to an EA. This means that the local land-use plan, created under §13a German Federal Building Code (2013), can be processed using an expedited procedure in cases of re-densification, where land is being restored, or for certain other measures of internal development. In these cases, the area should be less than 20,000 m^2 in size. Or, if the permissible floor area is between 20,000 m^2 and 70,000 m^2 - a rough examination can dictate that the local land-use plan is not expected to have significant environmental effects.

The Landscape program

The Landscape Program is a strategic planning instrument to manage integrative environmental protection (SenStadtUm 2016). It aims at addressing the integration of environmental concerns into urban development at the city level. This is a basic instrument to ensure the protection and consideration of soil, water, air, wild animals, and plants, along with sufficient recreation areas for people in urban planning (von Haaren 2004).

The local landscape plan with Biotope area factor

The local landscape plan represents the requirements and measures needed to adhere to the recommendations of the landscape program at the local scale. The plan should include concrete objectives and principles of nature conservation and landscape management within a defined scope (SenStadtUm 2013; von Haaren 2004).

The Biotope Area Factor (BAF) is meant to improve the ecosystem functions in the city center. The landscape plan is the instrument used to implement the BAF. It can control which greening measures will be addressed, especially in densely populated inner city areas. The BAF designates the area ratio of land to serve as space for plants or other features of the natural environment (e.g., infiltration, evaporation) (SenStadtUm 1990).

German Federal Building Code

In Germany, the law with the strongest impact on the local level is the German Federal Building Code. The German Federal Building Code includes a list of possibilities to implement adaptation measures and enforces climate-friendly development in cities (§1 (5) and from §9 (1) No. 1 to No. 26 German Federal Building Code 2013). Land-use planning in Berlin includes the development of a comprehensive land-use plan (§5 (1) German Federal Building Code) on the city level and a local land-use plan on the local level (§1 (5) German Federal Building Code). Both plans play an important role in the implementation of climate adaptation measures.

Comprehensive land-use plan

The comprehensive land-use plan regulates city-wide urban development. The plan was last revised in 2004 and has been continuously implemented from the lot level up since then (von Haaren 2004). The plan "(...) shall represent in basic form the type of land-uses arising for the entire municipal territory in accordance with the intended urban development which is proposed to correspond to the anticipated needs of the municipality." §5 (1) German Federal Building Code (German law archive 2014). On the basis of these, the local land-use plans are drawn up.

The Local land-use plans

The object of the local land-use plan is to assure the structural use of land according to the German Federal Building Code (2013). A local land-use plan contains the legally binding rules for the local level, to be developed in accordance with the comprehensive land-use plan (von Haaren 2004). "Local land-use plans shall safeguard sustainable urban development and a socially equitable use of land for the general good of the community, and shall contribute to securing a more human environment and to protecting and developing the basic conditions for natural life" §1 (5) German Federal Building Code (German law archive 2014).

To visualize that the German Federal Building Code contains everything to incorporate climate adaptation into local land-use plans, we compiled in Table 5.1 those numbers of the §9 German Federal Building Code where adaptation measures can, from our point of view, be integrated.

Table 5.1 shows that adaptation to urban heat stress via local-land-use plans seems possible. All local land-use plans are created by using a sample regulation designed by the Senate Department for Urban Development and Environment (SenStadtUm 2012). This template contains a table of contents in which all the required topics for the plan are listed. As such, it guides the creation of Berlin's local land-use plans. During their preparation, urban development contracts can be drafted which represent a particular form of binding public service contract between public agencies and investors. It is possible in this context to specify e.g., configuration of buildings by demanding a particular roof or façade design.

In the German legal system, the public is given the opportunity to participate prior to the adoption of certain plans and programs.

> "The public is to be informed at the earliest possible stage about the general aims and purposes of planning, about significantly different solutions which are being considered for the redesign or development of an area, and of the probable impact of the scheme; the public is to be given suitable opportunity for comment and discussion (German Federal Building Code §3 (1) 2013; German law archive 2014)."

The German Federal Building Code §3 (1) 2013 includes the right to participate for both individuals and associations such as environmental organizations. As part of the preparation of local land-use plans, citizens have the opportunity to participate in two stages encompassing both the normal process as well as participation at an early stage (German Federal Building Code 2013).

Table 5.1.: Summary of paragraph 9 of the German Federal Building Code (BauGB) to implement adaptation measures via local land-use plans. (German Federal Building Code German law archive 2014; German Federal Building Code 2013; Battis et al. 2010; Mitschang 2009).

Paragraph	Number
Paragraph 9 (1) - The content of the local land-use plan	The local land-use plan may on urban-planning grounds make designations regarding:
	1. the type and degree of building and land-use 2. the coverage type, plot areas which may or may not be built on and the location of physical structures 3. minimum dimensions for the size, width and depth of building plots, and also maximum dimensions for residential plots in the interests of economical and considerate exploitation of land 4. spaces for secondary structures which are required in accordance with other regulations on the use of land, such as play, leisure and recreational areas, and car-parking spaces, garages and drive-ways; ... 10. spaces to be kept free from built development and their use ... 15. public and private green spaces, such as parks, allotment gardens, sports grounds and playgrounds, camping sites and bathing areas, cemeteries ... 20. measures for the protection, conservation and development of topsoil, of the natural environment and of the landscape, where these arrangements cannot be made in pursuance of other regulations, and spaces for measures for the protection, conservation and development of the natural environment and the landscape ... 24. protected areas to be kept free from development with their uses, spaces for specific installations and measures to provide protection against harmful environmental impacts within the meaning of the Federal Control of Pollution Act, and the provisions to be made, including building and other technical measures, to provide protection against such impacts or to prevent or reduce such impact 25. in respect of individual spaces or of areas covered by a binding land-use plan or parts thereof, and of parts of physical structures, excluding spaces given over to agricultural use or for woodland a) planting of trees, shrubs and greenery of any other kind b) obligations relating to planting and to the preservation of trees, shrubs and greenery of any other kind and of water bodies

Public participation at an early stage and normal public participation

Public participation at an early stage and normal public participation are the same but in contrast to normal participation, the participation at an early stage is voluntary for the authority leading the proceedings in the expedited procedure of an local land-use plan (§13a German Federal Building Code 2013). In the case of normal public participation, it is obligatory. During the one-month public display (§3 (2) German Federal Building Code 2013), citizens can comment on the draft plans. The participation at an early stage usually has a much greater impact on the creation of the plan because public participation enables an early consideration of specific issues. The citizenry have the chance to comment on the provided documents (environmental report and draft of the plan). For this purpose, the citizens must inform themselves independently with the help of daily newspapers or via the homepages of the respective districts. There is no central registry for local land-use plans yet; neither on the block-level nor on the level of the Senate Department) (Odparlik 2017). In politically important projects, sometimes the early stage participation is combined with stakeholder and citizen workshops. These should bring participants together to exchange arguments and ideas and to develop solutions. With the help of the involved citizens, the preparation of the plan and identification of potential problems is possible at an early planning stage. All comments received from both participation processes have to be observed and answered by the authority leading the proceedings. In doing so, the authority has the duty, to the best of its knowledge and conscience, to observe or reject the objections. Therefore, attentive actors are necessary. In difficult projects, citizens dispute those decisions and legal processes must settle the matter.

5.3. Methods and analytical framing

5.3.1. Analytical framing

This project analyzed six of Berlin's local land-use plans and their coverage of climate issues, specifically measures to adapt to urban heat stress (Table 5.2).

Plans were considered for analysis according to the year in which the planning process formally began and that in which the plan was ultimately adopted. They were organized based on whether these dates fell before or after the formal adoption of the Berlin City Climate Development Plan. The City Climate Development Plan was approved in 2011 as the first climate adaptation plan for Berlin; any plan created after that has to follow the policies laid out by this document. As we also wanted to speak to experts involved in the development of each of the selected plans, the sample was further limited to those plans completed after 2006 to ensure that these professional contacts were available.

86 local land-use plans (61 prior to and 25 post the Berlin City Climate Development Plan) were eligible after excluding those lacking the formal planning process documentation required for a complete analysis. We then used the neighborhoods identified as priority action areas in the bioclimatic map of the City Climate Development Plan. This heat section is to further narrow down the number of plans under consideration and to focus on areas with a clear need for adaptation work. Figure 5.1 shows our analyzed local land-use plans in the areas of adverse climatic impacts (and for a better comparability one plan (4a) which is not in any priority area) identified by the citywide climate development plan and prioritized for action.

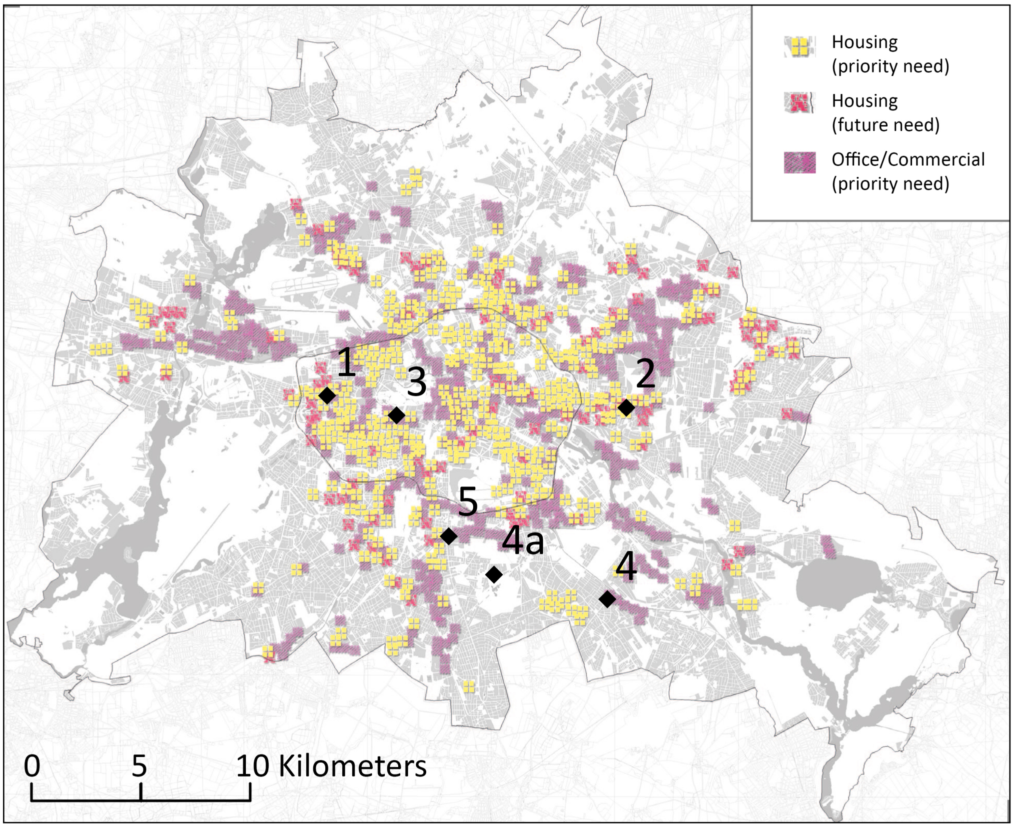

Figure 5.1.: Bioclimatic Strategy Map (SenStadtUm 2011)

Six local land-use plans from five different districts (Charlottenburg-Wilmersdorf, Lichtenberg, Mitte, Neukölln, and Tempelhof-Schöneberg) were selected (Table 5.2). Two of the plans included environmental reports and four used the simplified procedure (§13a German Federal Building Code 2013).

From February 2016 to March 2016, 14 central qualitative problem-centered interviews (cf. Meuser and Nagel 1991) were conducted with the help of questionnaires (Appendix 6.12.1) with Berlin administrative officials, members of the planning and architecture offices, and members of nature conservation organizations.

Table 5.2.: Selected plans for the analysis

Nr.	District	Before/After the City Climate Development Plan	Environmental Reports	Expert interview
1	Charlottenburg-Wilmersdorf	After	No	2,8,5
2	Lichtenberg	Before	No	6,8
3	Mitte	After	No	2, 9,11
4	Neukölln	After	No, also no landscape plan	4
4a	Neukölln	After	Yes (no landscape plan)	4
5	Tempelhof-Schöneberg	Before	Yes	3, 5

The interviews and analysis of local land-use plans were used to identify those specific elements of the local planning process which are the essential drivers for the implementation of a climate adapted local land-use plan and which should receive the most attention. To investigate this, and to assess how likely an implementation of adaptation measures is, we used the Bayesian Networks methodology.

5.3.2. Bayesian Network

In order to choose the best course of action, decision-makers need ways to understand which planning measures are truly effective. For our analyses we used the strategies of Bromley (2005), Cain (2001), Pollino and Henderson (2010) and input the data using the Netica software in version 5.15 of Norsys Software Corp. (Norsys 2015) to calculate a Bayesian Network (BN).

The BN enables calculation of the likelihood of different outcomes and can thus be used to inform important planning decisions (Barton et al. 2012). As Cain (2001, 54) states, "the real value of the BN lies in the way it helps you understand your management problem in a more integrated way. It should be used as a 'tool for thinking' not an automatic answer provider."

The advantage of using a Bayesian network approach is that it is a static model and therefore elements can be assigned in isolation if they represent a scenario at a specific point in time - the probabilities that are assigned indicate the likelihood of the scenario.

Bayesian Networks display actors, systems, and fundamental structures of a process as individual elements. The shared conditions of these elements and mutual influences on each other are shown as directed links. So called Parent Elements determine the state of other elements. Potential final outcomes or situations are assigned to each element. The likelihood of a certain target outcome taking place is a function of the combination of the likelihood of each individual outcome connected to it (Otto 2006).

Quantitative data on climate change adaptation measures are not available. However, qualitative data drawn from expert interviews and academic literature on adaptation and planning document analysis can be used to replace quantitative data. By the creation of a comprehensive BN, a first conceptual model can be established with the experts throughout the interviews (Chen and Pollino 2012; Sprondel et al. 2016).

For our analysis, 10 of 14 interviews were conducted as a part of the study itself. These ten were illustrated because their interviewees agreed to prepare the conceptual model and to complete the quantitative questionnaire afterwards. We interviewed experts from all relevant actor groups who were involved in the examined local land-use planning processes; the Senate Department, district office, local land-use planning office, architectural association, the open space planning office and Non-Governmental Organisations (NGOs). The experts were chosen according to their professional and disciplinary perspectives on the selected local land-use plans.

During the interviews, experts were asked which elements are most relevant for a climate adapted local land-use plan. All relevant elements were listed and arranged by discussing their possible states (Chen and Pollino 2012). This is a good starting point and helps to map the causal chain of the general system and to structure the BN later (Chen and Pollino 2012). The 10 conceptual models were amalgamated into a comprehensive Bayesian Network which then incorporates feedback loops from all experts. This creation process can contribute to finding the answer to the research question (Sprondel et al. 2016; Uusitalo 2007).

To receive the probability values for the BN, the interview participants received a questionnaire (Appendix 5.9.2) asking them to estimate likelihoods for different conditions and outcomes in this network. It was difficult to deal with diverging expert opinions. We weighed the calculations depending on the expertise and work field of each expert (Cain 2001; Keith 1996). The resulting information (literature and interviews) and likelihood (questionnaires) estimates could then be integrated into the network (Uusitalo 2007). The BN is illustrated in Figure 5.2.

