TIMEWISE: Temporal Urban Dynamics for Urban Resilience - Lessons from the Global North and South

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TIMEWISE: Temporal Urban Dynamics for Urban Resilience - Lessons from the Global North and South

Accelerating climate change and climate-related emergencies require cities to improve resilience across multiple short- and long-lived systems. Urban systems have individual change dynamics that are highly interconnected. However, the aftermath of disruptions is often characterised by myopic decision-making that disregards the long-term implications across systems. In this study, we develop the theoretical foundation for temporal dynamics for urban resilience. (1) We briefly characterise and conceptualise the interplay of major temporal dynamics in urban planning, including endogenous lifecycles and exogenous drivers. (2) We empirically examine temporal dynamics through climate urbanism in regions representing the Global North (GN - Amsterdam, the Netherlands) and Global South (GS - Mumbai, India). Our findings reinforce the need to embed short-term planning goals within long-term resilience visions. To address the lack of systematic planning approaches incorporating temporalities, we present options for temporal planning processes that harmonise the lifecycles of urban systems, adapt to disruptions and align planning horizons toward resilience. We discuss the potential applications of both options in the Global North and South.

Keywords
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INTRODUCTION
Temporal dynamics are vital for urban resilience

The IPCC’s 6th Assessment Report emphasizes the long-term planning to close climate adaptation gaps, especially in developing regions. It highlights the urgency of preparing cities for extreme climate-related events. Hence, urban regions have become the focus of policy formation and the implementation of objectives to achieve adaptation and resilience goals under climate change. However, long-term planning for urban resilience is challenging as cities need to reconcile ambitious developmental and mitigation agendas with increasing threats of climate disruptions.

Current urban planning timeframes that support decision-making in urban systems are linear and fixed, making them inadequate to account for dynamic changes and disruptions. For instance, addressing the IPCC’s stark warnings to limit global warming within a decade requires transformational responses over the lifecycles of multiple interconnected urban systems that are constantly changing. Not understanding the interconnected dynamics can exacerbate negative impacts via cascading risks and threaten the resilience of urban areas.

The gap in understanding temporal urban dynamics has brought myopia to urban planning, which falls back on short-term, low-regret interventions. As cities encounter urgent developmental issues, they focus on responses only in individual fast-changing systems. These short-sighted and siloed responses lead to lock-ins and path dependencies that ignore or jeopardize achieving long-term climate goals. Reversing undesirable developments becomes a roadblock to achieving resilience or sustainability goals.

Achieving climate goals in urban planning requires harmonising multilevel temporal urban dynamics that inform significant physical reconfiguration of urban systems. However, temporal dynamics, especially for planning under climate disruptions, remains an alarmingly under-researched area, even though planners could proactively harness temporal urban dynamics to reconcile short-, medium- and long-term development goals essential for urbanization under climate uncertainty.

Further, exogenous disruptions are described as windows of opportunity for transformative change. Yet, especially in the aftermath of disasters, planning and policy conventionally become trapped in the 'tyranny of urgency', focusing on rapidly re-establishing the status quo ante instead of pursuing resilience or sustainability agendas. As cities experience observed increases in the frequency and intensity of climate and weather extremes, we argue that the current understanding of the dynamics of existing and emerging urban regions does not lend itself to long-term transformative planning, essential for resilience.

This paper makes headway in leveraging an understanding of temporal urban dynamics of “connected and moving” cities towards achieving urban resilience under uncertainty. We aim to develop the theoretical foundations of temporal urban dynamics across interlaced systems for urban planning to improve resilience. Based on urban planning theory, we use multi-case analysis to assess the role of temporality in two contrasting case studies representing significant characteristics of the Global North (GN - Amsterdam, the Netherlands) and Global South (GS - Mumbai, India). From there, we formulate two vignettes of urban planning processes to demonstrate how planning...
timeframes can be adjusted to harmonize and leverage urban temporalities.

