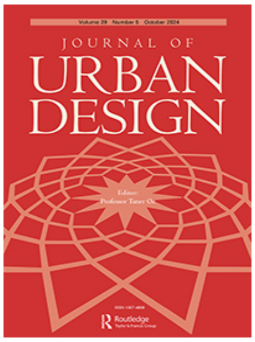

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Implementation of urban climate-responsive design strategies: an international overview

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ABSTRACT

Urban climatic challenges can motivate urban planners and designers to implement urban climate-responsive design strategies. But does this process occur sufficiently, and if not, why? This study explores the implementation of urban climate-responsive design strategies, potential functional and aesthetic conflicts, availability of policy instruments that support implementation, strengths and weaknesses, and missed opportunities for integrating agendas. Semi-structured interviews were conducted with experts familiar with urban climate-responsive design. The results suggest that greening measures are most often implemented, strategies tend to compete with other land-uses, designers face aesthetic conflicts, and strategies are predominantly mainstreamed within existing policy instruments.

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Urban heat; urban climate; urban design; urban planning; policy instruments

Introduction

Urban areas exhibit distinctive microclimatic conditions that emerge as a function of their form and materiality across many scales. Design decisions about urban form can affect the urban energy balance and influence these microclimatic conditions, which generally differ from those in non-urban landscapes (Oke et al. 2017). As a result, urban planners and designers make important decisions that influence urban morphology, density, roughness, and frequency and distribution of parks and water bodies. For example, the structure of parks, squares and streets governs factors such as sunlight and shade access, heat accumulation, wind nuisance, downwash, wind channelling effects and ventilation (Blocken and Carmeliet 2004; Lenzholzer and van der Wulp 2010; Nugroho, Triyadi, and Wonorahardjo 2022; Speak and Salbitano 2022). Further, urban surface materials exhibit a range of thermal characteristics, including reflectivity, absorptivity, conductivity, and emissivity (Oke et al. 2017; Taleghani et al. 2021; Taylor 2016). Finally, urban density and roughness, and presence or absence of green structures influence relative humidity, air

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temperature, wind and ventilation (Aniello et al. 1995; He, Ding, and Prasad 2020; Chapman et al. 2018; Stone and Rodgers 2001).

When the urban climatic effects of heat and wind are not carefully considered, challenges can arise from thermal discomfort, nuisance and avoidance of places to heat stress and heat-related fatalities (Brown 2010; Larsen 2006; Lenzholzer and Koh 2010; Sandholz et al. 2021; Steeneveld et al. 2011; Tan et al. 2010; Vasilikou and Nikolopoulou 2019). In addition, climate change is expected to intensify these challenges (Li and Bou-Zeid 2013), which include changing and shifting climate zones (Beck et al. 2018; Bastin et al. 2019), and an increase in the frequency and duration of heat and drought periods (IPCC 2018). Thus, addressing and reducing the effects of climate change requires expertise about how to adapt cities and improve urban climatic conditions all over the world.

In response, urban climate-responsive design strategies have been developed at a range of scales to address factors such as wind speed, longwave (heat) and shortwave (solar) radiation, air temperature, relative humidity, and human perception of surroundings (Lenzholzer et al. 2020a). For example, at smaller scales, the strategic use of materials for walls, roofs, pavement and other outdoor elements can mitigate daytime heat accumulation (Herath et al. 2021; Takebayashi and Moriyama 2007). At urban block and street scales, strategically designed urban configurations, including parks and streetscapes, can increase access to sun and shade, contribute to networks of cool routes, facilitate ventilation and reduce wind nuisance (Brown et al. 2015; Jamei et al. 2016; Kleerekoper 2016; Klemm 2018; Klemm, Heusinkveld, Lenzholzer, and van Hove 2015; Merlier et al. 2018; Ng et al. 2011). And at neighbourhood, city and regional scales, ventilation corridors and sufficient number of green areas can be designed to facilitate evaporative cooling and reduce heat during the day, while open spaces can provide cooling at night (Chatzipoulka and Nikolopoulou 2018; He, Ding, and Prasad 2020; Oke et al. 2017; Wong et al. 2010). Further, human perception of urban climate can be influenced by the strategic use of colour, vegetation and material textures (Cortesão, Brandão Alves, and Raaphorst 2020; Klemm, Heusinkveld, Lenzholzer, Jacobs, et al. 2015; Lenzholzer and van der Wulp 2010; Nikolopoulou and Steemers 2003; Tsushima et al. 2020).

For decades, researchers have articulated urban climate phenomena and available urban climate-responsive design strategies in handbooks tailored for both urban design professionals and lay people (Brown 2010; Brown and Gillespie 1995; Erell, Pearlmutter, and Williamson 2011; Lenzholzer 2015), and expertise about urban climate-responsive design strategies has been introduced in educational settings (Lenzholzer and Brown 2013) and shared on publicly-accessible digital platforms (Ennos 2015). Within the urban climate-responsive design field, a rich body of expertise is available to guide urban designers and planners in implementing urban climate-responsive design strategies. Recently, Lenzholzer et al. (2020b; 2020b) found an increased international awareness and sense of urgency regarding urban climate processes and the need to implement urban climate-responsive design strategies.

Research from the fields of water adaptation and climate change mitigation suggested that new agendas can be instrumentalized within policies by following *mainstreaming* or *dedicated* approaches (Reckien et al. 2019; Runhaar et al. 2018; Uittenbroek, Janssen-Jansen, and Runhaar 2013; Wamsler and Brink 2014). *Mainstreaming approaches* typically focus on incorporating agendas with objectives, identifying synergies in decision-making processes, and steering efforts towards the implementation of integrated solutions

(Uittenbroek, Janssen-Jansen, and Runhaar 2013). Generally, these approaches require institutional entrepreneurs to integrate measures within policies, which are often performance-based and can be erratic or deliberate (Uittenbroek et al. 2014). By contrast, *dedicated approaches* concern single-focus stand-alone policy instruments and measures (Runhaar et al. 2018; Uittenbroek et al. 2014) that are typically indicated by direct political commitments or agendas. Here, the objective is the implementation of measures, which tend to be compliance based, relatively fast and effective, and managed through dedicated government departments and policies.