The BN method allows different scenarios to be tested (Bromley 2005). Potential outcomes of each element can be adjusted individually to be more or less likely. Ultimately, the effect of these changes on the target outcome indicates the relative importance and level of impact of that element in the larger system (Pollino and Henderson 2010) and, therefore, how the status quo can be altered. Multiple elements should be altered in order to test the effect of combinations of changes, which is a more accurate portrayal of real-world scenarios (Bromley 2005). As the number of elements and influencing factors increase, it can become confusing for experts to accurately estimate the potential for specific outcomes and the overall network quality suffers (Cain 2001; Bromley 2005; Chen and Pollino 2012; Sprondel et al. 2016).

It is particularly important to ensure that the network is designed around the research question in order to avoid irrelevant information (Cain 2001), the network can always be changed but after this point a change of the network would lead to a second interviewing round with the experts. Experts' differences of opinion on likelihoods or missing answers can also be problematic. Therefore, answers have to be weighted. The interview process can help confirm that the elements and their connections are organized logically. Fundamentally, the goal of creating the network is to identify which actors and (planning) steps are needed in order to integrate adaptation strategies into urban planning (Uusitalo 2007).

5.4. Results and Discussion

Figure 5.2 displays the Bayesian Network (BN), built on the results of the expert interviews. The Bayesian Network elements depict the process of building a local land-use plan. It was designed to categorize the processes through which local land-use plans are orchestrated. The Bayesian Network is described and interpreted with a text and visualized by elements. The BN is divided into three main facets of the planning process: borough councilor/district planning, city-wide planning, and citizen and agencies participation.

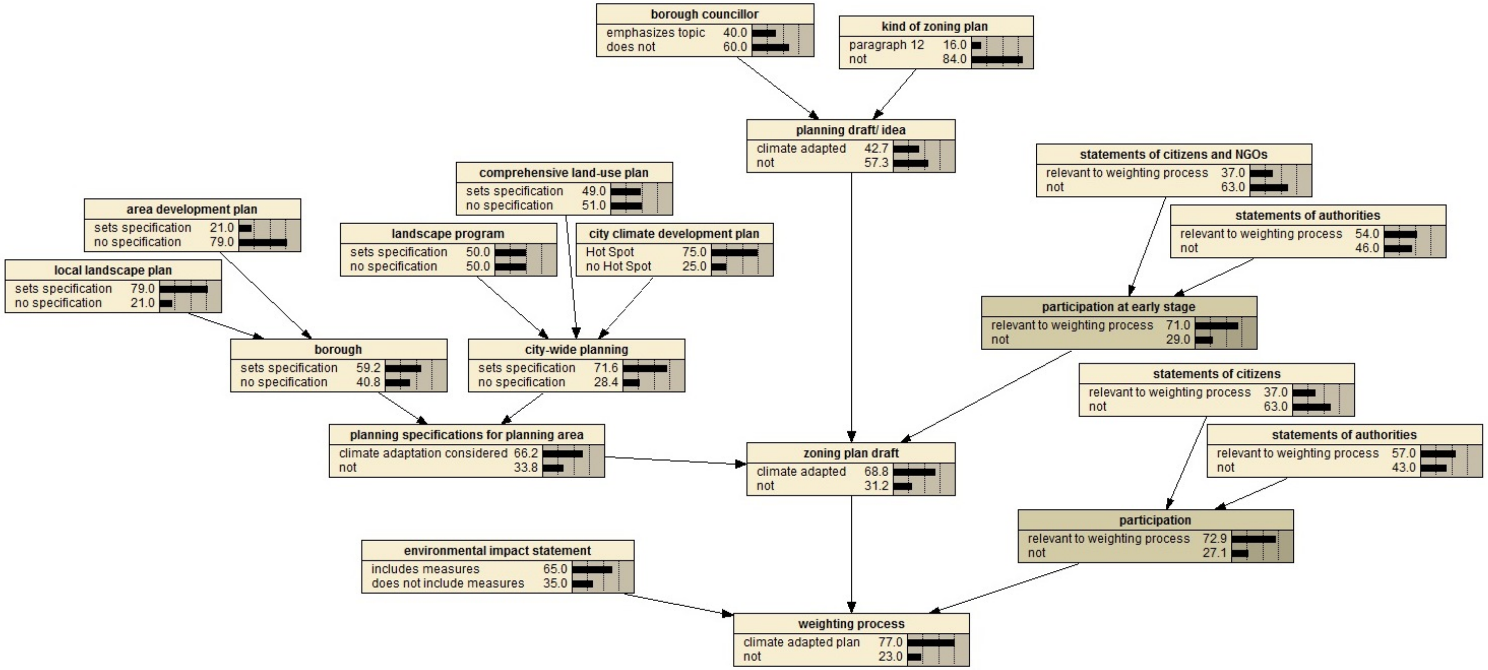

Figure 5.2.: Bayesian Network displaying the likelihood of success of adaptation strategies to urban heat in a local land-use plan in a status quo scenario

5.4.1. BN elements

Borough councilor/district administration

In the beginning, the borough councilor/district administration, sometimes in cooperation with an investor, translate the idea for building a local land-use plan into public policy. Even before the plan is created, the planning idea exists. Either the plan is initiated by the district administration to shape the district via preventing planning (e.g., to prevent too many playing halls and promote residential area) or an investor wants to initiate a construction. In the case of an investor who is positively adjusted to nature or wants to market a green image for their company, more adjustments can be implemented in a later process than one who would like to maximize profits from the project.

With the decision of the district administration, if the policy framework allows it, the local land-use plan is made according to §13a German Federal Building Code 2013. This means that the plan is developed using a simplified procedure. During that procedure, the local land-use plan is not subject to an environmental report. That can be applied when the plot is located in the inner-city and no estimated significant impacts are expected. As environmental reports are time-consuming and rather costly, investors prefer the simplified procedure [3]. The analyzed local land-use plans show, and the experts confirm, that a simplified procedure is used whenever it is possible [2-14]. This suggests that the §13a German Federal Building Code 2013 has led to an impairment of the environment. For this reason, some of the experts recommend that changes should be made in the next amendment of the §13a German Federal Building Code (2013) for principle enforcement of Environmental Assessment (EA) [2, 3]. In cooperation with the district administration, the investor is a hidden key element in the local land-use plans because they can influence the framework of adaptation strategies for urban heat stress “behind the scenes”. A green leaning investor can install greening measures despite that fact that these standards are only recommended by the officials (e.g., plant species composition). Another element is that the staff of the district can fix more adaptation measures into the plan with the involvement of an investor. Because the investor is applying for building permits, the district staff can insert more adaptation measures into the local land-use plan and both parties benefit [2, 3]. This illustrates that even in the first step of the planning process, the bar can be set for the potential to implement adaptation strategies.

On the city-wide level, the City Climate Development Plan, the comprehensive land-use plan and the landscape plan play a role.

City Climate Development Plan

The City Climate Development Plan has played a pioneering role in Berlin. Its challenge is to analyze climate change adaptation planning and determine how to systematically integrate the City Climate Development Plan into administrative processes (BBSR 2015). It should be a guiding policy instrument in the implementation of urban heat stress measures and introduces possible measures as well as strategies relating to spatial impacts. The plan should bring attention to relevant local actors, available instruments, and spatially defined hot spots of risks (SenStadtUm 2011). Through the creation of strategies to address heat threats, the plan is an informal instrument that affects perceptions and preferences to provide addressees with an orientation as to how to apply it (Dupuis and Knoepfel 2011). It is intended to address relevant actors, and possible means, by the explicit assignment of responsibilities. The experts generally agreed that the City Climate Development Plan plays a role in the level of attention given to heat stress. Under the existing German Federal Building Code (§1 Abs. 6 Nr.11 German Federal Building Code 2013), the City Climate Development Plan should be taken into account in the evaluation phase. During the interviews, the experts recommended that an area identified as a hot spot - in City Climate Development Plan- should be subject to follow-up actions in the planning process. These claims do not correspond with our findings from the local land-use plan analysis. Our analysis showed, that despite hot spot classifications, no particular attention was paid to heat stress. The City Climate Development Plan was referenced, and indeed observed, but has not led to a change in the planning process. To a certain extent, the current housing deficit in Berlin explains this. Berlin's continuing growth and the influx of refugees means even more housing will be needed in the near future. All those interviewed agreed that considering this and the resulting building boom, they could not put climate issues ahead of housing construction needs [2-13]. Some experts affirmed that they do not know how to translate the listed measures of the City Climate Development Plan into the work they are doing in their field [5, 7]. To fix that gap, the Senate Department has adopted a concrete City Climate Development Plan. It is an instruction manual, published in summer 2016 (SenStadtUm 2016). The plan provides practical and concrete recommendations for adaptation in Berlin. Further research is needed to figure out the impact of this informal plan.

Comprehensive land-use plan

The comprehensive land-use plan regulates city-wide urban development. For the implementation of urban heat stress measures, the plan can set district guidelines for the subordinated local land-use plans. By including urban heat stress scenarios into the plan, a long term planning function for the whole city would be fulfilled (Greiving 2009 - 2010; Othengrafen 2014). Adaptation measures such as air corridors, provided by the precise positioning of green and open spaces, can only be planned on a city wide level. This makes it clear that, if climate adaptation is to be given greater significance in development plans, it must be given increased attention in the preparatory planning stages. Only then will this issue likely be carried over into local land-use plans. Both the comprehensive land-use plan and local land-use plan play important roles, and are incorporated at different stages, in the planning process of the local land-use plan. Experts identified this outdated plan as an obstacle to the implementation of climate change adaptation. It is important to note however, that an update to the comprehensive land-use plan would only have an effect on adaptation in areas where a sufficient scale can be met. It would pertain to, for example, greenways as a distinct land-use representation. The ongoing practice in Berlin, the so-called parallel process, is an argument against revision of the comprehensive land-use plan. There is no full amendment of the plan currently underway to incorporate strategic climate adaptation planning and environmental analysis (cf. Köppel et al. 2016) and, according to the experts, it is also not planned for the near future [6, 9, 13]. The interviewees were of the opinion that an amendment to the whole plan would lead to a significant improvement of the city's ability to integrate climate change adaptation strategies.

Landscape program

In Germany, the landscape program is a strategic statewide planning instrument to achieve integrative environmental protection. Adaptation strategies against urban heat stress can only be implemented when a strategy for the whole city exists. During the interviews, the experts mentioned that for an adaptive local land-use plan, the landscape program does not play a significant role. It was amended comprehensively for the last time in 1994 (SenStadtUm 1994). At this point in time, climate change was not a prominent topic in the Senate Department and so policy objectives addressing urban heat in mandatory city-wide planning instruments (comprehensive land-use plan and landscape program) are missing. Since 2016, a revision of the landscape program has become available (SenStadtUm 2016). For our study this could not be considered as the examined plans have been created with the landscape program in 1994.

On the district level the area development plan and the local landscape plan can set standards.

Area development planning

Area development planning is a planning instrument implemented at the local level. The area development plan is particularly focused on a medium to long-term planning horizon. It sets surface requirements for social infrastructure facilities, green and open spaces, centers, commercial establishments, public space and transport infrastructure, as well as for housing. For the experts, area development planning does not play a role for adaptation strategies because the plans are generally not up to date and have other priorities. A focus on adaptation is still missing [2, 3, 11].

Local landscape plan

The task of the local landscape plan (concretizing the aforementioned city-wide landscape program) is to observe principles of nature conservation and landscape management. Because they are optional for each district, they are used sporadically in some districts and not at all in others. Three of the analyzed local land-use plans include local landscape plans with a Biotope Area Factor (BAF). The experts recognized that the need is not necessarily to provide for new local landscape plans. However, if a new building is planned and the district has adopted local landscape plans, it is an effective instrument. The fact of the matter is that the plan only applies to new construction. For adaptation measures to be effective, they must encompass the existing building stock.

The information of the district planning and city-wide planning instruments must be taken into account during the preparation of the local land-use plan draft. Summarizing both levels, the BN calculation shows that the planning specifications for planning areas consider climate change adaptation at a rate of about 66.2%.

Participation at an early stage

On the right side of the Figure 5.2 the results of the participation at an early stage have been included. During this process, the objections of the citizens, NGOs, along with those of the officials themselves, are incorporated into the draft of the plans. How many citizens participate depends on several factors; principally the initial situation, the location, and the level of public interest (Odparlik 2017). There are plans with an enormous amount of participation (thousands of comments) and those without a single letter from citizens or NGOs [3]. From the six analyzed plans, we could not determine if inadequate dissemination of information was the reason for a lack of participation. The experts noted that no statement by officials on climate change adaptation was presented. Only a couple of public opinion statements were related to adaptation or ‘greening’ the city. The contents of these statements were classified as not relevant to the planning process [2, 3, 4]. Although public opinions and input are available, they do not necessarily need to be heeded by those responsible for the plan. On the one hand, experts agree that in contrast to those of the agencies, the comments of the citizens are often not relevant for the planning. On the other hand, participation at an early stage helps to access and respond to a specific local knowledge of the citizens and fosters greater public acceptance. That is why early participation is conducted in almost all cases even if no legal obligation exists [2, 3, 4].

Weighting process

When the final evaluation is performed, the important contributions made by public participation, participation of the agencies as well as environmental report are crucial. The analyzed planning specifications for area planning and the results of participation at an early stage are incorporate into the local land-use plan draft. The environmental report is analyzed during the weighing process and constitutes the element with the single greatest impact on the goal outcome. Holding other elements constant, the presence of an environmental report increases the chances of the creation of a climate adapted local land-use plan from 77.0% to 88.3% (see Table 5.3). Therefore, environmental reports are important components for the inclusion of adaptation strategies. Stakeholder participation and existing planning guidelines have similar, though smaller effects. In cases where the simplified procedure is applied, the probability that a local land-use plan is climate-adapted falls between 31% and 34% (plan number 1, 2, 3 and 4). The plans with environmental reports have much improved chances (getting climate adaptation involved) of 80-82% (4a and 5) (Figure 5.3).

Shown below are the likelihoods of successful climate-adapted plan adoption calculated for each of the six scenarios, drawn from the six Berlin local land-use plans chosen for analysis (Figure 5.3).

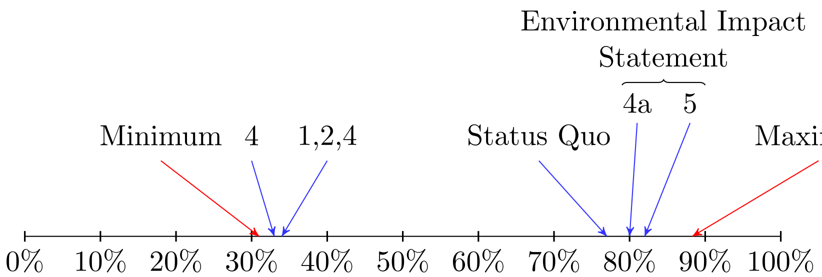

Figure 5.3.: Likelihood for climate-adapted local land-use plan creation combined with the sensitivity analysis to identify the key determinants. Every element will be analyzed by testing it against a totally positive or negative influence - minimum/maximum (see Table 5.3).