The uniqueness of this study lies in analyzing temporal dynamics through the lens of climate urbanism with an equal focus on the Global North (GN) and Global South (GS). Urban research on resilience and sustainability has been dominated by scholars and case studies from the GN,13,14. Urban planning and research are context-specific, and the dominance of research on the GN has led to a lack of approaches tailored to the fast-growing cities in the GS. This study aims to capture northern and southern insights on urban resilience using the same conceptual and empirical lines of inquiry. This enables us to develop, compare and reflect on context-specific issues and opportunities surrounding planning.

Conceptualising temporal urban dynamics

Urban systems are driven by two major dynamics: endogenous dynamics (such as speed and duration of change, rhythms and lifecycles of renewal and decay) and exogenous dynamics (political decisions, extreme events, disasters, emerging technologies, economic shifts).

For endogenous dynamics, starting from Wegener’s theory of urban change,15 along with the concepts of ‘Time geography’ and time-space cubes or prisms,16 Urban DNA,17,18 and Urban Morphological fingerprints,19 research has analysed cities based on spatial form and to a limited extent, speed of growth.20 Blumenfeld’s theory of spatiotemporal dynamics was one of the earliest contributions describing urban growth as waves,21, vital to understanding rhythms in urban expansion. Today, an urban environment is understood as polyrhythmic, consisting of fast-changing behavioural rhythms resulting from live-work patterns; and slow-changing physical rhythms, resulting from physical changes. Importantly, as is true for other social or social-ecological systems,24 urban systems that change slowly set the conditions within which faster and smaller behavioural rhythms emerge. However, a deeper look at the literature reveals a heavy focus on behavioural rhythms.25,26 While there are some studies on short and long-term physical rhythms of land use and networks lasting several decades,27,28,29,30 there is a lack of a generalized planning approach that embraces the polyrhythmic nature of cities.

Exogenous drivers, such as extreme climate events and disasters, can accelerate or impede the speed of urban change31 and offer windows to integrate changes across systems.32 The low points of resilience created by disasters present an opportunity to bring in abrupt but transformative changes in urban systems.33 Catastrophe theory,34 explains non-standard transformative changes such as rapid emergence of central places, real estate bubbles, expansion of cities in one generation, depopulation of cores, and rebuilding entire cities post disasters. However, no systematic planning approach leverages disasters as intervention points that can be consolidated ex-post with long-term planning goals.

Planning under climate uncertainty requires combining incremental and structural planning responses across the short-, medium- and long-term. Currently, the temporal horizon planners use are formal planning timeframes, typically spanning between 5 to 20 years. Within this timeframe, planners identify changing insights and align them with decision-making windows for different systems.35,34 Temporal rhythms often conflict (‘arrhythmia’), leading to deadlocks in decision-making.36 The disjuncture in dynamics is further reinforced by capacity and knowledge gaps.

Figure 1 conceptualises the interplay of major temporal dynamics in urban planning, namely the endogenous lifecycles of different urban systems, exogenous drivers or disruptions (red) and the formal urban planning lifecycles (grey circles) within which decisions must be made. At any given point, urban systems will be at different stages in their lifecycles. However, conventional planning decisions are focused at the beginning or endpoint of the lifecycles of urban systems where they have wholly decayed or fulfilled their functions.37 Mid-course corrections or modifications in systems are often not accounted into planning timeframes where such decisions have to be made for multiple systems with different temporal dynamics. Hence, they remain disconnected from the plan.

Figure 1 also illustrates the misalignment of endogenous lifecycles with planning timeframes, which are further thrown off by exogenous disruptions. Restrictive planning timeframes do not align themselves to abrupt changes essential to transition to climate-resilient futures. The literature highlights a clear gap in a systematic understanding of the interplay of multilevel temporal dynamics in planning. This is compounded by the lack of clear approaches and tools that can leverage an understanding of the dynamics of individual and connected systems, essential for mindfully reconciling short- and long-term urban resilience goals.

RESULTS

Across both cases, participants acknowledge the need to integrate a long-term vision and align the different urban dynamics via nested temporal frames to plan for uncertainty. They also discuss the role of exogenous drivers in bringing about real urban change. For planning approaches, participants spoke both to the possible enablers (e.g., scenarios, storylines, high-level strategies) as well as to the many challenges and barriers that prevent long-term planning in practice.