Although research has been done on the global implementation of climate adaptation strategies (Araos et al. 2016; Aylett 2015; Eliasson 2000; Parsaee et al. 2019; Williams et al. 2021), in the field of urban climate-responsive design it remains unclear which of these strategies are being implemented and which policy instruments are being used to support them. Therefore, the objective of this study is to explore: (1) which urban climate-responsive design strategies are being implemented by urban planners and designers, (2) which functional or aesthetic conflicts are being experienced by urban planners and designers, (3) which legally- and non-legally binding policy instruments (i.e., mainstreaming or dedicated) are being used to implement urban climate-responsive design strategies, (4) which strengths and weaknesses have been observed within these measures and instruments, and (5) which opportunities and potentials for synergies with other type of functions or agendas are being missed.

Methods

This research is part of a larger cross-sectional study that was conducted between 2015–2017 to investigate the degree of awareness and urgency regarding implementation of urban climate-responsive design strategies in several countries worldwide (see Lenzholzer et al. 2020a, 2020b). The current study explored the implementation and instrumentalization of urban climate-responsive design strategies in the field of urban planning and design.

Semi-structured interviews were conducted with 93 urban planning and design experts. Participants included 31 urban designers and landscape architects, 32 urban climate and sustainability specialists, and 30 urban planners and governance experts (see Table 1). At the time of these interviews, the participants were affiliated with organizations such as urban design and landscape architecture firms, scientific institutions, government agencies, business consultancies or NGOs. Based on their professional or academic backgrounds, these experts were considered well-informed about how their respective nations or regions have historically adapted to local climate and landscape conditions, about their future landscape-related challenges, and about the implementation of urban climate-responsive design strategies within their respective countries. All

Table 1. Backgrounds of interviewees.

Background	Academics	Business/NGO	Government	total
Urban design/landscape architecture	10	14	7	31
Urban climate/sustainability	13	6	13	32
Urban planning/governance/other	8	11	11	30
Total	31	31	31	**93**

participants were based in countries in which the implementation of urban climate-responsive design strategies is considered relevant (Beck et al. 2018; IPCC 2018): Belgium, Bulgaria, China, Germany, Indonesia, Kenya, the Netherlands, New Zealand, and South Korea. These countries lie within three Köppen climate classification zones (Beck et al. 2018; Kottek et al. 2006), namely Zone A: Equatorial Climates (Indonesia, Kenya); Zone C: Warm Temperate Climates (Belgium, Bulgaria, Germany, Netherlands, New Zealand); and Zone D: Snow Climates (South Korea). While China spans several climate zones, 90% of the Chinese participants were based in Zone C. Together, these countries represent the climate zones that include most of the global population.

A non-random sampling plan was applied for selecting participants using convenience samples of experts within the researchers' professional networks. Semi-structured interviews were conducted by colleagues and students who spoke the language of the respective participants. Following the study objectives, interviewees were asked eleven open-ended questions (see Table 2) regarding the implementation of urban climate-responsive design strategies, the observed functional or aesthetic conflicts, the availability of legally binding or non-legally binding policy instruments used for implementing strategies, the strengths and weaknesses of these strategies and policy instruments, and the potential for synergies with other types of measures and instruments.

All responses were transcribed and ordinally and descriptively coded in ATLAS.ti software using a coding scheme of variables linked to the interview questions.[1] These variables included urban climate parameters (e.g., radiation, evaporation, wind, ventilation, sun or shade) and type of urban climate-responsive design strategies as described in the urban climate literature. To investigate the scales to which these strategies apply, each strategy was coded according to the urban climate typologies described by Oke et al. (2017): facet (e.g., wall or roof), element (e.g., building or tree), block (e.g., building block or park), canyon (e.g., street or canal), neighbourhood, city, and urban region. To code policy instruments, a distinction was made between

Table 2. List of interview questions.

Question	focus: implemented urban climate-responsive design strategies
1	Which concrete urban climate adaptation measures/interventions are currently being implemented or have been implemented in your country?
2	What are the strengths and weaknesses of these mentioned urban climate measures/interventions?
3	Do conflicts between aesthetics and these mentioned urban climate adaptation measures exist?
4	Do conflicts between urban functions and these mentioned urban climate adaptation measures exist?
5	Are certain chances/potentials (e.g., coupling with other interventions/'no regret' measures) missed when implementing these mentioned urban climate adaptation measures before?
	focus: legally binding policy instruments for implementing urban climate-responsive design strategies
6	Are legally binding instruments (e.g., zoning plans) used to implement urban climate adaptation measures? If YES, please explain how they work?
7	What are the strengths and weaknesses of the legally binding instruments used?
8	Are certain chances/potentials missed when using the legally binding mentioned instruments (e.g., coupling with other instruments)?
	focus: non-legally binding policy instruments for implementing urban climate-responsive design strategies
9	Are other policy instruments used to implement urban climate adaptation measures? If YES, please explain how they work?
10	What are the strengths and weaknesses of the other policy instruments used?
11	Are certain chances/potentials missed when using other policy instruments (e.g., coupling with other policies)?

governmental level (i.e., national, provincial, local and municipal), legally binding or non-legally binding instrument, and type of implementation approach (i.e., mainstreaming or dedicated). After the initial analysis of the interview data was complete, additional codes were added to strengthen the coding scheme.

Results and discussion

This section presents and discusses the data analysis results. The first part focuses on the implementation of urban climate-responsive design strategies, followed by the legally binding policy instruments used to implement strategies, and finally the non-legally binding policy instruments used to implement strategies. For each part the main findings are discussed.

Overview of implemented urban climate-responsive design strategies

Interviewees were asked about what urban climate-responsive design strategies are being implemented in their country. The results (see Table 3) show that for all countries, participants reported that strategies are generally being implemented at small scales (i.e., facet, element, block and canyon) but rarely at larger scales (i.e., neighbourhood, city and urban region). Most countries apply greening measures, predominantly at the facet, element, canyon and block scales, such as green walls, green roofs, green streets, tree planting programmes, parks and gardens. In China, Kenya, New Zealand and South Korea, participants reported that building materials and surface textures are selected to reduce radiation and prevent heat accumulation. Only a few countries apply strategies that focus on sun and shade, evaporation, ventilation, wind and emergency warning systems. In particular, Germany implements ventilation strategies from the facet to neighbourhood scale.