The reason for this significant increase in probability (80-82%) could also be related to the fact that according to the methodology of the BN “interventions that are closer to the objectives will have a greater impact” (Cain 2001, 55). In their interviews, however, experts emphasized the importance of environmental report in bringing attention to conservation concerns in planning. All experts recommended that no new tools are needed to improve the integration of climate adaptation strategy. All of them felt that the existing tools are adequate for the incorporation of adaptation measures. For the sensitivity analysis to identify the key determinants, every element (parentless nodes) will be analyzed by testing it against a totally positive or negative influence - 100%, holding all others constant see Table 5.3.

Sensitivity analysis

Table 5.3.: Analysis of the impact of each element on the target variable compared to the status quo scenario

Element, with positive state at 100%	[status quo: 77.0%]
Borough councilor/ district administration	77.7
Type of local land-use plan	77.3
Statements of citizens and NGOs (early)	78.0
Statements of agencies (early)	78.0
Statements of citizens (participation)	80.6
Statements of agencies (participation)	80.6
City Climate Development Plan	77.2
Comprehensive land-use plan	77.3
Landscape program	77.3
Area development plan	77.2
Local landscape plan	77.3
Environmental reports	88.3

Element, with negative state on 100%	[status quo: 77.0%]
Borough councilor/ district administration	76.6
Type of local land-use plan (state: not)	77.0
Statements of citizens and NGOs (early)	76.5
Statements of agencies (early)	76.0
Statements of citizens (participation)	75.0
Statements of agencies (participation)	72.4
City Climate Development Plan	76.6
Comprehensive land-use plan	76.8
Landscape program	76.8
Area development plan	77.0
Local landscape plan	76.3
Environmental reports	56.2

5.4.2. BN analysis

The Bayesian Network methods used here enables the visualization of the planning process alongside an investigation of individual elements and their significance in the larger system. This is important to help planners understand which capital investments will make the best use of often scarce resources. There are still some drawbacks to this method, though, which are important to mention. Complex networks require a lot of data. While the use of quantitative data is often seen as an advantage of the method and expert knowledge can be incorporated to calculate values and ensure the accurate portrayal of certain views, this can lead to problems. When little relevant knowledge or few data are available, experts' estimates alone can result in some uncertainty (Otto 2006; Welp et al. 2005).

Another identified issue is the inability to change or update the network after the initial design phase has been completed. Additional elements that may be discovered, or found to be irrelevant, cannot be added or removed without starting a new round of expert interviews. This created a problem for our analysis, as the environmental reports was found to already be part of the local land-use plans at the beginning of the process (§2a German Federal Building Code 2013). Thus, the environmental report should have been combined with the local land-use plan draft element. But, the same section of the Building Code (§2 Abs. (4) German Federal Building Code 2013) also states that the results of the environmental analysis should be considered in the final evaluation. Therefore, we felt that the position of this element was justified; none of the experts consulted objected to this design.

The development of the network from interviews was often challenging due to the tendency of experts to draw linear diagrams and their difficulty in conceptualizing the complex relationships between multiple elements.

Experts' answers also varied based on their field of work and area of specific knowledge (Morgan and Henrion 1990; Chen and Pollino 2012). The calculations showed that, under the status quo in 77.0% of cases, adaptation strategies will be included in a local land-use plan. Changes to certain conditions will cause this value to rise or sink. The high overall probability (77.0%) of adoption of a climate-adapted local land-use plan in Berlin, under the status quo, tends to support a positive outlook for success in these planning efforts. The six scenarios analyzed above (Figure 5.3), however, also demonstrate that this probability value can fluctuate depending on specific situations and conditions.

Table 5.3 depicts the points with the strongest impacts on this system. The experts agree that local planning should not be overloaded with requirements. Successful incorporation of climate issues can only be guaranteed if related goals are defined at higher planning levels [3, 6]. It is also important to know how the most significant elements, such as the environmental report, work in this system; although the presence of one element is not sufficient to ensure the integration of adaptation strategies in local land-use plans.

The experts we consulted also pointed out that the so-called climate protection amendment of the German Federal Building Code (§1 (5) und §1a (5) German Federal Building Code 2013) from 2011, has led to almost no changes in terms of their daily work on climate issues. The German Federal Building Code already includes many suggestions (see Table 5.1) for the incorporation of climate change adaptation measures into local land-use plans. Green spaces, for example, are used to offset other impacts and have additional climate benefits [5]. Both before and after the amendment, section nine of the code allowed for the effects of urban heat stress to be combatted. Therefore, the legal authorization for the implementation of climate adaptation strategies has already been provided by the German Federal Building Code (BauGB 2013). The reluctance of planners to act on this stems from their uncertainty about the impacts of climate change and concerns about over-loading the planning process when there is no clear or immediate need [11].

The sample regulation guides the creation of Berlin's local land-use plans. It would be ideal, according to the experts we interviewed, if this sample regulation made stronger reference to greenspaces and promoted best practice for climate adaptation planning [5]. Most of those interviewed said they felt changes to the sample regulation are necessary and that they would like to see action taken on that matter (probability of 80-100%). Even so, some feel that despite the clarification provided by the sample regulation regarding possible implementation opportunities, a better understanding of the role of planning in climate change adaptation is required. During the process of drafting a local land-use plan, the planner may not have a grasp of the full spectrum of urban issues and a sample regulation is therefore a necessary tool. Those who are responsible for the content of the sample regulation place the likelihood of a revision of the text at around 10% and estimate the ultimate effect of the changes to be minor (2 on a scale of 1 to 10). This demonstrates the differing perspectives on the topic.

In Berlin, changes to the comprehensive land-use plan have been made using the 'parallel process' referenced above for quite some time. Currently, the bidding process and master plan creation for an urban development can be completed without any assessment of the environmental situation. This brings up the question: does an environmental report at the local level happen too late, not only for climate change adaptation, but also for other ecological concerns [11]?

Experts complain that local land-use plans are overloaded with environmental concerns such as biodiversity requirements, land consumption, emission control, etc., and the urban climate is therefore difficult to prioritize [3, 4, 5]. In contrast to noise, guidelines and orientation thresholds for the topic of urban heat are missing [5, 6].

According to the expert interviews, the results of the BN show that the integration and implementation of adaptation measures rely primarily on five requirements: the preliminary plan draft or idea for the area to be (re)developed, whether the project has an investor, whether the district-level plan considers climate concerns, and whether an environmental statement is included. The experts agreed that integration also depends on the people who are responsible for the creation of the plan.

5.5. Conclusion

Ongoing discourse on the topic of adaptation is vital. Formal local-level planning is derivative of broader general planning, and deals primarily with those themes and topics that were previously part of higher-level planning processes. For this reason, it was important to model and analyze the planning assumptions, formal and informal, that are part of localized land-use planning. Although BNs can be complex, they are a convenient method for detailed investigation of how a planning or management goal can be reached. They help visualize causal links and identify deciding factors for discussion. Most importantly, the analytical portion of the BN method brings important decision points to the forefront, making the implementation of the process more transparent and demonstrating how these central factors affect the likelihood of reaching the goal outcome (Cain 2001). The huge effort required for research into the effects of climate change stays in striking contrast to the number implemented strategies, which is relatively small. Although these strategies could lead to a well-organized approach to climate change impacts through various planning and analysis tools, this effort will most likely be avoided. In general, climate change remains a socially and politically challenging issue, which, due to many factors, is only slowly being incorporated into the planning process. Our interviews also showed that the integration of new topics, like climate adaptation, is often difficult. It requires integrated approaches to coordinate between many different actors and activities in order to tackle the complexity of adaptation measures to address urban heat stress. Practitioners complain about the changes in thinking and policy that these issues entail. Ultimately, the colleagues need training courses on how to approach the subject and what can be done [11]. Local land-use plans alone cannot shoulder all the responsibility for implementation of climate adaptation strategies. Success in this area can only be guaranteed if these strategies are embedded at a higher level. In Berlin, this requires clear instruction and guidelines from the Senate Department under political pressure of the Land Governance. The problem is that the Senate Department sees its role as more conceptual and shifts the task of implementation onto the individual districts in the city. These districts, however, do not have the financial or human capital needed to complete this work. They are not set up well for implementation and do not know how best to go about it. The districts would prefer that this process and the necessary knowledge were compiled by Senate Department so that it could be better used for specific planning needs [2, 11, 13]. All actors need a translation of climate change adaptation strategies into their daily work. They need to know how the formal and informal planning and governance instruments at different levels can be linked. This requires advanced training and/or the development of knowledge platforms (Tethys 2017) and constant communication between all urban government levels.

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5.8. Interviews

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[4] District office Neukölln, 18.02.2016

[5] Planning office_1, 19.02.2016

[6] District office Lichtenberg, 22.02.2016

[7] Architectural association, 25.02.2016

[8] Planning office_2, 25.02.2016

[9] District office Charlottenburg-Wilmersdorf LaPla (Landschaftsplanung), 25.02.2016

[10] Senate Department legal examination, 26.02.2016

[11] District office Mitte, 29.02.2016

[12] Nature conservation organisation _1, 16.03.2016

[13] District Council, 06.04.2016

[14] Nature conservation organisation _2, 05.04.2016

5.9. Appendix

5.9.1. Probability of success for climate change adaptation in local land-use planning in Berlin

Date: Name: Institution and Expertise:

How much importance to you attach to the topic of climate change adaptation compared to other topics of urban planning/environmental issues (in your district)?

Is heat stress a current or a future threat?

Which heat stress reducing measures can you implement with your work?

What is the right planning level/the right instrument for climate change adaptation?

How can the implementation of adaptation measures be facilitated? Which instruments need to be activated?

What are the greatest barriers in the implementation of climate policies on the local land-use planning level?

Were there driving or inhibiting forces for climate change adaptation?

Has there ever been a successful implementation of planned measures?

How do you assess the importance of ...

- Informal planning in Berlin? Especially the City Climate Development Plan?
- Public and administration participation in local land-use planning?
- The environmental report in local land-use planning?
- §13a of the German Federal Building Code?
- Is the planning procedure according to §13a a trend nowadays?
- A local landscape plan?
- Preparative framework planning? How strong is the influence of a district development plan?
- Amendment of the German Federal Building Code in 2011 (concerning climate)?

5.9.2. Quantitative Questionnaire

We use Bayesian Networks to identify the relevant elements influencing the probability of climate change adaptation measures in a local land-use plan.

The Bayesian Network was created on the basis of the interviews with you and other experts. It shows all required elements for local land-use planning and their states. This questionnaire is designed to investigate the probabilities of the states. In the end we can calculate the probability of success for climate change adaptation measures in local land-use planning.

Please consider that the network is a model and some circumstances are simplified and narrowed to include only the elements playing a (potential) role for climate adaptation in the planning process.

The questions refer to your overall knowledge and experiences with local land-use planning in Berlin since approx. 2006. The questions arise from the method of the Bayesian Networks and may appear constructed. If this is the case, a brief examination of the network will help.

The probability values should be indicated as percentages.

1) How likely is it that the borough councilor emphasizes the topic of climate change adaptation?
   Answer: %

2) Estimation/Experience: How many of the local land-use plans (you are currently working on) are according to §12 of the German Federal Building Code (= related to a specific project with investor)?
   Answer: %

3) Estimation/Experience: How many of the local land-use plans (you are currently working on) are according to §13a of the German Federal Building Code?
   Answer: %

4) At the beginning of the planning process a planning draft/idea for the planning area is needed: how likely is it that this planning draft/idea already considers climate change adaptation?
Rate the following 4 scenarios.

	Borough councilor	Kind of local land-use plan	Planning draft/ idea: climate adapted
1	Emphasizes topic	§12	%
2	Emphasizes topic	Not §12	%
3	Does not	§12	%
4	Does not	Not §12	%

5) How likely is it that you can derive climate adaptation contents from the comprehensive land-use plan for the planning area?
Answer: %

6) Consider the case that the City Climate Development Plan shows a "Hot Spot" for the planning area. How likely is it that this information will be included into the content of the local land-use planning?
Answer: %

7) From city-wide planning documents like the comprehensive land-use plan, landscape program and the City Climate Development Plan, planning specifications can be derived. How likely is it that the city-wide planning sets specifications about climate change adaptation? Rate the 8 scenarios.

	Comprehensive land-use plan	Landscape programme	City Climate Development Plan	City-wide planning: sets specification
1	Sets specification	Sets specification	Sets specification	%
2	Sets specification	Sets specification	No specification	%
3	Sets specification	No specification	Sets specification	%
4	Sets specification	No specification	No specification	%
5	No specification	Sets specification	Sets specification	%
6	No specification	Sets specification	No specification	%
7	No specification	No specification	Sets specification	%
8	No specification	No specification	No specification	%

8) How likely is it that the local landscape plan (if applicable) sets targets relevant for climate change adaptation in the planning area? (Like e.g., the biotope area factor)?
Answer: %

9) How likely is it that a district development plan (if applicable) sets targets relevant for climate change adaptation in the planning area?
Answer: %

10) How likely is it that the borough planning documents set specifications for climate change adaptation?
Rate the 4 scenarios.

	Local landscape plan	District development plan	Borough planning: climate adaptation considered
1	Sets specification	Sets specification	%
2	Sets specification	No specification	%
3	No specification	Sets specification	%
4	No specification	No specification	%

11) Planning specifications are derived from the city-wide and the borough-specific planning documents. How likely is it that those specifications set targets for climate adaptation in the planning area? Rate the 4 scenarios.

	Borough planning/ district administration	City-wide planning	Planning specifications for planning area: climate adaptation considered
1	Sets specification	Sets specification	%
2	Sets specification	No specification	%
3	No specification	Sets specification	%
4	No specification	No specification	%

12) How likely is it that the public or NGOs note public interests concerning climate adaptation in the participation at an early stage (relevant to the weighing process)?
Answer: %

13) How likely is it that other administrations note an interest concerning climate adaptation in the participation at an early stage (relevant to the weighing process)?
Answer: %

14) Local land-use plan draft: How likely is it that this draft is adapted to climate change?
Rate the 8 scenarios.

	Planning specifications for planning area	Planning draft/idea	statements from the participation at early stage	Local land-use plan draft: climate adapted
1	Climate adaptation considered	Climate adapted	Relevant to weighting process	%
2	Climate adaptation considered	Climate adapted	Not relevant	%
3	Climate adaptation considered	Not	Relevant to weighting process	%
4	Climate adaptation considered	Not	Not relevant	%
5	not	Climate adapted	Relevant to weighting process	%
6	not	Climate adapted	Not relevant	%
7	not	Not	Relevant to weighting process	%
8	not	Not	Not relevant	%

15) How likely is it that the environmental report proposes measures for climate change adaptation?
Answer: %

16) How likely is it that the public or NGOs note a public interest concerning climate adaptation in the participation process (relevant to the weighing process)?
Answer: %

17) How likely is it that other administrations note interests concerning climate adaptation in the participation process (relevant to the weighing process)?
Answer: %

18) Weighing process: How likely is it that the local land-use plan now includes climate change adaptation measures?
Rate the 8 scenarios.