In the following, we formulate four main findings reflecting on planning responses, perceptions and processes related to considering temporal dynamics. Findings 1 and 2 present the major challenges and roadblocks in considering endogenous dynamics/lifecycles for planning. Findings 3 and 4 address the impact of exogenous factors and the question of if and in how far these exogenous dynamics can be leveraged for urban transformation.

Finding 1: Short-lived rhythms and tactical urbanism dominate planning in the face of actual or perceived lock-ins

Although participants discussed the importance of resilient long-lived systems,29 concrete climate-resilience strategies, especially in the MMR, were widely bottom-up with short-lived rhythms such as plot-level adaptation, rooftop rainwater harvesting, and water retention squares. These
Figure 1. Conceptualising the interplay of major temporal dynamics in urban planning, namely the endogenous lifecycles of different urban systems (various colors); exogenous drivers or disruptions resulting from extreme events (red), political changes, economic shifts etc., and the formal urban planning timeframe (grey/blue circle) within which decisions must be made for multiple urban systems. The circles in various colours represent the lifecycles or rhythms of urban systems, starting from short-lived systems that can be renewed every 1-10 years (unplanned spaces) to long-lived systems that last beyond 50 years (networks, natural resources). Within a single planning timeframe, different systems are at different lifecycles stages, which must be harmonised for planning under climate stresses and shocks. Mid-course corrections or modifications in urban systems are often not accounted into planning timeframes. Hence, they remain disconnected from the plan. The figure shows that the conventional urban planning timeframe intersects with multiple lifecycles instead of harmonizing and planning across them. Exogenous drivers and disruptions may further interfere with planning.

strategies, are often insufficient to manage extreme events [P21,P35,P36,P38]. “Planning discussions in MMR are always about solving urgent problems emerging rather than a central idea” [P22] or alternatives for future development [P23]. Participants clarified that “India’s planning is stuck in a 10-year time step” which forces short-term actions as financial and political processes align to this timeline [P36]. P38 further emphasised "a mismatch where the speed at which practitioners can implement plans, which is much slower than official planning cycles of the region”.

While MRA has a similar trend, in contrast to MMR, it has been able to develop formal programs to consolidate tactical local-level responses for climate adaptation such as Amsterdam Rainproof [P10]. The program targets adaptation of planned and unplanned open spaces & buildings/neighbourhoods but can be further scaled up to systems with longer lifecycles such as networks [38]. P5 endorses that “You must consider the long-term transformation process. Plot developments bring a lot of uncertainty.”

In sum, interventions in both cases focus on immediate returns as there are few reliable examples of long-term climate investments, with fewer cases in MMR than in MRA. Existing lock-ins due to high densities (MMR) and previous infrastructure investments (MRA) offer little scope for spatial readjustment essential for transformative interventions. Hence, climate-related strategies are often tactical, targeting fast-changing urban systems. This is in line with the literature, where tactical urbanism measures are adopted when institutional gaps or resource scarcity prevent sustained, long-term responses to risks [39].

Finding 2: Long-term urban planning is considered futile

Both MMR and MRA make formal urban plans for 20-30 years. The timeframes are fixed and can be described as short-term based on guidelines set by the IPCC [short-term (2021–2040); medium-term: 2041–2060; long-term (2081–2100)]. Furthermore, participants in both cases endorse plans that can be modified every year [P27], every five years [P7,P31] or every 10-20 years [P14]. This approach requires considering multiscalar temporal planning rhythms, which is neither explicitly discussed or understood. Instead of embracing and planning for complexity, P2 and P34 recommended that “interconnected (urban) rhythms must be cut loose from each other”. However, in a complex environment, this is not feasible.

Overall, MRA acknowledged temporality better than MMR as it must conserve and renew older infrastructure...
systems while meeting resilience and sustainability goals. Participants explicitly state that “planning and policies must account for multiple and nested temporal frames within a single planning timeframe.” [P7]. However, the underlying masterplan or urbanization concept that ties systems together is static. Like P3 stated, “We really need to try to not make very big investments, where they are locked-in and we later think we shouldn’t have done them.” An outfall of not accounting for longer-term temporal dynamics is that plans and policies become outdated earlier than expected. For instance, Amsterdam’s Structure Vision (2012) for 2040 became outdated within a few years as the city grew faster than expected [P3, P4]. Similarly, MMR’s Regional Plan 2014-2034 was sanctioned only in 2021 [P37].