These results suggest that the implementation of urban greening strategies has become the dominant method used by urban planners and designers to address urban climate challenges. However, a sole focus on greening can be a cause of concern when other types of strategies are not implemented. For example, when not carefully considered, greening strategies can affect other urban climate-responsive design, such as when trees obstruct ventilation or limit nocturnal cooling (Klemm 2018; Erlwein, Zölch, and Pauleit 2021). In such cases, it is important to focus on additional strategies, such as those based on urban geometries, skyview factors, sun and shade access, materiality, ventilation and evaporation. The absence of applying combinations of strategies at various scales confirms that urban climate-responsive design strategies are not consistently implemented within climate adaptation (Aylett 2015; Eliasson 2000; Hebbert 2014). Further efforts should be made to strategically align the diverse set of urban climate-responsive design strategies from large to small scale in urban planning and design (Gunawardena, Wells, and Kershaw 2017; Klemm 2018; Norton et al. 2015). For example, participants rarely identified measures that focus on wind and shade at the facet and element level and legally binding wind ordinances were not identified at all. This might be due to the fact that some interviewees live in countries for which wind protection ordinances are either non-existent or follow wind protection guidelines (e.g., Dutch NEN norm 8100) that are not obligatory (Blocken and Carmeliet 2004).

Table 3. Overview of implemented urban climate-responsive design strategies per scale and country.

country	strategy	facet (roof, wall, road, leaf, lawn, pond)	element (residential building, high-rise, warehouse, tree)	block (city block, factory, park, wood, storage pond)	canyon (street, canyon, line of street trees/ gardens, river, canal)	neighbourhood (city centre, residential quarter, industrial zone, greenbelt, forest, lake, swamp)	city (built-up area, complete urban forest)	urban region (city plus surrounding countryside)
Belgium	*greening*	green wall, green roofs, garden, urban agriculture		parks	green-blue axes			
	not specific				limiting car space, create living streets			
Bulgaria	*evaporation*	irrigation system						
China	*greening*	rain water gathering for urban green	urban green constructions, tree planting programme	urban greening				
	influencing radiation	materials for roof and façade, energy conservation measures aiming at urban climate, light colors						
	slowing or avoiding wind		consider wind in architectural style					
	not specific		adjusting industrial structures, bionic architecture	urban design				
Germany	*greening*	green roofs, façades, green gardens, free plants, unsealing surfaces	tree planting programmes	urban greening, green courtyards, parks	green streets	green wastelands		
	ventilation	surface texture	orientation of building mass, building heights	building densities	ventilation aisle	ventilation corridor, building densities		

(*Continued*)

Table 3. (Continued).

country	strategy	facet (roof, wall, road, leaf, lawn, pond)	element (residential building, high-rise, warehouse, tree)	block (city block, factory, park, wood, storage pond)	canyon (street, canyon, line of street trees/ gardens, river, canal)	neighbourhood (city centre, residential quarter, industrial zone, greenbelt, forest, lake, swamp)	city (built-up area, complete urban forest)	urban region (city plus surrounding countryside)
	access to sun and shade		planting trees for shadow					
Indonesia	*greening*	open space, gardens	green buildings	urban greening programmes				
Kenya	*greening*	urban agriculture	tree planting programmes		tree planting along streets, reduce mobility			
	influencing radiation	materials for walls and roofs	building according to traditional architecture					
	ventilation		building according to traditional architecture					
	access to sun and shade		shade next to building					
Netherlands	*greening*	green roof, roof park, unpaving areas		urban greening, cooling park				
	(moving) water				moving water			
	slowing or avoiding wind		wind screens					

(*Continued*)

Table 3. (Continued).

country	strategy	facet (roof, wall, road, leaf, lawn, pond)	element (residential building, high-rise, warehouse, tree)	block (city block, factory, park, wood, storage pond)	canyon (street, canyon, line of street trees/ gardens, river, canal)	neighbourhood (city centre, residential quarter, industrial zone, greenbelt, forest, lake, swamp)	city (built-up area, complete urban forest)	urban region (city plus surrounding countryside)
New Zealand	*greening*	planting programmes						
	influencing radiation	apply materials with less thermal mass, permeable surfaces						
	slowing or avoiding wind			wind reduction		wind reduction		
	not specific		building height, building offsets, sustainable building	encouragement of outdoor areas within developments				
South Korea	*greening*	green roofs		urban greening, green spaces				
	evaporation		fog and misting systems					
	influencing radiation	material use						
	access to sun and shade	urban vegetation						
	warning system		alert system, emergency medical care, temporary shelters					

Strengths and weaknesses of implemented urban climate-responsive design strategies

Interviewees were asked about the observed strengths and weaknesses of urban climate-responsive design strategies implemented in their respective countries (see Table 4). The results suggest that implementation of urban greening measures can support user participation, as people tend to easily relate to greening. Further, small measures can often produce large effects, and thus be positive investments that help to create awareness and thus further implementation. But these measures can also exhibit weaknesses, such as when they are not part of integrated plans, are too fragmented or small, are symbolic, or serve wealthy residents only. As one participant stated: *'In new urban areas, urban climate adaptation is taken into account much more, but that is costly and leads to gentrification'*. (Urban designer/landscape architect; Belgium). Interviewees also referred to cases in which measures may not reach their full potential due to low understanding or poor implementation, such as incorrectly installed green walls, unsuitable plantings, or technical challenges which are faced when measures are installed on existing buildings. Finally, participants reported that these measures can be expensive, may only realize desired effects over the long term. Greening measures can even cause nuisances, as when they are poorly maintained, produce litter, or contribute to fire hazards or allergies.

The results suggest that the availability of simple and affordable measures seems to be a precondition to supporting broader implementations. A step towards urban greening seems logical if users have a basic knowledge about greening (Aalbers and Sehested 2018). In addition, implemented measures seem to be considered more effective when they are part of long-term strategies and integrated plans, which suggests the need to combine urban climate-responsive design strategies within urban design and planning policies at various scales (Klemm 2018). Only a few interviewees identified the potential risk of

Table 4. Overview of observed strengths and weaknesses of implemented urban climate-responsive design strategies.