	Environmental report	Local land-use plan draft	statements from the participation	Weighting process: climate adapted plan
1	Includes measures	Climate adapted	Relevant to weighting process	%
2	Includes measures	Climate adapted	Not relevant	%
3	Includes measures	Not	Relevant to weighting process	%
4	Includes measures	Not	Not relevant	%
5	Does not include measures	Climate adapted	Relevant to weighting process	%
6	Does not include measures	Climate adapted	Not relevant	%
7	Does not include measures	Not	Relevant to weighting process	%
8	Does not include measures	Not	Not relevant	%

19) How likely is it that §9 of the German Federal Building Code is fully exploited for climate adaptation measures?
Answer: %

Are amendments of laws and other regulations needed?

20) Is an amendment of the German Federal Building Code necessary concerning an easier integration of adaptation measures into local land-use planning?
Answer: %

21) How important would an amendment of the comprehensive land-use plan be (concerning climate adaptation)?
Answer: %

22) How likely is it that the landscape programme contains climate change adaptation measures for the specific planning area? Answer: %

23) How likely is an amendment of the sample regulation concerning the integration of adaptation measures in the catalogue of the most common designations? Answer: %

24) How strong would the impact be (scale 1-10) of such an amendment of the sample regulation concerning climate adaptation designations of the local land-use plan?
Answer: %

6. Urban climate and heat stress: How likely is the implementation of adaptation measures in mid-latitude cities? The case of façade greening analyzed with Bayesian networks.

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6.1. Background

Urban heat is a challenge for mid-latitude cities possibly aggravated by global climate change making it necessary to adapt the urban fabric. Façade greening has been identified as an important measure to adjust the building stock and new buildings to adverse climatic impacts. Yet, little is known on factors that influence implementation probabilities for adaptation measures. Therefore, we tried to figure out the driving forces and barriers for implementation of façade greening applying the methodology of Bayesian Networks (BNs). The article presents the Bayesian Network (BN) as an analytical system to examine the probability for the implementation of adaptation measures by including expert opinions.

6.2. New information

The results show that experts in Berlin estimate the likelihood of an implementation of façade greening under current conditions at 2%. The article also examines further supportive factors that exist to raise this comparatively low value. A scenario including financial incentives from a backyard greening program raises the chances to 14%. However, BN results confirm that it depends on the factor of "willingness" of involved actors and the right combination of supportive factors, as there are no regulations to fix the implementation of a façade greening legally.

Keywords

Bayesian networks, façade greening, implementation, ecosystem services, climate change adaptation, Berlin

6.3. Introduction

Impacts of global climate change, among them rising temperatures and higher frequencies of extreme events such as heat waves, are already noticeable (IPCC 2014). Adaptation is necessary and important - especially for cities (Satterthwaite 2006; McCarthy et al. 2010). Due to their distinctive features - the geometry of street canyons, the amount of heat absorbing materials, the additional anthropogenic heat, and a lower vegetation ratio - the temperatures in cities are higher than those in the surrounding countryside (Oke 1988; Kleerekoper et al. 2012). Global climate change potentially aggravates the so-called urban heat island effect (Lemonsu et al. 2015).

In the past years, most German cities have developed climate change adaptation strategies which particularly focus on measures of urban planning to tackle the impacts of urban heat (Donner et al. 2015). Overall, these adaptation strategies display a strong trend towards so-called "nature-based solutions" (Kabisch et al. 2016), "ecosystem-based adaptation"(e.g., Wamsler and Pauleit 2016) or "green infrastructure" (EC 2016). These concepts center around a similar goal, namely to use "biodiversity and ecosystem services as part of an overall adaptation strategy to help people and communities adapt to the negative effects of climate change at local, national, regional and global levels" (UNEP 2016). Main reasons for increasing attention of decision-makers for "nature-based solutions" are their supposedly lower costs and higher durability than technology-based solutions to climate challenges (Naumann et al., 2014). The German cities' strategies recommend a variety of greening measures such as planting street trees or greening tramway tracks as well as the installation of façade greening to mitigate urban heat islands (Kappis et al. 2014; SenStadtUm 2011).

Façade greening is mentioned in 15 of the 24 German adaptation strategies as a measure to improve microclimatic conditions (Donner et al. 2015) and bears some interesting characteristics as an example for "nature-based solutions" to climatic challenges in cities. Façade greening renders various Ecosystem Services (ESS) (TEEB 2011) such as human health improvements (Tzoulas et al. 2007), new habitats for animals and plants (Bartfelder and Köhler 1987; Lundholm and Richardson 2010; Solecki and Rosenzweig 2004), noise reduction (Renterghem and Botteldooren 2009), microclimate regulation (Haase et al. 2014), filtering of particulate matter, and absorption of air pollutants (Escobedo et al. 2011; McPherson et al. 1997; Morani et al. 2011; Kuttler 2011).

In the urban context green façades are especially attractive as they are not used for other purposes, unlike most of the horizontal green and open spaces in cities. Façade greening needs very little space on the ground, thus, user pressure and user competition is unlikely to occur (Debus 2009). In Germany, no permission under planning law is needed to green façades if it does not involve public streets or listed buildings (FLL 2000). Therefore, it is a measure considered to be relatively easy to implement also by private actors. It would be possible to fix façade greening via local land-use plans, landscape plans with Biotope Area Factor (BAF), impact mitigation regulation, or design regulations (FLL 2000). As these ways of implementation are not commonly applied in planning practice, it is not part of this study to examine how to implement façade greening with these instruments. To realize this adaptation measure of façade greening, municipalities need to rely heavily on the initiative of homeowners and tenants (Akbari and Konopacki 2005; Mahammadzadeh et al. 2009) - which is the focal point of this study.

The effectivity of façade greening with regards to mitigating urban heat has been examined by a range of case studies: It can decrease the (cooling) energy demand of a building as it weakens wind speed (Kikegawa et al. 2006; Mazzali et al. 2013; Perini et al. 2011); and the shading effect from leaves contributes to cooling façades (Cameron et al. 2014; Hoelscher et al. 2016; Hunter et al. 2014). This needs to be distinguished from another less pronounced effect of façade greening, evapotranspiration, which leads to lower temperatures between building walls and plants and raises relative humidity (Hoelscher et al. 2016; Hunter et al. 2014; Pérez et al. 2011). Kleerekoper et al. (2012) regard façade greening as one of many ways to establish vegetation in cities and ascribe a cooling effect to vegetation in general.

Some studies take a more skeptical stance to the cooling potential of green façades. They discovered only minor temperature change at buildings (Cameron et al. 2014; Jänicke et al. 2015). Bowler et al. (2010) also point out that all previous proof of the cooling effect of façade greening have been generated by single case studies and it has not been confirmed that it is solely down to the greening measure. However, skeptics do not question ecosystem services provided by green façades in general and many studies also proved that effectiveness of façade greening for climatic services can be raised under certain conditions. The cooling effect is dependent on the choice of the plants/ plant traits, e.g., number of leaf layers, the availability of water, and location/ meteorological conditions (Cameron et al. 2014; Sheweka and Mohamed 2012).

Research has shown that an implementation of climate change adaptation measures rarely occurs (e.g., Wamsler et al. 2013; Carmin et al. 2012). Barriers and incentives to the governance of implementing adaptation measures have mainly been identified in a qualitative way (e.g., Biesbroek et al. 2013). Actor-specific characteristics, the institutional environment, i.e., formal and informal rules that guide interaction, and the natural and socio-economic environment have been shown to be crucial variables to explain why barrier and opportunities to implementing adaptation measures arise (Lehmann et al. 2015; Mahlkow and Donner 2016). However, an analysis is missing that combines qualitative and quantitative elements to study the interplay of factors that decide whether the implementation fails or succeeds.

Besides the number of studies confirming the ESS of façade greening, to date there has not been any research on the implementation of this particular climate change adaptation measure. This study intends to figure out probabilities for implementation success of façade greening by applying the method of Bayesian Network (BN). Initially, BNs were used to support medical diagnoses (Wang et al. 2002), for a long time the application of BN for environmental research questions has been limited (Bromley 2005). However, recently the application of BN has expanded and been tested for further research problems, especially with relation to water resources management (Bromley 2005; Henriksen and Barlebo 2008), environmental management linking nature, society, and economy (Uusitalo 2007), and in environmental modeling (Aguilera et al. 2011). For questions concerning the implementation probability of climate change adaptation measures, no example is known to the authors.

Therefore this study pursues the following questions:

- What are the influencing factors for the implementation of the adaptation measure of façade greening in the city of Berlin?
- How likely is the implementation, the so called success probability, for the variable of façade greening?

6.4. Study site

The study was conducted in Berlin, the capital of Germany. It is the biggest (89,000 ha) as well as the most populated city in Germany with 3.5 million inhabitants (Statistical Office 2015). Berlin is situated in the temperate climate zone, transitioning from maritime to continental climate, with warm, mild summers and cold winters (Peel et al. 2007). Climate change projections imply a rise in temperatures of 2.5 °C degrees by 2050 with more hot days and tropical nights (Lotze-Campen et al. 2009). 32% of the city area is covered by public green spaces and forests, while 57% of the city area of Berlin is used for settlement and transport purposes (SenStadtUm 2014). A recent study showed that the Urban Heat Island leads to a temperature difference of an average of four to five Kelvin (K) during summer nights in Berlin compared to the surrounding rural areas (Fenner et al. 2014).

Berlin's climate change adaptation plan identifies neighborhoods with current and future priority needs for action against urban heat especially in the city centre. Façade greening is recommended as a suitable adaptation measure (SenStadtUm 2011). The city aims at "greening façades wherever possible" (SenStadtUm 2011: 5). Nehls et al. (2010) have identified a 600 ha area as potentially available for façade greening in Berlin. Those figures illustrate that theoretically an implementation of green façades could be feasible in the city of Berlin.

6.5. Methods

6.5.1. Bayesian networks

The study followed the guidelines of Bromley (2005), Cain (2001), Pollino and Henderson (2010) and used the software Netica in the version 5.15 of Norsys Software Corp. (Norsys 2015) for Bayesian Network modelling.

Bayesian Networks are analytical manifestations of real systems: Actors, planned interventions, and unchangeable parameters are displayed as Elements in a graphic model. Conditions of certain elements affect the state of other elements, which is shown by directed links between the elements. Elements that determine the state of other elements are so called Parent Elements.

For single elements any number of states can be formulated and the probabilities for these states are calculated to finally gain the conditional probability of the target variable; in the present case this is shown for implementing façade greening. The final outcome is the conditional probability of the target variable, which reflects the potential to achieve the desired target state under current circumstances. This particular state is commonly referred to as the status quo.

The first step in the creation of a comprehensive BN is the development of a conceptual model of the investigated system in cooperation with experts (see Chen and Pollino 2012). Four qualitative expert interviews have been conducted to build a conceptual model for the case of implementing façade greening. Two researchers in the field of façade greening and two climate protection commissioners from different Berlin borough administrations were interviewed due to their knowledge on façade greening and their familiarity with the administration in Berlin. Uusitalo (2007) states that the quality of a BN is not negatively affected if only few experts are interviewed and only limited data is available. Interviewed experts provided information on the necessary elements for the conceptual BN model from their professional and disciplinary perspectives.

All mentioned elements were listed and arranged, a discussion of possible states of all elements followed. The intention was to display the current as well as the desired state of the elements (Chen and Pollino 2012). Elements potentially affecting the target state were integrated even if they are not yet relevant. The model creation process focused on identifying the actors and planning steps that are necessary to implement façade greening. The model was discussed with each expert and those expert discussions were thoroughly focused on the research object. The process of model creation and recognizing the defining structures can already contribute to answering the research question (Uusitalo 2007).

The single conceptual models created by the four different experts were combined to form a conclusive and comprehensive Bayesian Network (Figure 6.1; 6.2). Research suggests that the network should at best be kept simple, as it can be a cognitive challenge for the experts to imagine combined probabilities using different factors (Uusitalo 2007). The assessment of probabilities can become confusing with a rising number of elements and influencing factors, potentially deteriorating the quality of answers (Cain 2001; Bromley 2005; Chen and Pollino 2012).

In a second step, a questionnaire (Appendix 6.12) has been developed and sent to the four experts to gain the probability values for the network. Different feasible scenarios for all single elements are determined by the network structure (Figure 6.1; 6.2). Table 6.1 displays the questions posed to assess the conditional probability in an exemplary way using the element "information material". Figure 6.1 demonstrates all four possible scenarios (depending on the state of the two elements of "general attitude"and "communication & information"). Experts were asked to indicate how likely they find the realization of the scenarios in the right column. In the present case: the probability that information material reaches the target group under the given preconditions of positive/negative attitude of the person and sufficient/insufficient communication of the topic.

A conditional probability table is assigned to every element in the network linking up with other elements. These tables serve to further calculate the following probabilities, and make it possible to calculate the conditional probabilities of the target variable. The values gained for single elements, however, do not give any concrete information about the state of the target variable (Table 6.1). When analyzing the returned questionnaires, difficulties lay particularly in the interpretation of different expert opinions concerning an element state's probability. How to handle diverging expert opinions within BNs has not been completely clarified. Using the arithmetic mean is one possibility; however, in some cases it is appropriate to weigh opinions depending on the expertise and work field of the expert (Cain 2001; Keith 1996). In particular, this approach is suitable if elements are specifically associated with the expert's different areas of profession. These values can be given emphasis in the calculation. The present study uses weighed values; if opinions differed too widely and a weighing process was not possible, both states were integrated into the network with a probability of 50%. Using 50% for both states corresponds with a "no-go statement" as the probability does not trend to one or the other direction.

Table 6.1.: Example from the questionnaire to gain the probabilities of the element of "information material".

How do you assess these scenarios for information material to reach its targeted group using probabilities?

Scenario	**general attitude**	**Communication + Information**	**information material reaches targeted group**
1	positive	sufficient	%
2	positive	insufficient	%
3	negative	sufficient	%
4	negative	insufficient	%

Finally, BNs allow for a scenario creation and studying questions of "what if?"(Bromley 2005). With the help of software, the states of single elements can virtually be made more likely or unlikely. The effect of the change in state on the target shows how relevant the element is or potentially could be (Pollino and Henderson 2010), thus what factors could influence the status quo. To display scenarios in a sufficient way, more than one element is often changed and the consequences of a combination of changes are tested (Bromley 2005).

Besides the possibilities of BNs there are some disadvantages in the methodology since the analysis relies on expert opinions and therefore contains uncertainties. The limitations of the methodology are demonstrated in detail in the present article's Discussion section.

6.6. Results

The probability for a successful façade greening installation is determined by the elements displayed in the network. The desired state for the target variable is the implementation of green façades (which would ideally be 100%). The likelihood of achieving this state under current circumstances is 2.03% (Figure 6.1).

According to the expert interview results, there are three main requirements to realize façade greening: Financial capacity, supportive legal/technical conditions, and willingness of involved homeowners to foster implementation. Those three preconditions are further differentiated in the network.

Willingness to realize façade greening marks the beginning of the decision cascade; if there is no basic disposition for the implementation, the financial, legal, and technical possibilities would not be considered.

It is assumed that a communication of political/administrative actors with experts/ researchers leads to the production of information material. The assessment of how active authorities and scientific experts engage in the communication showed that authorities are responsible for distributing information among private actors; however, a lack of a scientific foundation means that the topic does not reach the political agenda. The information needs to address the target group - in this case, in particular, the homeowners. They are key actors, whose willingness is decisive for the implementation of façade greening.