In MMR, long-term thinking is done sporadically in systems such as transport, which traditionally provide the spatial structure for urban expansion. MMR is expanding rapidly, investing in multiple long-lasting infrastructure systems, emphasising the urgency to adopt a risk-informed approach to planning. Participants also highlighted the role of mega infrastructure projects in catalysing urban transformation [P29]. However, planning beyond 20 years was considered counterproductive “given the speed of technology and climate change”[P22,P30,P36]. As the projects are often disconnected from the original master plans, even the positive path dependencies emerging from them are not channelised well.

MMR participants cite the shortsightedness of planners (P29: “planners cannot see beyond three years”) and an overarching resistance to change as roadblocks for long-term thinking. P21 states that “We haven’t been able to actively integrate risk information or climate projections in long-range planning decisions or visions.” Delays in statutory acceptance and implementation of the plans mean that the original assumptions and projections are outdated while the plan is still in force. Slow institutional responsiveness translates into low adherence to formal planning timeframes, with only 25-30% of the plans implemented in MMR [P29]. The lag further increases asynchronicity with the lifecycles of urban systems, making it challenging to consider expected lifecycles in decisions [P35].

Overall, planners in both cases acknowledge the theoretical importance of thinking long-term. However, as existing spatial complexity and density impedes any transformative planning responses, long-term is considered futile and even counter-productive to meeting climate resilience goals.

Finding 3: Disasters fail to inform transformative urban change

MMR experiences recurrent flooding events, including the 2005 mega-flood, a 1 in 100-year event that inundated over 60% of the city. While the event led to a surge of reactive interventions such as installing weather stations and flood control structures and discussing risks in development plans, it has not led to any risk-informed spatial policies. P25 explained that “In consultations on climate change or disasters, they [the city] will always discuss traffic, parking, and solid waste management issues.” Despite recurrent flooding, land continues to be reclaimed for development in low-lying areas [P39]. P33 stated the need to think of courageous trade-offs and accept trial-and-error planning mechanisms to use disasters as an opportunity for building region-wide resilience.

In the Netherlands, the 1953 flood disaster catalysed a shift in flood management strategies from relying on historical metrics to focusing on future probability41. The recent Western Europe flood (2021) has also renewed interest in resilience planning, especially for outlier events42. However, the intentions remain abstract, and integration of disruptions or disasters as temporal windows in urban planning, especially under climate change, is considered low [P2].

Systems shocks, disasters and disruptions are low points of resilience that allow breaking, shifting and resetting temporal dynamics and present the opportunity for transformations that would not be available in a business-as-usual scenario. In line with that, MRA & MMR participants expressly acknowledge the role of disasters as catalysts for change for political shifts and strong industrial lobbies. However, despite the potential of disasters to bring transformative change, planning practice only treats them as ‘episodic events’ [P30] and does not use them to bring in long-term, systemic change.

Finding 4: Overtly structured (MRA) and prescriptive (MMR) urban planning is restricting the temporal flexibility to respond to disruptions

MMR’s planning approach is unanimously characterised as “conservative, prescriptive & mechanical”, where decisions rely on past metrics and market forces and are largely inflexible to temporal changes [P35, P36, P37]. Physical planning is done at the level of the parcel or plot using mathematical restrictions for ground coverage and setbacks, leaving very little flexibility to integrate additional resilience goals. MMR also does not have an official repository of land-use changes, nor do participants discuss tools or approaches to assess temporal dynamics. A critical factor hampering well-coordinated and flexible responses is the lack of a vision. However, such a vision, or ‘attractor’ to strive for, is essential to succeed in attaining alternative development trajectories10.