Cover term	Answers by interviewees	Country
Strengths		
User participation	Urban greening is participative	CN, KE
	Measures are child friendly	BE
	Measures increase motivation to deal with sustainability	KR
Long term impact	Many small interventions have much effect	NL, KE
	Measures are considered a strong investment on the long term	NL
Knowledge gain	Measures support learning and improved recommendations	ID, KE
Weaknesses		
Missing integrality	Interventions are fragmented or too small	BE, KE, NL
	Effects happen on long term	BE, NL
	Possible risk of gentrification	BE
	Interventions are symbolic	NZ
	Technical challenges to instal measures	DE, KE, NZ
Technical challenges	Incorrect installation	NZ, KE
	No attention given to details	CN
Costs	Installation costs	BE, ID, KE
	Maintenance	NL, KR
Lack of understanding	Public misunderstanding	CN, KE, NL
Nuisance	Nuisance (e.g., falling leaves, fire hazard, allergies, poor maintenance)	KE, KR

Belgium (BE), Bulgaria (BG), China (CN), Germany (DE), Indonesia (ID), Kenya (KE), Netherlands (NL), New Zealand (NZ), South Korea (KR).

gentrification. Within integrated planning approaches, the availability of urban climate-responsive design strategies should be considered in terms of division of wealth and inequality at the urban scale (Dialesandro et al. 2021; Mashhoodi 2021).

Aesthetic conflicts with urban climate-responsive design strategies

The hypothesis arose that the implementation of urban climate-responsive design strategies could be hampered by aesthetic preferences of planners, designers or the public. Hence, the interviewees were asked if conflicts exist between aesthetic preferences and urban climate-responsive design strategies. The results suggest that citizens often consider greening to be positive and beautiful (Belgium, Indonesia, Kenya, Netherlands, South Korea), but also that users sometimes find functionality more important than beauty (Kenya). In addition, urban climate-responsive design strategies may conflict with the urban identity (Bulgaria, Germany), the historical value of monuments and structures (Germany, Netherlands), and UNESCO World Heritage values (Belgium). Interviewees indicated that designers should play a role in preventing aesthetic conflicts (Belgium, Germany, Kenya, New Zealand), but in many countries designers themselves have ideas about beauty which conflict with urban climate-responsive design strategies. Architects and urban designers follow conventional design ideas that cannot be combined with urban climate-responsive design strategies (Netherlands, New Zealand, South Korea). According to some responses, designers do not necessarily appreciate green walls (Belgium) or tend to reject urban climate-responsive design strategies that do not meet their taste (Netherlands). Also, local urban design traditions are not always compatible with urban climate-responsive design strategies. As one interviewee stated, '*Sometimes, local urban design traditions are not optimally fitted to future challenges*'. (Academic; Netherlands).

These results suggest that aesthetic conflicts faced by urban planners and designers can be an important barrier to implement urban climate-responsive design strategies. This barrier exists despite an awareness among urban planners and designers of urban climate phenomena and having a sense of urgency to adapt (Lenzholzer et al. 2020b), and despite understanding urban climate-responsive design strategies (Lenzholzer et al. 2020a). The dominance of aesthetic preferences and urban design traditions might have a foothold in the globally widespread modern Western aesthetic discourse which tends to favour visual experience and formal composition (Koh 2013; Saito 2012).

Conflicts between urban climate-responsive design strategies and other urban functions

Interviewees were also asked about conflicts that arise between urban climate-responsive design strategies and other types of urban functions. Some participants stated that implementation of strategies can increase competition for space and intensify conflicts. Here, implementation of strategies mainly conflicts with car parking and transport infrastructure (Belgium, Germany, Kenya, Netherlands), but also with urban functions such as housing, water, and commercial space (Germany). Sometimes, underground infrastructure also restricts the implementation of strategies aboveground (Netherlands). Further, green measures can obstruct daylight in homes (Belgium, South Korea), shade solar panels (Belgium), obstruct ventilation (Netherlands), and contribute to a sense of social insecurity (Belgium, Netherlands). Interviewees stated it is always a matter of considering diverse interests (Belgium, Germany, Kenya, South Korea). In Bulgaria, China, and New Zealand interviewees did not report conflicts.

These results suggest that urban climate-responsive design strategies often compete with other urban functions and land uses, primarily car and transport infrastructure. The priority given to car mobility seems to confirm the dominance of mainstream car mobility thinking (Brömmelstroet et al. 2022; Gössling 2020). To overcome experienced conflicts and be able to develop alternative solutions urban planners and designers should understand the processes that shape urban climatic conditions.

Opportunities for integrating urban climate-responsive design strategies with other types of functions

Interviewees were asked which chances and potentials for integrating urban climate-responsive design interventions with other urban functions are missed when implementing strategies. First, some interviewees noted that these strategies often provide multiple benefits, such as enhancing biodiversity and water management (Netherlands), health (Germany, South Korea), community building (Kenya, Netherlands), and air pollution mitigation (China). However, opportunities can also be missed when strategies are required to be integrated within projects (Belgium, Germany, Kenya, Netherlands, South Korea), and a strategic approach must be applied (Belgium). Only a few suggestions for integrating urban climate interventions with other functions were given, such as nature restoration (Bulgaria), energy measures, and recreation (Kenya).

These results suggest that while opportunities for integrating urban climate-responsive design strategies with other urban functions exist, opportunities for their integration are often missed. One explanation for the limited number of respondent examples of integration could be the relative novelty of urban climate-responsive design, as implementation of new strategies requires cultural transitions and systemic changes that require time (Geels and Schot 2007). However, external landscape developments can pressure existing systems and create 'windows of opportunity' to implement 'niche-innovations' (Baldwin and Ross 2020; Bradford and Bell 2017; Geels and Schot 2007). For the urban climate-responsive design field, extreme natural processes and weather events might create (new) windows of opportunity to implement available urban climate-responsive design strategies, and support the implementation of integrated measures. As politicians are motivated by internal goals when advancing climate change agendas (Anguelovski and Ann Carmin 2011), it is worth exploring how these strategies can be tailored to local agendas, such as those relating to housing, mobility, health, community building, energy, water management, biodiversity and urban agriculture.