Personal dispositions of homeowners towards greening their façades result mainly from their general attitude towards the subject, the available information, and the presence of good practice in the city. Legal requirements that need to be considered with regards to façade greening are, for instance, heritage protection regulations of buildings. The technical preconditions for greening a façade depend on the chosen plant species and its growth, but also the façade being free of damage and it being possible to apply stays (Köhler 2012). For the present case, legal and technical requirements are combined in the BN as they both are controlling and externally induced constraints.

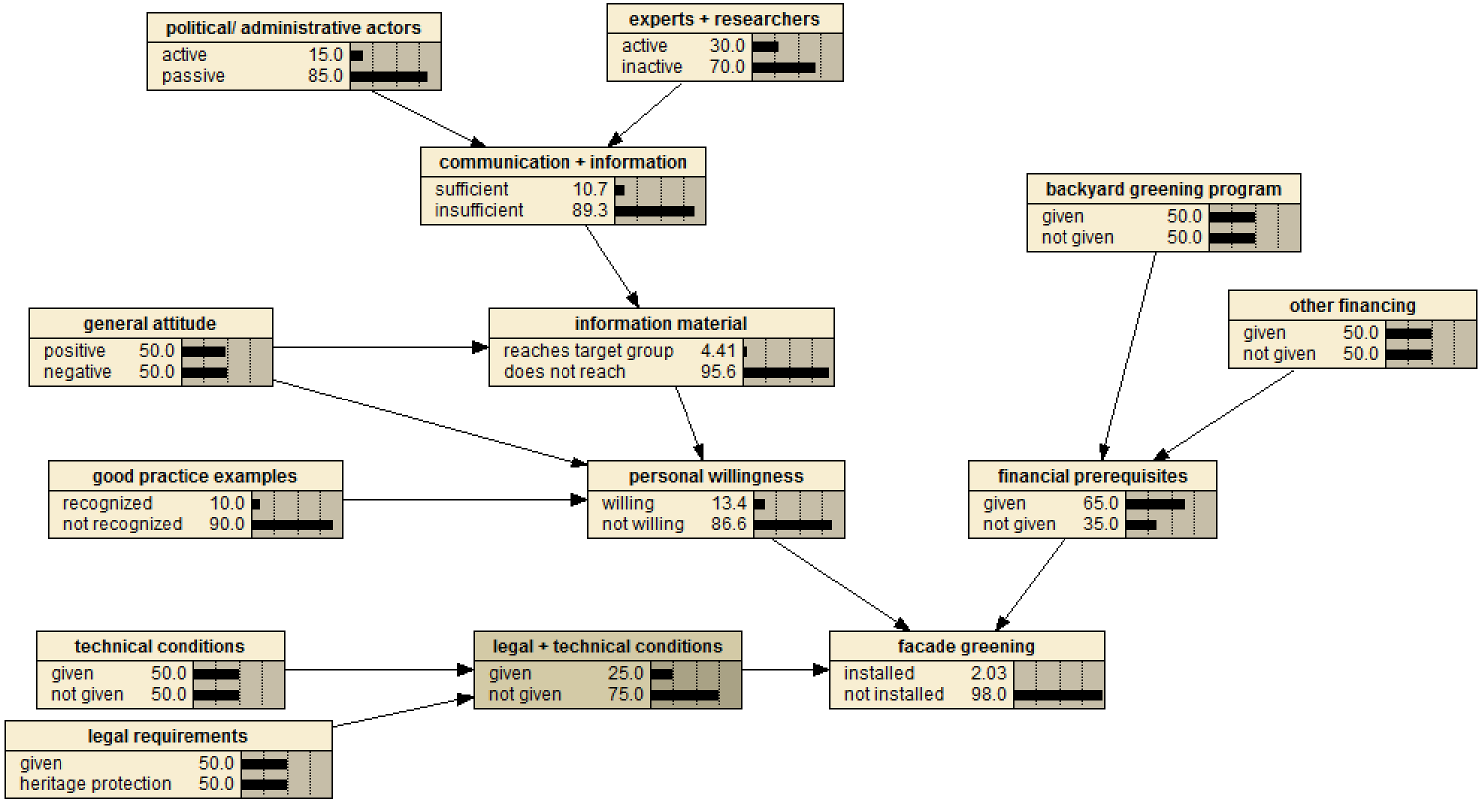

Figure 6.1.: Bayesian network displaying likelihood of success for façade greening in the status quo in Berlin.

Financial needs can be met if private capital is available, or there are financial incentives offered by the authorities, in the Berlin case either the Senate or borough administrations. A backyard greening program (providing financial incentives) can be included into the network. Such a program has been acknowledged by the experts as a strong instrument to raise the chances for a successful implementation of façade greening. The integration of a backyard greening program refers to a respective instrument of the Berlin Senate administration introduced in 1983 (Köhler and Schmidt 1997). The program is explained in detail in the discussion section.

Subsequently, the significance of every single element of the network will be analyzed by raising the desired state of the tested element to a fictitious 100% (Table 6.2).

Table 6.2.: Analysis of the influence of single elements on the target variable of façade greening.

Element	**Desired state that fictitiously is achieved by 100%**	**Results for probability of success for the target variable (Status Quo= 2,03%)**	**Increase of likelihood for success compared with status quo**
General attitude	positive	3,54%	1,51%
Technical conditions	given	3,18%	1,15%
Legal requirements	given	3,18%	1,15%
Financial prerequisites	given	2,77%	0,74%
Backyard greening program	given	2,77%	0,74%
Good practice	recognized	2,55%	0,52%
Experts and researchers	active	2,04%	0,01%
Authorities	active	2,04%	0,01%

A ‘positive general attitude’ towards façade greening turned out to be the most influential element of the network. A virtual increase of the element to 100% raises the probability for success by 1.51% to 3.54%, if all other states stay the same. The general attitude of actors is a consequence of one’s upbringing, education, and the social environment, becoming influential to a certain extent. Examining the results in more detail reveals that none of the elements, if they are changed individually, have a decisive effect on the implementation of façade greening. A more detailed conclusion, which elements are worth investing in, can in this case not be drawn. In addition, an even further increase of success probability can be achieved by combining various changes in elements. To do so, a preferably realistic scenario has been developed by including the backyard greening program (Figure 6.2).

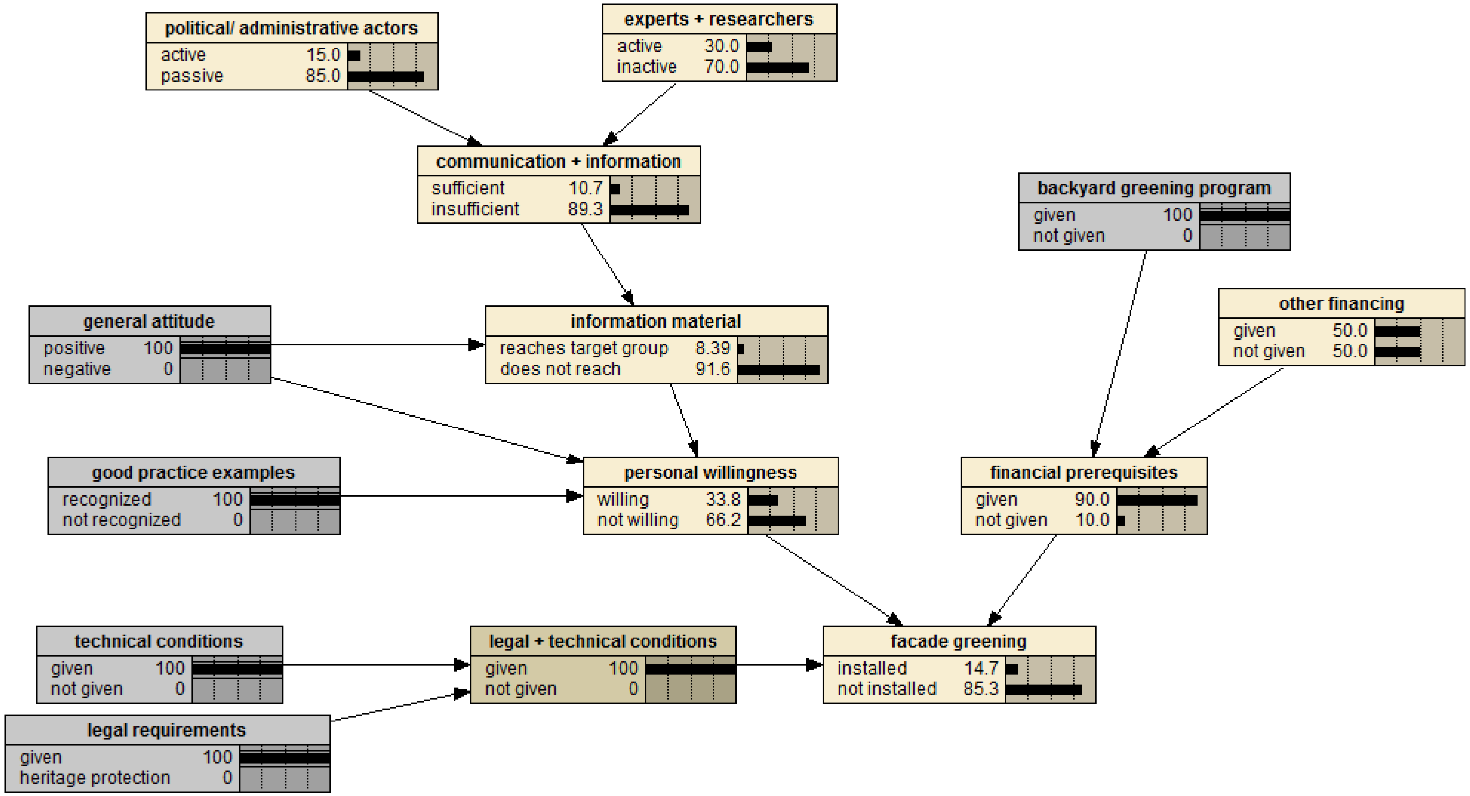

Figure 6.2.: Bayesian network for the implementation of façade greening with a backyard greening program and further assumptions. The altered elements are displayed in grey color.

In this scenario, façade greening is implemented at a probability rate of 14.7%. On a fictitious level, a backyard greening program can be introduced and other requirements that homeowners need to make use of it can be assumed to be fulfilled: A positive attitude; open-mindedness towards ‘good practice’ of façade greening in the city, and also that the façade qualifies technically and legally for installing greening measures. The result shows that even if all necessary requirements are given, it does not lead to a 100% chance for implementation.

The question remains what reasons there are for low expectations concerning the probability for implementation of façade greening. Experts expressed further ideas in the interviews, the most frequently mentioned was that façade greening is not likely to be implemented as long as it is not financially worthwhile or obligatory. These requirements cannot be fulfilled by a backyard greening program, as greening does not pay off economically. Nevertheless, a backyard program would have benefits for the implementation probability.

Moreover, the assumption was stated that as long as a definite confirmation for the suitability of façade greening for climate change adaptation purposes is missing, authorities will not actively pursue the implementation of façade greening beyond the no-regret approach (4 oral). Another reason could be that green roofs are a more widely-known measure (Köhler 2008); with homeowners installing them, they get an accessible roof garden and therefore receive direct benefits. Furthermore, the political focus has strongly been on Carbon Dioxide (CO_2) reduction measures such as energy efficiency and isolation in buildings (Donner et al. 2015; 3 oral).

The question remains how the network can be influenced by elements that have no parents. Within the chosen scope of analysis they cannot be influenced. However, with other available means and opportunities beyond the ones suggested in the network, those elements can be subject to change, too. This is applicable, for example, if there is a change in the elements of technical and legal compliance. Different approaches for action can be derived from fictitious scenarios including these elements. For instance, this could include the construction of future houses in a way that façade greening can be fitted retrospectively; therefore, 100% of all new buildings would be suitable for façade greening purposes. The same holds true for the legal eligibility of façades. A change in heritage protection laws, for example, could increase façade greening chances as more façades would be legally eligible.

6.7. Discussion

Previous studies stress that there are only few adaptation processes which have reached implementation (see Wamsler et al. 2013; Carmin et al. 2012; Moser and Ekstrom 2010). This study also finds low implementation prospects for the adaptation measure of façade greening. The current constellation of factors identified to be decisive for the implementation of façade greening in Berlin shows only a very low probability value (2%). In the first instance the result suggests that decision-makers need to consider if this adaptation measure is a suitable option. Other measures might be more successful with regards to their implementation prospects in the current local political landscape.

Yet, the study identified several factors that play an important role for the implementation of green façades, which mostly also play a role within the field of adaptation planning and governance in general (e.g., Moser and Ekstrom 2010; Biesbroek et al. 2013; Mahlkow and Donner 2016). The BN analysis, however, allows for ranking the influence of each of the factors on the outcome. In the case of façade greening the "general attitude" of determinant actors is of outmost importance, while financial prerequisites, legal and technical conditions also have an influence on the decision to install green façades. These findings show the necessity to identify instruments and build institutional structures that help to make the installation of façade greening more independent from actor preferences.

Many authors have found similar factors to inhibit the implementation of climate change adaptation. Lehmann et al. (2015), for example, showed the need for financial support and political will. Appropriate incentives need to be set by the government. However, these studies do not provide an insight into the actual influence such incentives can have on the implementation of measures. The BN analysis can display different scenarios which raise the probability for green façade installation. The influence of enabling policy instruments (Bulkeley and Kern 2006) could be shown in one scenario, which can be considered realistic (Figure 6.2). BN allowed to virtually study the impacts of a "backyard greening program" along with other requirements and could be identified as an incentive to significantly raise the implementation probability.

While the network does not give an insight into the configuration of different elements integrated into the BN such as the backyard greening program, their qualitative features are of importance to underline the plausibility of the BN results. These features can be singled out in the expert interviews used for the BN. For façade greening implementation the experts referred to a program that was initiated by the Berlin Senate Administration and has been in place between 1983 and 1995. The state budget covered costs for the materials to green the grey backyards of Berlin's tenements, whereas the residents had to do the gardening work, including greening roofs, façades, and backyards (Wrozlaw 1997). Without the impulse and the material incentives set by the program, residents would not have considered or realized greening measures in most backyards (Wrozlaw 1997). During its twelve years running time, the program helped to green 32,475,000 ha of façades in Berlin (Köhler and Schmidt 1997). Based on its success, it seems valid to call for the (re-)initiation of a similar program; especially as an implementation of façade greening implies more than just positive effects for the climatic situation in a city (Albers et al. 2015; SenStadtUm 2011).

For studying the implementation of adaptation measures, developing Bayesian networks offers the advantage of identifying the impact single elements have on solving the policy problem of implementation, moreover, applying scenario analysis for policy problems that are riddled with uncertainty, complexity and controversy can provide important information for decision-makers (Mees et al. 2014). Probability values are often used to measure uncertainties, and therefore are an opportunity to approach topics previously characterized by a lack of empirical data (Morgan and Henrion 1990; Uusitalo 2007). The innovative aspect of the study is that the factors influencing the implementation of very specific adaptation measures as façade greening can be identified, as well as linked with probabilistic values which shows their conditional relation.