Although the Netherlands is exploring the dynamics of individual systems using the ‘urban layers approach’ and beginning to assess its application to regional plans43, its planning approach is characterised as ‘too structured’ by participants, which restricts the ability to respond to sudden disruptions. The plan’s inertia to change [P1] extends to planning policies and climate adaptation strategies that use a fixed scenario and time horizon despite the uncertainties acknowledged by participants [P7,P9]. MRA’s urban planners discuss flexibility by keeping several options open and avoiding negative path dependencies, even if the system is inflexible [P3,P4]. Participants from MRA, to some extent, discuss concrete planning approaches identified in the literature, notably urban landscape dynamics44, as MRA benefits from a national record of historical land-use changes. They propose the development of abstract visions [P1], storylines [P8], and scenarios under changing dynamics. While scenarios are developed nationally, they are
Figure 2. Current status quo of urban planning is myopic to long-term implications of urban change. It follows a fixed, linear sequence of 20-year periods (grey circles), which may have smaller incremental time steps within to update plans (due to exogenous drivers such as politics and technology). Under disruptions (in red), the planning timeframe is reset, and cities fall back on re-establishing the status quo due to the restrictive nature of planning. Processes of recovery extend into future timeframes impeding long-term resilience goals. Hence, cities are stuck with tactical, small-scale technical planning where they continue to promote incremental alleged ‘quick wins’ in urban systems with short lifecycles. Harmonization of nested lifecycles is discarded as too complex.

not yet implemented at the metropolitan region scale where implementation actually happens [P3,P13].

Reflecting the need to consolidate rhythms of old and new infrastructures in a complex environment, MRA discussed the dynamics of urban renewal and transformation as a way to meet resilience goals [P5]. MMR also emphasised on renewal and maintenance as it was the only temporal window that offered any flexibility in a dense urban landscape. However, all of these approaches are time-consuming and focused on one fixed point in time. Given the relatively short time available in the aftermath of a disruption, visions and storylines would need to be (re-)developed continuously to ensure they are available and ready for use when (climate) disaster strikes.

The barriers in incorporating temporal thinking

Participants across MRA and MMR acknowledge the necessity of reconciling short and long-term goals. However, the interviews with both regions showed that there is no systematic consideration of temporal aspects in urban planning. Planning processes consider urban systems to be in temporal equilibrium and static.

Fig. 2 presents the status quo of urban planning processes representative of both cases, which follow a fixed, linear sequence of 20-year periods, which may have shorter time steps within to update plans. Hence, cities are stuck with tactical, small-scale technical planning where they continue to promote incremental alleged ‘quick wins’ in urban systems with short lifecycles. Harmonization of nested lifecycles is discarded as too complex. Climate-related strategies within these timeframes are short-lived and target fast-changing systems only. There are no clear mechanisms, processes or incentives to enable long-term planning, which is why policies are often outdated, and the relevance of thinking across temporal scales is not valued.

Under disruptions, the planning timeframe is reset, cf. Fig. 2. Cities fall back on re-establishing the status quo soon after disruptions due to the shortsighted and restrictive nature of planning. Processes of recovery and re-calibration of goals (if any) extend into future timeframes impeding long-term resilience goals. Finally, both cases demonstrate an aversion to non-confirmative planning processes, where there is a fear of failure and strong inertia to change. They promote the perception that long-term planning is futile and further discourages planners from pushing longer-term temporal boundaries in the planning process. P17 warns that “the climate crisis has bypassed us as even an issue that needs to be considered politically”.

DISCUSSION

The starting point of this research is that understanding and harmonizing temporal dynamics (endogenous lifecycles and exogenous drivers of urban change) is essential for transitioning to urban resilience under climate uncertainty and supporting progress towards the SDGs. This paper synthesizes literature and empirical interviews across two case studies to present four findings in relation to the status quo of urban planning and how that affects the understanding of temporal dynamics. Capitalising on climate ambitions of MRA and MMR allowed diving into priorities, approaches and challenges in practicing climate urbanism.
We find that practitioners’ perceptions are largely consistent with literature wherein they emphasise the importance of embedding resilience in long-lived urban systems to meet future urbanization goals\textsuperscript{45,46,47}. This is in sharp contrast to the actual approaches and processes in practice where climate-related strategies focus on fast-changing systems such as rooftops and water squares. A critical challenge practitioners face in considering multilevel temporal dynamics are the uncertainties surrounding long-term responses, difficulties in undoing undesirable investments, even on paper, and the overall lack of flexibility in planning processes. Overall only 2-3 participants out of 39 explicitly discuss mention flexibility in planning to integrate changing insights.