Instrumentalization of urban climate-adaptive design strategies within legally binding policy instruments

Interviewees were asked if legally binding policy instruments were used to support urban climate-responsive design strategies. Here, a distinction was made between policy instruments in which strategies are mainstreamed, and policy instruments that are dedicated to strategy implementation (see Table 5). The results suggest that many countries focus on

Table 5. Overview legally binding policy instruments used for implementing urban climate-responsive design strategies.

	instrument	national government	provincial government	municipal/city government
Belgium	*mainstreaming*	Building regulations (contains rules about light albedo materials and green roofs)	Building codes (contains rules about green roofs for new buildings and renovations)	Acts (which takes interventions regarding urban climate into account)
	dedicated			
Bulgaria	*mainstreaming*			Overall spatial planning plans, development plans, urban zoning plans (mostly in major cities)
	dedicated			
China	*mainstreaming*	National Plan on Climate Change (2014–2020), Urban and Rural Planning Law		
	dedicated			regulations
Germany	*mainstreaming*		Landscape plan (in some federal states)	
	dedicated			
Indonesia	*mainstreaming*	National Action Plan for Climate Change Adaptation (RAN-API or RAD), building regulations (only for governmental buildings)		
	dedicated			
Kenya	*mainstreaming*	Building code, National Climate Change Strategy, Environmental acts (Physical Planning Act, National Urban and Cities Act, Environmental Management and Coordination Act, Climate Change Act, Forest Act, NDMA Act)		Masterplan (e.g., Nairobi), Integrated strategic plans (for some towns), zoning plans, zoning by-laws (varies for each county), development control regulations
	dedicated			
Netherlands	*mainstreaming*	Tree felling restrictions		
	dedicated			
New Zealand	*mainstreaming*	Building codes, Resource Management Act (requires goverments to consider effects of climate change on projects)		Building consent approvals
	dedicated			Offsets for shading
South Korea	*mainstreaming*	National Comprehensive Plan for Climate Change Adaptation (support for green growth)		Environmental Planning Regulations (for developers to build green buildings or set aside green space in new developments)
	dedicated			

mainstreaming urban climate-responsive design strategies within existing policy instruments, with significantly less effort made on developing dedicated policy instruments. Mainstreaming primarily occurs at the national and local/municipal levels, in Belgium and Germany it is also seen at the provincial level. The results also suggest that across all countries and governmental levels, a broad diversity exists in the types of instruments used to mainstream strategies, including national action plans and planning regulations, landscape, structural and zoning plans, and building standards and codes. Finally, dedicated policy instruments are rarely used to implement strategies, as only New Zealand uses legally binding conditions about shading offsets. Legally binding wind studies also did not appear in the results.

These results suggest that there is as yet little to no consistent application of legally binding policy instruments for implementing urban climate-responsive design strategies, which supports previous findings (Aylett 2015; Eliasson 2000; Hebbert 2014). In this respect, the implementation of urban climate-responsive design strategies does not differ much from the inconsistent way in which adaptation strategies are implemented within policy instruments in the fields of climate mitigation and water adaptation (Anguelovski and Ann Carmin 2011). Further, because urban heat-related fatalities are individual silent disasters, there is little point in developing legally binding instruments for urban climate-responsive design that focus on disaster recovery, such as with forest fires or urban flooding. Instead, the prime focus of legally binding instruments should be on preventing silent disasters to happen. Many ways exist in which strategies can be incorporated into legally binding policy instruments. For example, strategies and measures could be mainstreamed within existing instruments, such as urban structure or zoning plans, and dedicated instruments can be developed, such as those that require modelling and analysis of urban climatic conditions for new plans. However, our results suggest that strategies are not yet sufficiently implemented in legally binding instruments, and that room for further action to be taken remains. A broad range of formal and informal tools are available for this purpose (Carmona 2017). Formal tools can guide, create incentives, or control these processes, and informal tools can enhance knowledge, promote, evaluate, assist and provide evidence for them. Finally, while urban planners can make better use of the full spectrum of these formal and informal tools, the ways in which formal and informal tools are combined and used should align with applicable cultural and geographical contexts.

Strengths and weaknesses of legally binding policy instruments

Interviewees were asked about the observed strengths and weaknesses of legally binding policy instruments used to implement urban climate-responsive design strategies. Participants identified a few strengths and many weaknesses (see Table 6). Respondents stated that legally binding policy instruments are considered effective, as they cannot be ignored and apply to everyone. For example, in Kenya and South Korea, national-level instruments are considered strong, as they tend to devolve power to lower governmental levels. However, instruments can also be ineffective in several ways. Instruments that are non-specific and lack detailed information about strategies and the local urban climate can hinder implementation of measures. As one participant reported, '*. . . the prerequisite of enacting policies is urban climate research and basic climate data*'. (Academic; China).

Table 6. Overview strengths and weaknesses of legally binding policy instruments.

Cover term	Answers by interviewees	Country
Strengths		
Binding effect	Binding instruments apply to everyone	BE, DE, KE, NL
Devolution power	Devolution of national laws to lower governments	KE, SK
Weaknesses		
Unspecific information	Detailed information is missing	CN, DE, ID, KE
	Data is not matching the project	BE, NL, KR
	Climate data is outdated	NZ
	Instruments are not showing best practice	NZ
Insufficient policy coordination	Overlap between departments	KE, KR
	Spread of responsible officials	BE
	Administrative burdens	BE
	Stakeholders do not collaborate well	DE
	Laws conflict	KE
Insufficient enforcement of law	Further guidance is lacking	KE, ID
	Lacking commitment to implement	ID
	Rules are not considered binding	CN
	Difficult to enforce	DE
Public participation	Missing opportunities for public participation	DE
	Participatory procedures hinder implementation	NL

Belgium (BE), Bulgaria (BG), China (CN), Germany (DE), Indonesia (ID), Kenya (KE), Netherlands (NL), New Zealand (NZ), South Korea (KR).