Besides the strengths some methodical features of Bayesian networks need to be born in mind with regards to the study of façade greening. The displayed network can only be a highly simplified display of the determining factors for the implementation of façade greening. Due to its exemplary nature, the network might miss certain aspects or might not differentiate others thoroughly enough; thus, it can depict reality only in a fragmentary way (Morgan and Henrion 1990). Uncertainties with regards to model creation reflect a missing consensus of interviewed experts on links between elements and dependence of elements on each other (Morgan and Henrion 1990). Moreover, it can be expected that expert opinions about the perception of the implementation of façade greening differ as every person develops their own notion of the likelihood of some event to occur according to their own knowledge and expertise (Morgan and Henrion 1990; Chen and Pollino 2012). Uusitalo (2007) points to difficulties, which result from creating BNs with expert knowledge: It is very uncommon for most interviewees to express their knowledge in the form of probability values. It is apparent that experts do not categorize their knowledge into probability values, but they are only demanded to do so in the course of the survey (Morgan and Henrion 1990). Expert opinions may be erroneous and only an approximation of reality, but they are better than “no data” and still the best available possibility to approach certain questions (Uusitalo 2007). Hence the final result, the probability of the target variable, cannot be considered an absolute number, but displays only a tendency. To gain exact results and prognosis, BNs cannot be the method of choice (Chen and Pollino 2012). However, they can be a valuable instrument to assess the influence of different factors on the implementation of adaptation measures, especially when they involve the engagement of private actors in the building stock such as façade greening, and can therefore inform decision-makers on what pathways to stress to raise implementation success.

6.8. Conclusion

This study deals with the supportive factors for the implementation success of façade greening by using the Bayesian Networks (BN) method.

Façade greening is one suitable way to establish vegetation in cities despite the development pressure. Ecosystem services gained by urban green have been known for a long time, but implementation of greening devices such as green façades often fails. The BN analysis confirmed that it is not a measure that is implemented willingly, even if requirements that experts identify as necessary seem to be given. The result leads to the assumption that the promotion of other adaptation measures might be of greater success. However, enabling policy instruments such as a backyard greening program can raise the prospect of implementation.

The paper shows Bayesian Networks to be useful tools to examine various factors and their probabilistic influence on the implementation of climate change adaptation measures such as green façades. Studying the probability of successful implementation of other climate change adaptation measures is a noteworthy follow-up research. Moreover, comparisons with other German cities with more financial means at their command than the city of Berlin could be interesting.

6.9. Oral references

[1] Research project UCaHS (oral): Interview on June 03, 2015.

[2] Professor for landscape architecture (oral): Interview on June 25, 2015.

[3] Climate protection manager borough administration (oral): Interview on June 02, 2015.

[4] Climate protection manager borough administration (oral): Interview on June 08, 2015.

Wrozlaw, 1997: Vortragstext zu einem Vortrag über das Hofbegrünungsprogramm Berlin (presentation about the backyard greening program).

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6.12. Appendix

6.12.1. Questionnaire: Façade greening as climate adaptation measure – Bayesian network analysis

1. How do you rate the probability that experts/researchers bring their knowledge about façade greening active in a communication process with the political/administrative actors?
   Answer: %
   Comments:

2. How likely is it, that the political/administrative part becomes actively involved in the communication process and manages the creation of information material about façade greening?
   Answer: %
   Comments:

3. How likely is it that a communication process between experts/researchers and political/administrative actors takes place? Rate the four scenarios:

Szenario	Political/ administrative actors	Experts/ researcher	Communication is sufficient and information material is drawn up
1	active	active	%
2	active	passive	%
3	passive	active	%
4	passive	passive	%

   Which of the both actors has a higher importance for a successful communication: the researchers and experts who generate knowledge or the political/administrative actors who are in charge to communicate this knowledge?
   Answer:
   Comments:

4. How many of the Berlin citizens do you think have a “green” attitude and are therefore open-minded about façade greening?
   Answer: %
   Comments:

5. How likely is it, that the available Information material reaches the desired target group (esp. homeowner)? Rate the four scenarios:

Szenario	General attitude	Communication + Information material	Information material reaches target group
1	positive	sufficient	%
2	positive	insufficient	%
3	negative	sufficient	%
4	negative	insufficient	%

Comments:

6. How likely is it, that citizens notice good practice examples of façade greening in Berlin (by accident, in the daily routine)?
Answer: %
Comments:

7. In the following the probability of the personal willingness of the homeowner (target group) is determined. Rate the eight scenarios:

Scenario	Information material about façade greening	General attitude	Good practice examples of façade greening in Berlin	Personal willingness of homeowner for implementation of façade greening
1	reaches target group	positive	are noticed	%
2	reaches target group	positive	are not noticed	%
3	reaches target group	negative	are noticed	%
4	reaches target group	negative	are not noticed	%
5	does not reach target group	positive	are noticed	%
6	does not reach target group	positive	are not noticed	%
7	does not reach target group	negative	are noticed	%
8	does not reach target group	negative	are not noticed	%

Which of the three factors (Information material, general attitude and good practice examples) influences the personal willingness of the homeowner the most?
Answer:
Comments:

8. Estimation – there is no right or wrong: how many percent of the Berlin façades would technically be suitable for a façade greening (with regard to exposition, fire walls, materials etc.)?
Answer: %
Comments:

9. Rate on a scale from 0-10:
Imagine the influence of a backyard greening program (mainly financial support), e.g., initiated from the senate department of environment. In your opinion, how would a financial support affect the implementation frequency of façade greening?

little				medium					strong	
0☐	1☐	2☐	3☐	4☐	5☐	6☐	7☐	8☐	9☐	10☐

Comments:

10. How likely is it that a homeowner has other financial means (assets, loans) for the implementation of a façade greening?
Answer: %
Comments:

11. Finally the implementation probability is determined. Rate the eight scenarios:

Scenario	Legal + technical conditions	Financial prerequisites	Personal willingness	Implementation probability
1	given	given	given	%
2	given	given	not given	%
3	given	not given	given	%
4	given	not given	not given	%
5	not given	given	given	%
6	not given	given	not given	%
7	not given	not given	given	%
8	not given	not given	not given	%

12. General remarks/ comments on the method:

7. Conclusion

“The challenge that climate change presents to planning, is unprecedented in scale and scope, but, in certain critical respects, this challenge is similar to other planning problems. (. . .) Planning is conducted every day under conditions of uncertainty, in the presence of system effects, and where programmatic options may be non-incremental, exclusive or irreversible (Donaghy 2007).”

The challenge described above lies in recognizing the underlying synergies and conflicts in the implementation process and determining how to deal with them, all while understanding the trade-offs necessary in planning. To respond to this challenge, climate change demands a three-pronged strategy in cities and urban areas. Measures to protect and preserve the global climate (mitigation) must be undertaken. At the same time, strategies to respond to the unavoidable impacts of climate change (adaptation) must be developed. Finally, both groups of actions must be coordinated with the other pressing tasks of sustainable urban development, like the urban building boom (BBSR 2009; Chapter 5). These influential decisions will reach far into the future and require the adoption of clear goals and guidelines for development in the coming decades.

Worldwide scientific attention to climate change has increased in recent years. Discussion of heat and how to deal with it has become embedded in national and international discourse and politics (Vink 2013). From both a climatologic and political perspective, the choice of city for this analysis, Berlin, Germany, makes for a very interesting case study (Jänicke 2016; [15]). As a northern mid-latitude city, Berlin has little experience with extreme temperatures. In the day to day life of a citizen, whether at work or in free time activities, heat concerns have generally been given little attention (Schuster et al. 2014; Mahlkow 2016; [15]). Climate models project a significant increase in extreme weather in the future, however. A higher mortality rate due to urban heat stress emphasizes the coming problems (Endlicher et al. 2008; Scherer et al. 2013).

Berlin developed from various villages that merged over time and this heterogeneity is still tangible both physically and in the institutions of government. The city administration consists of the Berlin Senate and the twelve District Authorities. Each district’s administration has developed differently over time and this also influences how they handle climate issues. For example, in the districts where there is a director of climate change mitigation, this position is sometimes in the Environmental Department and sometimes directly under the local mayor’s control ([2]; Chapter 3).

According to interviews, climate adaptation has been promoted in Berlin’s administration as part of a process in which individual departments examine the currently important themes in the international political discourse, attempt to bring these into the local frame, and establish Berlin’s position related to them [15]. Political response to these complex ideas has been erratic at all levels (Vink et al. 2013). For some time, local politicians and planners have also debated climate adaptation. Berlin has tried to be a pioneer for climate adaptation nationally and internationally.

Real-world implementation, however, has lagged and will require a different type of work - research alone cannot put adaptation strategies into practice (Chapter 3).

7.1. Which urban planning level is the most promising for releasing, steering, and fostering supportive interventions for the integration of urban heat stress mitigation and adaptation policies?

Reducing the current and future impacts of climate change will require substantial efforts by planners. The previous chapters identified several opportunities for promising or supportive interventions for the integration of climate adaptive strategies in planning. The central question is: how can Berlin develop lasting resilience to the negative consequences of climate change? The primary goal in this should be to preserve and, where possible, improve quality of life in the city. In order to achieve this, numerous levels government and stakeholders from different fields will be responsible, though in this dissertation only the environmental planning and urban planning have been illuminated.

Analysis of different levels of the planning process in Chapters 2-6 clearly demonstrates many possibilities for the integration of climate adaptation measures in practice. Options at the level of the Berlin Senate Department down to the individual block level were identified and examined in their respective chapters. In order to implement guidelines at the district level, they must be created and adopted at the city-wide level by the Senate's Department for Urban Development and Environment. Therefore, the planners and decision makers must coordinate the different actors at different levels and positions, a challenging task (Chapter 5).

Considering the extreme effects of climate change on the local community, adaptation highlights the special responsibility of urban planning legislation to protect the public (Urwin and Jordan 2008; Watts et al. 2015). At the highest administrative level, the city's comprehensive land-use plan is especially relevant to climate adaptation. This plan is the foundation for all further urban planning in Berlin's individual districts (Chapter 3; Chapter 5; Chapter 6; Battis et al. 2010; Birkmann et al. 2012; Kumar and Geneletti 2015; Measham et al. 2011; [1]). In addition to the comprehensive land-use plan, which shapes policy at the city level, Berlin's experts cite the local land-use plan (which formulates provisions for the block level) as the most important instrument through which adaptation strategies are actually implemented e.g., greenery or façade greening (Chapter 3; 5; 6).

For a deeper look, Chapter 5 analyzed to what extent climate adaptation measures play a role in environmental and land-use planning. Consideration of these issues was shown to be inconsistent at best and, in many cases, nonexistent. One major problem is that heat is not given political priority in Berlin as a risk factor for urban residents, infrastructure, and environment (Chapter 3 and 5). A number of possibilities to tackle barriers for heat risk preventative governance have been identified in this work (e.g., public participation and an existence of an environmental assessment), but formal policy and planning instruments will need to be targeted more specifically to that purpose. The likelihood that these changes would be integrated was estimated at 71.8% (see Chapter 5). This relatively high number raises an important question, though: why aren't our local land-use plans climate adapted? Until now, different government levels and departments, as well as other actors, have acted relatively independently from one another. A coordinated approach to tackle heat risks systematically and specific policy guidance on how handle implementation in plans has not yet been created (Chapter 3 and 5; Berke 2006). Vulnerability to urban heat is unquestionably linked to governance strategies for urban development (SenStadtUm 2016c). Furthermore, the responsibilities of individual tiers of local government need to be clearly delineated and coordinated. Allocating specific roles related to heat risks will improve the integration of heat stress into planning policy and governance processes.

The results underline that there is no single urban planning level most promising for releasing, steering, and fostering supportive interventions for the integration of urban heat stress mitigation and adaptation policies into urban planning. At first glance, the local land-use plan seems to be the strongest instrument. But it is not solely responsible for the implementation of climate adaptation measures, and it can be influenced by outside players. The results of this study reveal a gap both in awareness and, especially, in implementation of measures to adapt the urban fabric to heat stress, as well as in the ability of institutions and actors to adequately handle related risks and vulnerabilities. The interviewees also confirm that successful implementation works only if all levels interact together (Baker et al. 2012; Chapter 3 and 5]. Therefore, a new institution is needed to take on responsibility for adaptation action and coordinate all relevant adaptation strategies, projects and discourses. This institution would provide others with necessary information and act as a resource, enabling knowledge transfer (UBA 2013; Odparlik 2017; Swart et al. 2014; Tethys 2017).

7.2. What challenges and constraints do urban planners face in their daily practice related to the integration of the concept of heat risk, and how can these be handled?

There is a broad field of research related to mitigation of and adaptation to urban heat stress, but it is mainly focused on very technical topics within the natural sciences (Mahlkow 2016). It is increasingly clear, however, that professional knowledge and experience with adaptation strategies is limited (Chapter 3; Vink et al. 2013). It is still unknown how planners and decision makers, especially in cities in moderate climate zones, should understand and confront the challenges of urban heat stress (Chapter 3; 5; Mahlkow 2016). The intrinsic complexity of cities, which the various adaptation measures must take into account, further confounds the issue.

Almost all German cities have developed strategies and plans for climate change mitigation and adaptation (Chapter 2). Climate regulations such as these are still very new and there is a lack of research about how they will be implemented in public and, especially, private practice (Chapter 3). So, how do decision makers deal with urban heat? What kind of challenges does this issue pose?

The international discourse of climate adaptation is important to spur the process [15], but how the idea is confronted and acted on is a local phenomenon. Urban sociologists consider this part of the intrinsic individual logic of cities (Berking and Löw 2008; Mahlkow 2016). Past legal and government practices have built unique institutional structures in cities and these influence how new issues are handled. Therefore, the fact that climate adaptation is not uniformly recognized nationally is due to different planning cultures and different ways of tackling the topic in plans and programs (Bubecka 2016).

Berlin's climate policy is led by the city government and by the Senate Department for Urban Development and Environment. In Berlin, the dominant political discourse at the administration level is focused on housing concerns (Chapter 3). Mitigation and adaptation have yet to play a significant role in urban development decisions (Chapter 3). The building boom in Berlin can be felt all over the city. Increasing demand for living space and the needs of the growing city are the first priority. Because of this, according to the experts interviewed, adaptation and heat stress are given little consideration: climate policies are secondary to other concerns.

The fact that Berlin is a very green city means that it is already somewhat adapted for urban heat (Chapter 3 and 5; Sprondel et al. 2016). That climate adaptation calls for an alteration to traditional building habits rather than a total ban on construction is an idea that is only slowly spreading. The high demand for living space has put quite some pressure behind the possible development of housing on available green and open spaces in Berlin (Chapter 5 and 6; Kabisch 2015). Depending on the intended lifespan of new buildings, that could mean an occupation of this space for up to 100 years [15]. This underlines that current policy and infrastructure decisions and strategies may have serious consequences for the next decades (Vink 2013). In the especially dense districts in the inner city, increased building density will lead to further warming if it is not done in a climate-adapted manner (Scherer et al. 2013). Decisions about this development, however, will be inconsistent, made at different times by different people and depending on the urgency of the process (Vink 2013). Additionally, these decisions concern new issues rather than the more traditional ones. The actors cannot rely on the knowledge they have gathered over previous years but must think in a future-oriented way (Greiving 2010).