Planning under climate uncertainty requires a clear framework to account for major temporal dynamics such as lifecycles and rhythms of decay and renewal when drafting new development plans and urbanization strategies. It requires explicit consideration of short-, medium- and long-term visions in planning and room to absorb changes due to exogenous disruptions.

Regarding exogenous dynamics, both cases acknowledge disruptions, from disasters and extreme climate events, technologies, political decisions or industrial lobbies shift urban rhythms drastically, opening up new intervention windows. Disruptions present opportunities for planners to introduce mid-course corrections in systems to extend system lifecycles and adapt to change. However, our interviews indicate that despite disruptions planning remains fixed and unresponsive, focusing primarily on building back the status quo ante. The overarching vision or ‘attractor’ required to implement transformative resilience goals is missing and cannot be developed in the few weeks or months available to plan for the recovery from disruptions.

Mitigating roadblocks for shortsighted decisions will require an enhanced understanding of current perspectives and state of thinking around temporal dynamics among practitioners. The four findings reflect the stark contrast between perception and practicalities of temporal dynamics and highlights the institutional, procedural, and regulatory gaps to why current urban planning cannot utilise temporal flexibility. Bridging the gap in the uptake of temporal dynamics will require existing planning theory to acknowledge the limitations of practice, increasing the emphasis on adapting planning processes over time as well as better monitoring systems to deal with anticipated and unanticipated changes.

### Integrating Temporal Dynamics into Urban Planning

To make headway in better using temporal dynamics in urban planning, we conceptualise two temporal planning processes that consider endogenous and exogenous dynamics in Fig. 3. We contrast them with the status quo of urban planning as shown in Fig. 2 to highlight how planning timeframes could be adjusted to accommodate disruptions and enable forward-looking decisions. The options serve as prototypical planning vignettes whose advantages, drawbacks and implementation requirements are discussed below.

Both options have a primary (grey) and secondary (green) timeframe (Fig. 3). The primary timeframe \textsuperscript{*} represents the formal window in which urban authorities make decisions. It is the basic temporal unit we use to explore variations. The impact of exogenous factors and disruptions is shown in red. In theory, both primary and secondary timeframes should be able to expand or contract under disruptions to align and harmonise system lifecycles to unforeseen climate change. In reality, the primary timeframe is often fixed due to financial or political rhythms.

**Option 1 (Nested timeframes)** presents two timeframes of 20 years (primary) and 100 years (secondary). In practice, a two-tier planning process is typically seen as a high-level national strategy and a detailed regional strategy (like in the case of MRA). However, we propose making the nested plans at the same spatial scale, in this case, the metropolitan scale. The secondary timeframe (green) allows monitoring changes in systems with slower endogenous dynamics (longer lifecycles) such as water or transport. Under disruptions, the secondary timeframe offers the room to absorb changes or enable abrupt transformations by guiding adjustments in primary timeframes. Explicit requirements and goals for each of primary planning timeframe can be derived and translated into planning visions for short-lived systems.

Option 1 may be effective in regions like MRA, with a history of structured spatial planning and existing capacities to develop multiple visions as the urban fabric is also not changing dramatically. MRA already adopts longer-term sectoral visions in the national adaptation strategy. On the other hand, for rapidly emerging regions like MMR that are investing significantly in new urban systems, making fixed long-term vision may be disabling to accommodate dynamics of newer urban systems.

**Option 2 (Flexible timeframes)**, similar to Option 1, presents a short-term primary planning timeframe guided by a long-term secondary timeframe. In this case, both timeframes are flexible and can evolve due to changing planning variables. Option 2 goes beyond Option 1 as the secondary timeframe can acknowledge dynamics of short- and long-lived urban systems and guide incremental decisions within primary timeframes. Decisions could range from major projects to consolidating measures for rainwater harvesting, developing amphibious neighbourhoods or re-hauling the water or energy systems.