Further, the urban climate data applied within legal policy instruments is often too general or outdated, or sometimes too detailed and therefore inflexible. As another interviewee stated, *'Inflexible instruments might hold back innovation and investments'*. (Urban climate expert; Germany). In addition, within governmental organizations and planning procedures a lack of coordination or inadequate enforcement of laws can weaken these instruments. Finally, regulations are meaningless when they are not considered binding by the public and officials, or as one interviewee reported, '*legally binding requirements are useless if there is no supervision or follow up on building developers*'. (Policymaker; Kenya).

These results suggest that a focus on general standards and universal principles alone is insufficient in implementing urban climate-responsive design strategies, and that instruments become more effective when methods are offered to assist planners and designers in implementing context-driven urban climate-responsive strategies (Scherer et al. 1999). Thus, policy instruments should be explicit and specific, while remaining open and flexible enough to allow incorporation with other local agendas. Moreover, to support enforcement, governments should invest in policy instruments that focus on consumer, private sector, and government participation in urban projects (Ten Brinke et al. 2022). However, additional research is required on how to encourage and enforce the adoption of urban climate-responsive design strategies across different countries.

Missed opportunities in legally binding policy instruments used for implementing urban climate-responsive design strategies

Interviewees were asked about missed opportunities regarding the use of legally binding policy instruments in their respective countries. The results suggest that while many instruments exist that can be used to implement these strategies, such as national standards, building standards, regional structure plans, urban

Table 7. Existing legally binding policy instruments that can be used to implement urban climate-responsive design strategies.

	national government	provincial government	municipal/city government
Belgium	National building regulations	Structure plan, building code	Structure plans, zoning plans (to apply local rules or to address green elements), design rules (to address use of materials or green walls)
Bulgaria			
China			
Germany	Code of Construction Law (BauGB determines the procedures for urban development planning)		Land utilization plan (Flächennutzungsplan), urban development plan (Bebauungsplan), urbanistic contracts, communal plans, statutes
Indonesia	Buildings regulations (KDB, KLB d11)		Zoning plan (RDTR)
Kenya			Urban development policy, strategic plan, zoning plan, building codes
Netherlands			Zoning plan
New Zealand			
South Korea			

development plans, district plans, zoning plans and design codes (see Table 7), they often remain unused. According to one Dutch interviewee, governments could show more ambition in leveraging these opportunities: *'Dutch municipalities are not proactive and don't implement urban climate in zoning plans, although they could'*. (Academic; Netherlands). Moreover, opportunities are sometimes missed in implementing measures within urban planning procedures themselves. For example, some interviewees reported that urban climate experts could be involved earlier in the development of urban plans (Netherlands, South Korea), and project boundaries could be extended beyond site limits to better consider urban climate processes (Netherlands). Public participation in urban planning procedures could be increased (Germany, South Korea), and an educational approach could be provided to help reduce public resistance (Kenya). Finally, some interviewees suggested that greater synergies with other policy fields could be achieved, such as climate mitigation and mobility (Belgium), flood-responsive design and urban forestry (Kenya), and public health (South Korea).

These results suggest that opportunities are often missed within available legal policy instruments and urban planning procedures in implementing urban climate-responsive design strategies. Only a few suggestions for synergies with other policy fields were reported, which was surprising given the range of potential options for incorporating strategies. One explanation for this finding could be that urban planners and designers remain insufficiently aware of the nature of the processes that govern urban climates (Lenzholzer et al. 2020b). Given the urgency to implement urban climate-responsive design strategies (IPCC 2018), the implementation of legally binding strategies in planning instruments should be effective and direct. However, far-reaching mainstreaming of strategies requires institutional entrepreneurs (Uittenbroek et al. 2014) who understand urban climate-responsive design. For example, chances for mainstreaming exist with the policy fields of biodiversity, water management, health, energy, food security, liveability, urban agriculture, economics, disaster infrastructure, housing and mobility (Boezeman and de Vries 2019; Endlicher and Lanfer 2003; Kolbe 2019; Lee and Won Kim 2018; Pitman, Daniels, and Ely 2015). Finally, all nations should investigate how strategies could be mainstreamed within planning policies, as the most effective approach for bridging different levels of government requires attention to national governing structures (Bauer and Steurer 2014).

Instrumentalization of urban climate-responsive design strategies within non-legally binding policy instruments

Interviewees were asked if non-legally binding policy instruments were used to implement urban climate-responsive design strategies. Here, a distinction was made between instruments in which strategies are mainstreamed and instruments that are dedicated to strategy implementation (see Table 8). In Bulgaria, China and Indonesia, interviewees reported that they were largely unaware of the availability of non-legally binding policy instruments for implementing strategies. The results also suggest that in other countries within local governments many types of policy instruments are used to mainstream strategies, such as long-term vision plans, public space programmes, reward and incentive initiatives, and funds for greening walls and roofs. Among the responses, Germany was identified as the only country with national level subsidies, funds and tax programmes. Moreover, strategies are also included in instruments developed to support or guide architects and urban designers in the design process, such as those articulated for strategic visions, spatial quality plans, urban design regulations, evaluation tools, design principles, green building ordinances, and greening workshops.

Urban climate-responsive design strategies are being articulated in instruments such as guides, design principles and workshops that support the design process. However, the results did not reveal the use of instruments to assist urban designers with measuring and modelling design alternatives. This is important, as the implementation of urban climate-responsive design strategies requires the use of discrete methods, including the use of climate maps and assessment procedures (Cortesão et al. 2016; Scherer et al. 1999). Here, the presence of policy instruments to provide financial support on a national scale confirms that Germany remains a frontrunner in urban climate-responsive design (Hebbert 2014). Within Belgium, Germany, the Netherlands and South Korea, the availability of policy instruments to provide financial support for urban greening at building level indicates a first response to a sense of urgency to adapt (Lenzholzer et al. 2020b). However, a focus on financial support for urban greening might take attention away from other design strategies to improve urban climatic conditions, such as adaptations that address anthropogenic heat, wind, ventilation, evaporation, radiation, or ambience (Brown 2010; Lenzholzer and van der Wulp 2010). To encourage further implementation of measures, it is necessary for each country to investigate how to combine non-legally binding with legally binding instruments, depending of course on national and local planning frameworks and traditions that rely on either formal or informal tools (Carmona 2017).