The city government must take a central role in the implementation of climate-related policy. They can set the topics which have to be observed by the Senate Department and they have to set clear standards. The private sector cannot be relied on to implement climate measures on their own. Berlin's administration is organized into several sectors, and, therefore, its work is defined by these pre-existing categories. Each sector has its own kind of reasoning or logic (Chapter 3; 5; Mahlkow 2016; Sprondel et al. 2016).

The Senate Department provides the conceptual framework for urban development. The twelve District Authorities, though they may have their own forms, are subordinate to the Senate. Experts have indicated that the work of the Senate's Department for Urban Development and Environment (SenStadtUm) and of the individual districts is often in conflict [2, 15]. The districts complain that SenStadtUm publishes informal concepts but does not explain their usage [3, 11, 16]. One issue is that all the implementation work is transferred to the lower levels of the local land-use plans (Chapter 3 and 5; [11]). The interviewees from Berlin's districts stated that they cannot discharge their responsibilities for implementation without staff, clear guidelines, and sufficient budget allowances (Baker et al. 2012; Heiland 2017, 172, 189; [2, 11, 15]). Another factor is that scientific knowledge of climate change adaptation has not adequately seeped into the operational planning level of each district [15]. These difficulties arise because the effects of climate change are so called new risks, and these objectives are less related to traditional, well-known issues [11]. Climate change poses new, forward-looking questions which cannot be easily answered without corresponding knowledge (Greiving 2010).

The experts believe that the Senate Department for Urban Development and Environment can play an advisory role for technical, modelling, and project-specific knowledge. The Senate Department provides information in the form of leaflets and brochures, but the district authorities claim that these documents provide too much general information and lack a concrete guidance on how to manage this new topic (Chapter 3). How sustainable this role can be, considering the often brief time allowed for scientific and technical guidance on active projects, is uncertain (Chapter 5).

For all these reasons, Berlin's governing bodies will find it challenging to push for the inclusion of adaptation measures in construction projects. To help address this issue, the City Climate Development Plan (StEP Klima) 'KONKRET' was adopted in summer 2016 as a support to the Berlin StEP Klima. The plan is both educational and solution-oriented. It identifies heat risks as a local problem and communicates how to handle it with coping strategies (Chapter 3; Dupuis and Knoepfel 2011). It represents an important step towards bringing attention to relevant local actors and available tools. Despite this, Berke et al. (2006) found that in cases such as this significant action is only taken on "(...) strict interpretation of policies, legalistic procedures, formal written communication rather than informal verbal communication (...)." Additionally, the implementation of climate change policy is difficult because it often competes with other fields like economic, social, and political processes. The special challenge here is to reframe climate adaptation's perceived role to include these socio-economic conditions (Bulkeley 2010; Carter et al. 2015; Chapter 4; [2, 13]).

The lack of competency in this field is a major problem. Climate change will have major political and social repercussions and many of these will play out spatially in the urban environment. It is obvious even now that a comprehensive set of response strategies will be needed. While this has been recognized, at least theoretically, clear division of responsibility at the administrative level has yet to appear. As recommended above, translation of adaptation strategies into daily planning practices requires an exchange of knowledge and experience between government and district levels. Our interviews also showed that the integration of new topics, like climate adaptation, is often difficult. Practitioners need to understand how to link the formal and informal planning and governance instruments at different levels (Chapter 3 and 5). This will require advanced training and constant communication between all urban government levels. Therefore, politicians need to increase the resources and personnel capacity assigned to support adaptation implementation (Carter et al. 2015; Chapter 3 and 5). The shortage of personnel in Berlin, mentioned repeatedly in our interviews, is one of the reasons these topics and the issues arising therefrom are not managed well currently (Berke et al. 2006). Studies show that staff capacity has an important influence on adaptation methods when plans are acted upon (Dalton and Burby 1994; Burby 2003; Chapter 5). More staff means more capacity to achieve plan goals, more attention to plan policies and associated rules, and better interaction and coordination with other public agencies (Berke et al. 2006; Chapter 4). After 20 years of no city employment expansion, Berlin is now beginning to staff new positions [2, 11, 15].

There is a striking contrast in the requirements of research into the effects of climate change as opposed to that into implementation of the strategies that could lead to a well-organized approach to climate change through various planning and analysis tools. In general, climate change remains a socially and politically inconvenient issue, which, due to many factors, is only slowly being incorporated into the planning process (Amudsen et al. 2010; Cannon and Müller-Mahn 2010; Chapter 3). Integrated approaches that include multi-actor and multi-level governance are needed to coordinate the complex interplay of the many different actors and activities tackling the complex issue of urban heat stress adaptation measures (Chapter 3). Practitioners are apprehensive about the changes in thinking and politics that this will entail.

Also problematic is the long-term nature of this type of planning and the uncertainty about climate change's exact effects. Strategies on timelines as distant as 2050 are discussed without a concrete idea of how the public will be impacted (Chapter 4). It is difficult for many stakeholders, who have pressing short-term concerns, to prioritize these issues. In Berlin, politics generally runs on a five year cycle. A change in long term planning practice is challenging because it is outside of the usual scope of policy makers who function inside these five-year policy phases [15]. In addition, the seriousness of the impacts of climate change is not emphasized because these cannot yet be seen or felt acutely [2, 6, 7, 10, 15].

Even considering the climate adaptation planning efforts to date, heat stress mitigation remains very novel in Berlin's urban planning context (Chapter 3). Specifically, Berlin's climate plan is more focused on the scale and nature of climate change impacts in the city. Because of the extremely localized character of these impacts and possible solutions it will be difficult to raise awareness and support through traditional media coverage, peer effects, and other channels as has been done for climate mitigation (Chapter 3; Millard- Ball 2012; [15]).

7.3. Do planners and policy makers have an adequate basic set of urban planning tools to make plan implementation, especially related to heat stress, successful?

All of the interviewed experts explored to what extent new planning tools could assist in urban climate change adaptation. They were, contradictory to the findings of several studies which demand new tools for climate adaptation (Birkmann et al. 2010; Greiving 2003; Greiving 2010; Kropp and Daschkeit 2008; Othengrafen 2014), in agreement that the tools currently used in planning practice are sufficient and there is no need for new planning instruments for this purpose [1-15]. However, documents that link policy implementation to planning practice (Mastop and Faludi 1997; Talen 1996) underline that planners have not yet developed a consistent ability to connect plans and or standard implementation practices to successful realization of goals (Berke et al. 2006; Stone et al. 2012).

To figure out if experts have an adequate basic set of urban planning tools, the urban planning instruments planners in Berlin do have to implement the adaptation strategies for urban heat stress into the local land-use plans should be explored. In addition, it is important to examine how much "weight" or influence on implementation the individual instruments have. To answer these questions, we analyzed current plans and the formal regulations and informal norms or habits which guide planning practice. Heat as a climate change adaptation issue is mentioned in policies related to the general strategic development goals, including the urban landscape strategy, planning and building competitions, and the ecological building concept.

If climate adaptation were valued higher at the basic, organizational level e.g., the German Federal Building Code (BauGB) or the comprehensive land-use plan, it would also receive more attention in local land-use planning. Therefore, an ongoing discourse is vital, as formal local land-use plans can only deal with the topics that were already included in their planning process. For example, the Senate Department could include the integration of adaptation measures in the evaluation requirements for bids to complete city projects. These requests for proposals and competitive bidding processes have a major impact on the success of the implementation of adaptation measures. Having a construction or project management company that is ‘green’ or climate-oriented plays a vital role. Together with the district processes, this type of intervention can help to anchor the position of adaptation in the policy and contracts that shape urban development (Chapter 5).

One instrument is the Biotope Area Factor (BAF). It provides an opportunity to safeguard a specific amount of dedicated green and open space and is best suited to the preservation of these spaces (Kazmierczak and Carter 2010). Its goal is to improve the ecological situation in Berlin’s inner city (Becker et al. 1990; Othengrafen 2014). The BAF plays a rather minor role, though, due to its position in landscape planning rather than local land-use plans. In some Berlin districts, the landscape plans were repealed because a lack of perceived necessity (Sprondel et al. 2016a). The experts we spoke to agreed, however, that the BAF can contribute to adaptation through its direct influence on green and open space allowances in new construction (Chapter 3 and 4; Othengrafen 2014).

An additional principle which can bring more attention to adaptation measures is a guideline known as sample regulation. This guideline, created by the Senate Department for Urban Development and Environment, serves to standardize the preparation of local land-use plans. Strategies defined here must be taken into account (Chapter 5). So far, climate adaptation measures do not play any role in this document. Although it requires consideration of housing and greenspace concerns, their specific relation to heat or adaptation to climate change is not mentioned (SenStadtUm 2012).

Studies also showed, though, that a binding commitment for integration must exist at higher levels. The best starting point would be an implementation of adaptation strategies into city planning competitive bids (Sprondel et al. 2016). Through these, the Senate Department can set the framework of requirements for the investor. With this established criteria, one can control the climate appropriateness concretely. Another option is action through public and administrative participation when a local land-use plan is implemented (Baker et al. 2012; Chapter 5). According to Sprondel et al. (2016), this administrative participation in legitimizing climate adaptation is one of the elements which, alone, has the strongest influence on the implementation of adaptation measures.

In order to give climate change concerns more significance, they should be included in environmental impact statement as well (Larsen et al. 2013; Larsen 2014; Odparlik et al. 2012; Sprondel et al. 2016). These reports are first developed at the level of the local land-use plans. As Chapter 5 showed, the presence of environmental impact statements leads to demonstrably better integration of climate adaptation measures.

From interviews, we learned §13a (simplified procedure) of the BauGB has led to a substantial reduction of environmental assessments in the inner city. Developers also often ask for exemptions from environmental assessment requirements because of time and cost concerns (Chapter 5). In order to promote climate-adapted local land-use plans, the BauGB should be amended to require environmental impact statements.

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) has recently published a draft amendment to the BauGB to implement Directive 2014/52/EU on urban planning and to strengthen the "new living in the city" (BMUB 2016). Therefore, the basic duty of the preliminary examination of the individual case (§2 (4) 4 BauGB) has been formalized for all applications. The mandate of this preliminary examination, on the one hand, reduces the perceived advantages of the accelerated process, but, on the other, serves as vital protection for ecological and health concerns through the support of an environmental impact statement.

Another possibility would be an amendment §34 of the BauGB. The §34 gives the investor admissibility to build his projects in developed districts without a preparation of a local land-use plan. Neither public participation nor environmental impact statement is necessary. This is the reason why there are sometimes no local land-use plans in Berlin. This aggravates the situation in areas of especially high climate impact [2], underlining that integrating climate adaptation measures will certainly require some changes to these planning norms. Therefore the BMUB should amend the §34 BauGB that the statute is to be excluded if there are indications that the installation of the respective plans is subject to the prohibition of the Federal Emmission Control Act (§50 (1) BImSchG 2016).

7.4. Discussion and Conclusion

Planning faces several other duties related to climate adaptation, including developing responses to the uncertainty of climate change's timing and impacts, the long-term nature of climate scenarios, and the existing planning structure (Othengrafen 2014). Identifying barriers is a first step to resolving that (Biesbroek et al. 2014).

Despite the many options for dealing with urban heat through planning, there has been little progress. Experience with how to deal with this has not yet been developed (Chapter 2; 3; 5). Unlike noise, for example, heat is only a major problem for a couple of weeks per year and thus it hasn't been assigned a high priority [4, 8, 9]. The experts cite a lack of targets and goals to indicate necessity of or success related to adaptation, which makes it difficult to justify, legally, the use of some planning tools for this purpose. No specific tipping points, measurements, or goals have been adopted by any administration in this field (Chapter 3 and 4; Mahlkow 2016). Some of the blame was also assigned to shortages in personnel and resources in urban planning departments: where staff are overwhelmed, it is difficult to take on complex challenges.

As the population of industrialized countries spends most of their time in confined spaces (90%) (Brasche and Bischof 2005; Höppe and Martinac 1998; Höppe 2002; Jänicke 2016), indoor heat stress must be given more attention in the planning process [15]. The outdoor climate affects the indoor climate (Mills et al. 2010; Nguyen et al. 2014), but the exact influence cannot be generalized easily because of the diversity of buildings (e.g., building design, material, cooling systems) (Höppe and Martinac 1998). The problem of indoor heat stress is mostly lost in the adaptation plans or is mentioned only in the course of the façade greening (SenStadtUm 2011; [15]).

Often, aspects related to climate adaptation are included in the implementation of the plans, but other reasons for their inclusion are given in outside communication (i.e., other environmental purposes) [3]. The courts are expected to push for more transparency in local planning and development in the near future [3, 11]. No current decisions could be found which deal explicitly with climate adaptation. The general recognition of climate adaptation in §1 Abs. 5 (2) of the BauGB has not been sufficient to bring it into planning practice. Instead, implementation has relied on the initiative shown by individual district staff in recognizing and tackling climate adaptation ([11]; Bubecka 2016; Sprondel et al. 2016).

This evaluation of the current legislation demonstrates that adaptation has been integrated explicitly into only a few laws and regulations. Only the German Regional Planning Act (ROG), the BauGB, the German Federal Water Act (WHG) and Berlin's Energy Transition Act take legal positions related to adaptation. Berlin is playing a pioneering role with the adoption of the law. Seen positively, this indicates that, at least in the legislation, a general consensus about the significance of climate adaptation is being reached. On the other hand, the length of time it will take for these ideas to take hold and seep through the long urban and regional planning process will delay the implementation of climate adaptation measures (Bubecka 2016).

The Senate Department of urban development and housing is responsible for the institutionalization of climate change concerns. The interviewees felt, however, that extreme heat and heat stress have not been fully incorporated because urban planning is perceived as being supportive of more development rather than obstructive. This contradicts the historic understanding of urban development in Berlin (Mahlkow 2016). Although the StEP Klima and the relatively new StEP Klima KONKRET exist, heat adapted building and development have not yet been embraced by the major stakeholders. Both plans have an informal character. Climate adaptation via an informal, flexible instrument is at risk of being pushed completely into the background by other targets which are dominate in local politics. To involve climate change adaptation measures into day to day planning practice, communication between the

Senate Department and the districts is necessary. Therefore, training courses on how to handle the topic and strict long- and short-term guidelines and standards have to be created (Chapter 5). The problem is that as long as an instrument is voluntarily, it is only used by those who also benefit from it (Chapter 5).

Urban citizens will need to be protected from heat indoors and outdoors as climate change worsens. While urban planning is characteristically occupied with new building sites and new development, increasing heat risk in cities will require re-focusing on the existing urban structure. How exactly city administrations will meet this challenge is uncertain. Some guidance may be taken from the development of urban greening programs, which have united public and private organizations and actors for tree planning and urban gardening. But, with many measures, the city's hands are tied. Adaptation measures on private land can only be implemented by the owners of land (Greiving 2008).