Under possible disruptions, both timeframes can adjust and re-align with changing objectives towards short-term goals and long-term vision for reference at each time step, which allows harmonizing dynamics. It also presents the flexibility to add additional layers of planning (shorter or longer than the primary timeframes) in case of a major disruption or system shock to allow rapid recovery without jeopardising long-term resilience goals. This option requires a highly responsive planning and governance structure to monitor, understand and capture the right variables to bounce

*the primary timeframe may vary between 5-30 years in the case of several major urban regions, including the MRA and MMR*
In Option 1 (nested timeframes), we propose two nested plans for the same spatial scale. Under disruptions, the secondary timeframe (green) offers the room to absorb changes or enable transformations by guiding adjustments in primary timeframes. It allows monitoring changes in systems with longer lifecycles, such as water or transport networks.

In Option 2 (Flexible timeframes), both timeframes are flexible and can evolve due to changing planning variables. The secondary timeframe (green) allows considering the impacts of major endogenous lifecycles of long-lived urban systems and guides incremental decisions within each primary timeframe. Under possible disruptions, both timeframes can adjust and re-align with changing objectives.

forward after a disruption. Planners need specific signposts to set new responses in motion, in the absence of which, the plan becomes vulnerable to political powerplay and urgent development agendas, and may fall back to the status quo.

This option could potentially become effective when regions, like the MMR/MRA review their urban resilience objectives every few years due to accelerating climate change, paving the path for newer insights. It enables a two-way knowledge exchange between the primary plan and the long-term vision. A downside of offering high flexibility for planning a region like MMR with significant capacity gaps is that it might not be able to regulate interventions between the two timeframes effectively.

**Contribution and Future Research**

While implementing temporally flexible planning processes in real-world is already difficult for planners, doing so under disruptions and climate uncertainties compounds the challenge. Uncertainties require moving away from decision-making solely at the end of the planning timeframe or the end of an urban systems’ lifecycle towards decision-making mid-cycle or in moving time intervals where insights can be continuously integrated and harmonised with system lifecycles. Several participants recommend updating plans every few years, which allows the opportunity to implement continuous insights, provided there are policies for it. In the absence of such temporal considerations, participants in both cases recommend formalising renewal and maintenance as temporal windows for updating insights [P6,P14,P32]. This is a key area for further research.

Introducing mid-cycle corrections in urban systems also requires a reliable knowledge base on the age and condition of systems that are accessible to planners. The lack of data and outdated data is cited as a major roadblock to planning in the MMR. The Netherlands has a building-level repository of construction age. A similar system may be scaled up
for other urban systems. This also opens up avenues to find couplings between urban systems to address climate resilience opportunities.

This study also expands on primary research on temporality in less-studied and rapidly changing urban contexts of the Global South-Mumbai. MMR exhibits different levels of resistance to adopting a long-term perspective essential for achieving urban resilience. Our findings show that the inability to respond to changes can be attributed to rigid and unresponsive planning processes and negative path dependencies embedded due to past investments. However, MMR’s status as an emerging region is also beneficial as it has relatively fewer structural lock-ins, enabling it to adopt newer temporal planning processes. However, our empirical findings suggest no strategies or thinking in that direction, making it an essential for future research.

The planning options presented in Fig. 3 serve as starting points to systematically reorganize existing planning processes to leverage temporal dynamics. They need to be contextualised, adapted or refined to suit individual regions to become mature for implementation in practice. This is becoming possible as planners access tools such as scenario thinking, visioning, model-based decision-making, and climate projections, as well as overall better availability of data that can be harnessed for forward-looking planning. However, significant data gaps exist in the GS. Moreover, understanding temporal dynamics in the GS will require investigating the dynamics of emerging, non-standard, newer typologies of growth (or ‘grey’ growth), which do not abide by conventionally considered lifecycles, for instance in informal settlements [P32,35,36].

**METHODS**

This section discusses the research design, selection of case studies, data collection, and analysis.