Strengths and weaknesses of non-legally binding policy instruments used for implementing urban climate-responsive design strategies

Interviewees were asked about strengths and weaknesses they have observed within non-legally binding policy instruments used for implementing urban climate-

Table 8. Overview non-legally binding policy instruments used to implement urban climate-responsive design strategies.

	instrument	national government	provincial government	municipal/city government
Belgium	*mainstreaming*			Sustainability evaluation tool for building projects (Duurzaamheidsmeter), reward programme, subsidies, stimulation programmes (for green walls/green tramway tracks)
	dedicated			Expert studies (wind nuisance)
Bulgaria	*mainstreaming*			
	dedicated			
China	*mainstreaming*	Evaluation standard for green buildings		
	dedicated			
Germany	*mainstreaming*	Financial instrument (indirect incentive by saving costs, less taxes), subsidies or bonus (for implementing adaptation measures by private individuals, investors or local governments)		Tender document (adaptation measures are given as design conditions), workshops (for urban greening)
	dedicated			
Indonesia	*mainstreaming*			Green City Development Programme, green building certificate
	dedicated			
Kenya	*mainstreaming*	Architectural association (approvement and monitoring of constructions)		Public space programme
	dedicated			
Netherlands	*mainstreaming*			Urban quality document (requirements on visual quality of streets and buildings), subsidy (programmes for green roofs/facade greening/de-paving playgrounds)
	dedicated	NEN-norms (against wind nuisance)		
New Zealand	*mainstreaming*	Urban Design Protocol (with principles for urban designers), Green Building Rating Tool (for commercial and residential rating)		Guides (on how to build adaptively and sustainably), long term strategic visions, investment decision making tool (focusing on investments, maintenance and replacement of infrastructures), knowledge sharing (100 Resilient Cities)
	dedicated			
South Korea	*mainstreaming*			Building guidelines (focus on building heights, availability of natural light), funding (to stimulate green roofs on commercial buildings)
	dedicated			

responsive design strategies (see Table 9). They reported that subsidies and funds are generally considered to be effective incentives, as they encourage governments and individuals to implement strategies, stimulate integrated approaches, and contribute to long-term profitability. However, interviewees also stated that these approaches can also be considered as ineffective if they lack sufficient resources or manpower to spur further implementation. Often, low priority is given to implement strategies. For example, as one participant stated, *'Workshops for urban greening are appreciated and stimulate awareness, but unfortunately not enough people apply [them]'*. (Policymaker; Germany). Moreover, policy instruments can also be considered ineffective if they are too abstract with respect to implementation or when their anticipated effects are too vague.

Participants reported that financial incentives are considered effective due to their participatory nature and guiding effect on implementing urban climate-responsive design strategies. However, the results suggest that a lack of funding, staff or awareness as well as competing priorities and difficulties in integrating expertise can hamper implementation. These observed weaknesses largely correspond to barriers faced when implementing adaptations in related policy fields, such as the fields of resource or water management, health, energy, or transportation (Aylett 2015; Runhaar et al. 2018).

Missed opportunities in non-legally binding policy instruments used to implement urban climate-responsive design strategies

Interviewees were asked if opportunities are missed with respect to non-legally binding policy instruments used for implementing urban climate-responsive design strategies. While many participants reported that they were unaware of missed opportunities, some suggestions were given to apply unused instruments, such as rules for public space (Belgium), testing tools, green structure plans, and water management decrees (Germany), urban development policies (Kenya), and sustainability funds (Netherlands).

Table 9. Observed strengths and weaknesses of non-legally binding policy instruments used for implementing urban climate-responsive design strategies.

Cover term	Answers by interviewees	Country
Strengths		
Activating power	Providing push towards concrete action	BE, KE, NL
	Giving direction	KE, NZ
	Citizen participation	NL
Integrated approach	Contributing to general knowledge and awareness	DE
	Integrated approach	KE
Financial profit	Investments safe money on long run	DE
Weaknesses		
Governance	Insufficient funding/high costs	BE, DE, NL, NZ
	Lacking priority	BE, ID, KE, NL
	Insufficient manpower	BE, DE, NL
	Lack of coordination between departments	BE, KE, KR
	Not legally binding	KE, NL, NZ
	Insufficient follow-up	BE, DE
Insufficient content	Lack of detailed information	BE, CN, KE, NZ, KR
	Impacts are weak to predict	BE, NZ
Education lacking	Public misunderstanding	BE

Belgium (BE), Bulgaria (BG), China (CN), Germany (DE), Indonesia (ID), Kenya (KE), Netherlands (NL), New Zealand (NZ), South Korea (KR).

Some interviewees also advocated for greater coherence between policy fields (Belgium, Kenya). For example, requirements for funds can also be directed towards solving social issues (Germany) and disaster management funds could steer towards anticipatory measures (Kenya). Here, non-governmental insurance companies might also have interests, or as one interviewee stated, *'When people take the right measures their insurance payments could be low'*. (Academic; Netherlands).

As interviewees reported few suggestions for missed opportunities, the extent to which opportunities are being missed within non-legally binding policy instruments remains unclear. However, the results do suggest that opportunities are being missed in bringing coherence across various policy fields and agendas. This includes opportunities to look beyond planning instruments to seek cooperation with insurance agencies or disaster management funds, especially given that warmer urban climatic conditions often lead to additional costs for insurers (Agarwal et al. 2021).

Conclusions and recommendations

This cross-sectional study explored the implementation and instrumentalization of urban climate-responsive design strategies within urban design and planning fields in several countries worldwide. The implementation of urban climate-responsive design is clearly in the early stages of the transition. Our results suggest that up to 2017, greening measures found their way, but many available strategies remain unused. Functional and aesthetic conflicts were also observed in the implementation of urban climate-responsive design strategies. At policy level, no systematic use of legally binding and non-binding policy instruments for the implementation of urban climate-responsive design strategies were found yet.