As Chapter 6 showed, 'green' ideas are currently popular in Berlin and have been promoted by the city government. This image as a green city is also important for heat risk policy. 45% of Berlin's total area consists of either green space or water (Dugord et al. 2014; Chapter 3). Greenery has an important role in evaporative cooling, which makes it an essential part of the response to climate change in urban areas. Because Berlin already has so much green space, the potential adaptive capacity of the city is relatively high (SenStadtUm 2011). This gives the appearance that we are well prepared for climate change here; an opinion which the experts interviewed also shared (Chapter 6). This indicates that the city's image has affected perception of the need for action (Chapter 3; Mahlkow and Kalt, submitted). How well these existing green spaces will retain their function in the future depends primarily on their resilience, i.e., how they can tolerate and adapt to changes in climate (SenStadtUm 2009). That other development concerns and extreme climate changes in the future may hinder or even eliminate the potential for urban greening is rarely discussed (Chapter 6).

The Berlin Senate's 2011 StEP Klima discusses climate adaptation and urban development in terms of the built environment of the city. The interviewees complained that the plan does not contain concrete administrative practice and formal planning tools. Therefore, the StEP Klima KONKRET, adopted in summer 2016, was intended to fill these gaps. Instead of new conceptual information, interviewees claimed they need specific instructions about how to take action on adaptation issues. StEP Klima KONKRET is intended to provide these in-depth guidelines that were requested and to act as a handbook for professional practice in this area. Thus, it should introduce and promote scientific and technical input at all levels.

On the other hand the Senate Department and the district staff have to have the diversity of vulnerability of the citizens in their mind. Our experts are guided for example by the StEP Klima of Berlin. If an area in that plan was not indicated as a hot spot, then no adaptation strategies were implemented for that area. But, a climatic improvement of the property can be done almost everywhere. In order to be able to do so the planners and politicians need to know which important role adaptation strategies can play in order to reduce morbidity and mortality (Kinney et al. 2008; Wolf et al. 2010).

7.5. Outlook and recommendations

This case study of Berlin demonstrates the various barriers that urban planning related to climate change can face within existing administrative structures and how some of these barriers can be overcome. Moser and Luers (2008) have proposed three categories for effective climate change action "awareness, analysis and action". Related to awareness, there is a clear need for an unambiguous delineation of responsibilities and for better coordination among the planners, government officials, and private actors who currently function relatively independently. Furthermore, the analysis of the forces that drive heat policy integration helps define what obstacles these solutions may face. Related to action, discussion and integration of adaptation concerns must be included from the beginning and at all levels of the planning process because local level planning is totally reliant on pre-existing, high level planning guidelines and structure. Thus, the basic assumptions that underlie and shape land-use planning are an important subject (Baker et al. 2012; Moser and Luers 2008).

Analysis of the individual plans and programs that have been adopted to address climate change clarify that urban heat stress is only touched upon in passing, if at all. In Berlin discussion of housing is dominant at all planning levels. During the weighting process, the climatic aspects cannot compete against the pressure from the building sector (Chapter 3 and 5). Berlin must create housing, but not every space should be used for construction. It is also necessary to pay attention to preservation and expansion of the greenery in Berlin.

Landscape planning can play an important role in ensuring high-quality development in inner cities.This means protection against extreme over-crowding, ensuring compensation with free spaces for the built-up area [2]. Therefore, further research is needed to generate manageable climate programs that are able to analyze for building initiative what exactly may happen if a plot is covered by buildings, unsealed, or revegetated with suitable plans. In the future it will be necessary to examine how the environment will affect the project and not how the project impacts the environment (Birkmann and Fleischhauer 2009).

Furthermore, it must be asked whether the comprehensive land-use plan in its current form is losing - or has already lost - its regulatory power (Chapter 5; Othengrafen 2014). A comprehensive land-use plan should provide reliable and consistent guidance for mandatory land-use planning. Considering the uncertain future presented by climate change, this current form of the comprehensive plan seems to be out of date

(Othengrafen 2014; [2]). Experts agree that increasing uncertainty will exacerbate the weaknesses of comprehensive land-use plans and, according to Chapter 5, the time and personnel required to create them may no longer be justified [2, 8, 11]. These experts suggest that comprehensive land-use plans forgo concrete, area-specific determinations of land-uses and focus instead on communicating clear strategies and goals. This would require, however, a re-working of the underlying legal structure.

Further research is needed to examine how the new amendment, StEP Klima KONKRET, from the summer of 2016 will affect the implementation of local plans, especially as related to climate. This includes three areas which need immediate action: urban spaces under particular climate stress, air cooling pathways into and out of the city, and Berlin's forests (SenStadtUm 2016a). The reduced validity of the comprehensive land-use plan in its current form needs more investigation. The Senate Department has initiated several adaptation strategies: the Berlin Energy and Climate Protection Program (2016) and a draft adjustment concept with strategic and activity-based orientations, which is to be implemented within the energy and climate protection program, both not yet adopted [15]. These are promising initiatives but their actual impact on the issues of climate adaptation discussed here will require further investigation.

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7.7. Interviews

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[2] District office Charlottenburg-Wilmersdorf, 11.02.2016

[3] District office Tempelhof-Schöneberg, 16.02.2016

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[5] Planning office 01, 19.02.2016

[6] District office Lichtenberg, 22.02.2016

[7] Architectural association, 25.02.2016

[8] Planning office 02, 25.02.2016

[9] District office Charlottenburg-Wilmersdorf LaPla, 25.02.2016

[10] Senate Department legal examination, 26.02.2016

[11] District office Mitte, 29.02.2016

[12] Nature conservation organisation 01, 16.03.2016

[13] District Council, 06.04.2016

[14] Nature conservation organisation 02, 05.04.2016

[15] Senate Department for Urban Development and the Environment, 06.12.2013

[16] District office Mitte 07.07.2014

A. Author Contribution Statement

Five of the core chapters of this thesis (Chapters 2, 3, 4, 5 and 6) have been developed by the author in cooperation with colleagues and the supervisor of this thesis. The author of the thesis in all five cases has been involved considerably in the conceptual design, research and writing of the five papers. The following sections provide more detailed.

A.1. Chapter 2

The manuscript: "Urban heat - towards adapted German cities? Journal of Environmental Assessment Policy and Management".

The conceptual design and the structure of the paper was developed by the author. The writing was mainly done by the author with additions and support by Juliana M. Müller. Johann Köppel furthermore provided critical feedback and reviewed earlier versions of the paper.

A.2. Chapter 3

The idea and the first version of this paper: "From Planning to Implementation? The Role of Climate Change Adaptation Plans to Tackle Heat Stress - A Case Study of Berlin, Germany" (Journal of Planning Education and Research) was developed by the author with additions of the supervisor Prof. Johann Köppel. Nicole Mahlkow then reviewed, reshaped and rewrote the manuscript. The data collection and analysis for the paper and the revision was conducted by Nicole Mahlkow and the author.

A.3. Chapter 4

The manuscript: "Developing storylines for urban climate governance by using constellation analysis - insights from a case study in Berlin, Germany."

Journal: Urban Climate. Nicole Mahlkow conceptualized, structured and wrote the article with contributions from Prof. Tobia Lakes. The data collection and analysis for this article was mainly done by Nicole Mahlkow with substantial support of the author. Furthermore, the author provided critical feedback throughout the writing process. Prof. Johann Köppel and Prof. Miranda Schreurs revised and proof-read all parts of the paper.

A.4. Chapter 5

The manuscript: "Climate adaptation at the local level: A Bayesian network analysis of local land-use plan implementation" (submitted by Journal of Environmental Assessment Policy and Management).

The conceptual design of the paper was developed by the author. The structure and main content of the paper was developed and written by the author, with additions and support by Nora F. Sprondel. Johann Köppel furthermore provided critical feedback and reviewed earlier versions of the paper.

A.5. Chapter 6

The manuscript: "Urban climate and heat stress: how likely is the implementation of adaptation measures in mid-latitude cities? The case of façade greening analyzed with Bayesian networks" (Journal one Ecosystem).

The manuscript is based on results of Nora F. Sprondel's Bachelor thesis "Urbaner Hitzestress in Berlin - Erfolgswahrscheinlichkeiten von Anpassungsmaßnahmen ermittelt mit Bayesian Networks"; supervised by the author and Johann Köppel. Data collection and analysis for the manuscript has been conducted by Nora F. Sprondel; continuously shaped through feedback and support provided by the supervisors. Major parts of the article were written by Nora F. Sprondel with contributions, revisions and extended information by the author of this thesis.

Nicole Mahlkow then reviewed, restructured and in parts extended the manuscript. Johann Köppel provided critical feedback and reviewed earlier versions of the paper.

B. Curriculum Vitae

Julie Donner is associate researcher at the Environmental Assessment and Planning Research Group at the Berlin Institute of Technology since 2012. Employed in the DFG (German research Foundation) - Research Group 1736 “Urban Climate and Heat Stress in mid-latitude cities in view of climate change (UCaHS)”. She graduated with a degree in Landscape Planning (Diplomingenieurin Landschaftsplanung) from the Berlin Institute of Technology (TU Berlin).

C. List of Publications

C.1. Peer-reviewed articles

Donner, J., Müller, J. M., Köppel, J. (2015). Urban Heat - towards adapted German cities?
Published in: Journal of Environmental Assessment Policy and Management.

Mahlkow, N., Donner, J. (2016). From Planning to Implementation? The Role of Climate Change Adaptation Plans to tackle Heat Stress - A Case Study of Berlin, Germany.
Published in: Journal of Planning Education and Research.

Mahlkow, N., Lakes, T., Donner, J., Köppel, J. (2016). A constellation analysis for developing exploratory and anticipatory storylines for heat stress analysis- insights from a case study in Berlin, Germany,
Published in: Ecology and Society.

Donner, J., Sprondel, N., Köppel, J.(2016). Climate adaptation at the local level: A Bayesian network analysis of local land-use plan implementation.
Submitted to: Journal of Environmental Assessment Policy and Management.

Sprondel, N., Donner, J., Mahlkow, N., Köppel, J. (2016). Urban climate and heat stress: how likely is the implementation of façade greening? Analyzed with Bayesian networks.
Published in: One ecosystem

Sprondel, N., Donner, J., Köppel, J.(2016). Urbaner Hitzestress: Wie wahrscheinlich ist die Implementierung von Klima-Anpassungsmaßnahmen in der Bebauungsplanung?
Published in: Naturschutz und Landschaftsplanung

C.2. Presentations

Donner, J., Köppel, J. (2013). Urban heat stress: Origins and strategies. Conference 33rd Annual Conference of the International Association for Impact Assessment - IAIA13 Impact Assessment: The Next Generation, Calgary, Canada on May 13-16, 2013.

Donner, J., Mahlkow, N. (27. Mai 2014) Shared knowledge- better planning. Constellation Analysis as a tool for local climate adaptation decision making, Urban Regions under Change: towards social-ecological resilience (URC 2014), Hamburg, Deutschland.

Acronyms

°C Centigrade/Grad Celsius.

ha hectare/Hektar.

K Kelvin.

km^2 square kilometre/Quadratkilometer.

m^2 square metre/Quadratmeter.

AFOK Anpassung an die Folgen des Klimawandels/Comprehensive Adaptation Framework Berlin.

app. approximately.

ARL Akademie für Raumforschung und Landesplanung/Regional Studies and Planning Academy.

BAF Biotope Area Factor.

BauGB Baugesetzbuch/German Federal Building Code.

BBSR Bundesinstitut für Bau-, Stadt und Raumforschung/Federal Institute for Research on Building, Urban Affairs and Spatial Development.

BEK Berliner Energie- und Klimaschutzprogramm/Berlin Energy and Climate Mitigation Program.

BfN Bundesamt für Naturschutz/Federal Agency for Nature Conservation.

BGBl Bundesgesetzblatt/Federal Law Gazette.

BIM Berliner Immobilienmanagement/Berlin Real Estate Management.

BImSchG Bundes-Immissionsschutzgesetz/Federal Immission Control Act.

BMBF Bundesministerium für Bildung und Forschung/Federal Ministry of Education and Research.

BMU See BMUB.

BMUB Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit/Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.

BMVBS Bundesministerium für Verkehr, Bau und Stadtentwicklung/Federal Ministry of Transport, Building and Urban Development.

BN Bayesian Network.

CA Constellation Analysis.

cf. conferre/compare.

CO_2 Carbon Dioxide.

COPD Chronic Obstructive Pulmonary Disease.

DAS Deutsche Anpassungsstrategie/German Strategy for Adaptation to Climate Change.

DFG Deutsche Forschungsgemeinschaft/German Research Foundation.

DGNB Deutsche Gesellschaft für Nachhaltiges Bauen/German Sustainable Building Council.

DIN Deutsches Institut für Normung/German Institute for Standardization.

DWD Deutscher Wetterdienst/German Meteorological Service.

e.g. exempli gratia/for example.

EA Environmental Assessment.

EC Europäische Komission/European Commission.

EEA Europäische Umweltagentur/European Environment Agency.

EIA Umweltverträglichkeitsprüfung/Environmental Impact Assessment.

EM-DAT The International Desaster Database.

ERDF Europäischer Fonds für regionale Entwicklung (EFRE)/European Regional Development Fund (ERDF.

ESS Ökosystemdienstleistungen/Ecosystem Services.

et al. et alumni/and others.

etc. et cetera/and so on.

EU Europäische Union/European Union.

EWG Bln Berliner Energiewendegesetz/Energy Transition Act of Berlin.

FLL Forschungsgesellschaft Landschaftsentwicklung und Landschaftsbau/Research Association for Landscape Development and Landscape Construction.

i.a. inter alia/among others.

i.e. id est/that is.

INSM Initiative neue soziale Marktwirtschaft/Initiative new social market economy.

IPCC International Panel on Climate Change.

IW Medien Institut der deutschen Wirtschaft Köln Medien GmbH/Institute for the German Economy Cologne Media GmbH.

LUGV Landesamt für Umwelt, Gesundheit und Verbraucherschutz/Ministry of Environment, Health and Consumer Protection of the Federal State of Brandenburg.

MERIT Management Enterprise Risk Innovation and Teamwork.

NGO Non-Governmental Organisation.

NY New York.

NYC New York City.

PM Particulate Matter.

PNAS Proceedigs of the National Academy of Sciences ofthe United States of America.

Pop. Population.

pp. pages.

ppl. People.

resp. respectively.

RM Research Module.

ROG Raumrdnungsgesetz/German Regional Planning Act.

SEA Strategic Environmental Assessment.

SenGUV Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz/Senate Department for Health, Environment and Consumer Protection.

SenStadtUm Senatsverwaltung für Stadtentwicklung und Umwelt/Senate Department for Urban Development and the Environment.

SIR Salzburger Institut für Raumordnung und Wohnen.

StEP Klima Stadtentwicklungsplan Klima/City Climate Development Plan.

TEEB The Economics of Ecosystems and Biodiversity.

TU Berlin Technische Universität Berlin/Berlin Institute of Technology.

UBA Umweltbundesamt/Federal Environment Office.

UCaHS Urban Climate and Heat Stress in mid-latitude cities in view of climate change.

UK United Kingdom of Great Britain and Northern Ireland.

UN United Nations.

UNEP United Nations Environment Programme.

URC Urban Regions under Change.

USA United States of America.

UVP Umweltverträglichkeitsprüfung/Environmental Impact Assessment (EIA).

WHG Wasserhaushaltsgesetz/German Federal Water Act.

WTO World Trade Organization.

List of Figures

List of Tables