Opportunities for system change can arise when systems are pressured by external landscape factors, such as urban heat and climate change. However, these external landscape factors seemingly have not yet put sufficient pressure for urban climate-responsive design strategies in order to break through. In 2023, urban heat, drought, forest fires and other extreme weather events were experienced worldwide, and the impact of these extreme climate change induced events likely became more apparent to decision makers, urban designers and planners. Thus, it is likely that these and future extreme events will further raise awareness and push the agenda for implementing urban climate-responsive design strategies in the urban planning and design fields.

Following the five objectives of this study, the main results and recommendations for further enhancing the implementation of urban climate-responsive design strategies within urban planning and design are presented:

(1) The first objective of this study was to explore which urban climate-responsive design strategies are being implemented by urban planners and designers. The results suggest that urban greening strategies are predominantly being implemented, while other types of strategies that focus on sun and shade, solar radiation, ventilation, and evaporation are implemented less frequently. Further, most strategies are implemented at small scales (i.e., roofs, walls, streets, buildings, blocks), and rarely at larger scales (i.e., neighbourhood, city and urban region).

The focus on greening strategies is of concern when other types of strategies are not considered. Designers should understand that urban greening can also exacerbate urban climatic conditions, such as when they block ventilation or limit nocturnal cooling. Thus, further efforts should be made to address urban climatic conditions across diurnal and seasonal timescales by strategically implementing different large and small scale types of urban climate-responsive design strategies in urban planning and design.

(2) The second study objective was to explore if aesthetic or functional conflicts are experienced when implementing urban climate-responsive design strategies. The results suggest that designers do not always tend to implement strategies when they hold conflicting aesthetic preferences, when strategies do not fit with dominant urban design traditions, or when strategies affect cultural or historical sites or values. Strategies were also found to compete with other urban land-use types.

To overcome functional and aesthetic conflicts, urban climate parameters should be emphasized in design processes to stimulate urban planners and designers in the development of integrated urban climate-responsive design solutions. Considering urban climate parameters at various scale levels can help in developing local solutions that contribute to aesthetic diversity while improving urban climatic conditions.

(3) The third objective of this study was to explore legally and non-legally binding policy instruments used to implement urban climate-responsive design strategies within urban planning and design. The results suggest that dedicated policy instruments and tools for measuring and modelling design alternatives are rarely used in implementing strategies. Most governments choose to mainstream strategies within existing legally and non-legally binding policy instruments at national or municipal levels. However, many policy instruments often remain underutilized, and opportunities are often missed to mainstream strategies within available policy instruments.

Governments should more ambitiously integrate urban climate-responsive design strategies by taking advantage of the broad range of available urban planning and design instruments. However, the use and combination of these instruments should also fit cultural, geographical and planning contexts, and further research is required to explore which instruments are most effective in these contexts.

(4) The fourth objective of this study was to explore observed strengths and weaknesses in urban climate-responsive design strategies and policy instruments. The results suggest that these strategies are effective when they encourage user participation and have long-term effects. However, implemented strategies can also be ineffective when they are not part of integral plans, face technical challenges, or incur high costs. Legally binding policy instruments can be effective, as they cannot be ignored, and non-legally binding instruments are effective in that they provide financial support, stimulate participation, and offer guidance. However, policy instruments tend to become ineffective when they are too general or inflexible, or lack local urban climate data, coordination between governmental organizations, or priorities for implementing and enforcing strategies.

To increase the likelihood of successful implementation, strategies should ideally be simple, affordable, and part of long-term strategies and integral plans. Moreover, policy instruments should not provide standards and universal principles alone. Urban planners and designers need policy instruments that help them in their design process, and give sufficient flexibility, support and guidance to help them develop strategic urban climate-responsive design solutions that fit with local urban contexts. Finally, to make policy instruments more effective, they should be informed by local urban climate data. Additional research is required on how the use of urban climate-responsive design strategies can be increased among consumers, the private sector and in governments within different countries.

(5) The fifth objective of this study was to explore missed opportunities with respect to integrating urban climate-responsive design strategies with other urban functions or agendas. The results suggest that many opportunities are missed to couple strategies with other types of measures or policy fields. Only a limited number of suggestions for integrating strategies with other functions, agendas or policy fields were provided. Further, opportunities are also often missed to include expert or public opinion within urban planning and design processes.

The need exists for more far-reaching integration of urban climate expertise into urban planning and design processes. Urban planners and designers can highlight present and future urban climate challenges in the analysis phase of planning and design processes and push decision makers to adopt urban climate-responsive design approaches. Moreover, urban climate expertise should be introduced and users should be involved early in design processes. Finally, to increase awareness about the potential for integrating urban climate-responsive design strategies with other functions or agendas, more design research should be shared within the urban planning and design disciplines.

Limitations and suggestions for further research

This exploratory study may have limitations in terms of representativity of the countries chosen, as participants from only nine countries in three main climate zones were included. Research that addresses regional differences in precipitation and temperature is necessary to extend the findings to additional climate and sub-climate zones. A follow-up study based on plant hardiness could also be considered, as many interviewees mentioned greening measures in their responses. For this study, interviews were conducted with urban designers, landscape architects, and sustainability and governance experts who were aware of the state of urban climate-responsive design in their respective countries. However, all responses should be considered within their given geographical and temporal contexts. Further, the results may not represent the latest developments in urban climate-responsive design, as these developments rely on the sometimes volatile changes in political agendas. In addition, in many countries, recent global experiences with extreme climate change induced events may have created an heightened sense of urgency to implement urban climate-responsive urban design and planning strategies, which might result in different responses if the interviews were conducted now. For example, interviewees might reveal an increase in programmes for and implementation of urban greening measures. Thus, further research is necessary to investigate if and how extreme weather events have influenced agendas for implementing of urban climate-responsive design strategies. In addition, a broader range of interviewees could have prevented potentially biased assertions. For example, it would be relevant to add public perspectives on urban climate-responsive design strategies. Finally, further longitudinal international studies could contribute to a better understanding of what strategies and approaches are more effective, and in which contexts. Such research could further support the findings of this exploratory study.

Note

1. To access the coding scheme, please get in touch with the authors.

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