**Case Studies**

Both Amsterdam and Mumbai have historic centres attached to solid financial and cultural functions. Geographically, both are expanding outwards and are undergoing urban regeneration of different types under the urgency to meet climate goals. Their interest in building evidence for planning under climate change frames the opportunity to derive diverse insights.

**Case Study 1: Metropolitan Region of Amsterdam (MRA), Netherlands:** The MRA is an agglomeration of 32 municipalities housing 2.48 million people spread over 2580 sqkm. MRA is an advanced urban economy with a history of formal planning, well-coordinated public investments, consensus-driven political processes, and robust planning structures. Its urbanization strategy includes a broad climate strategy for 2050 and identifies vital urban systems that must become resilient under climate change. MRA’s future growth involves consolidating and streamlining temporal dynamics of ageing infrastructure, building a large volume of housing, and transitioning to a fossil-fuel-free economy.

**Case Study 2: Mumbai Metropolitan Region (MMR), India:** The MMR is the fourth-largest urban agglomeration globally, spread over 6640 sqkm and expected to house 27 million residents by 2036. It is a developing economy where planning is a mix of formal and informal processes and ‘demand supersedes development’ in almost every sector. Its regional planning strategy includes high-level actions for climate change, but they are not integrated with infrastructure and land-use aspects. MMR’s future growth involves capitalising on temporal dynamics to invest mindfully in a large volume of long-lived infrastructure, including metros, industrial corridors, new airports, high-speed rail, and coastal roads.

**Data Collection and Analysis**

The authors used a combination of snowball sampling, personal referrals, and social media to shortlist 200 participants, of which we selected 20 for MRA [P1-P20] and 19 for MMR [P21-P39]. We conducted a total of interviews with 39 senior practitioners in both cases, covering four domains that play a crucial role in urban planning: (a) Urban Planners; (b) Strategic/ Policy Advisors/ Bureaucrats; (c) Academic Researchers; and (d) Specialists in Sustainability/ Engineering. The selection of participants is elaborated in, a preceding study focusing on a broader framework for long-term planning under climate uncertainty. The interview questions were framed based on findings from the literature to understand how participants acknowledge temporality variables, such as duration, planning timeframes, and urban system lifecycles. The analysis involves engaging participants to reflect on the perception of time and long-term thinking among participants to touch upon significant challenges (Interview Protocol in Appendix A).

The qualitative content analysis of interviews is a systematic process of interpreting text data and deriving insights on research objectives or extending theoretical insights. For the analysis, we developed a corpus of interviews by transcribing the voice recordings and applying bank written during the interviewing process. Each case was analyzed separately using uniform qualitative coding categories. In Step-1, we used open coding to extract broad findings on experiences on planning under climate change, long-term thinking, planning mechanisms, climate-related projects, urban systems, planning values, and challenges. In Step-2, we used selective coding to extract findings under two main coding categories to investigate the knowledge streams derived from literature:

**Category-1: Endogenous Dynamics & Exogenous Drivers of Urban Change,** covers theories characterising urban change (speed, duration, rhythms, planning timeframes); external drivers (extreme events, disruptive technologies and political shifts).

**Category-2: Approaches/ Tools to leverage an understanding of Urban Change & Planning Perspectives on Urban Change,** covers specific approaches and tools to assess temporal dynamics of the urban landscape, networks, and flows; participants’ perspectives and challenges in long-term thinking (institutional issues, delays).
### Table 1. Table presenting coding categories discussed by participants in both cases with example quotes

(AMsterdam participants (MRA): P1 to P20; Mumbai participants (MMR): P21 to P39)

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<th>S.no.</th>
<th>Coding Category and Terms</th>
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<td><strong>[Category 1]: Endogenous Dynamics &amp; External Drivers of Urban Change</strong></td>
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<td>Speed &amp; Duration&lt;br&gt;speed, duration, temporal, dynamics, planning, timeframes, time horizon, short-term, long-term, scale, period, future</td>
<td>“P30: When you do a city as large as Mumbai, obviously, you cannot make short-term plans.”&lt;br&gt;“P38: The speed of the temporal and statutory cycles is a mismatch.”</td>
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<td>Rhythms&lt;br&gt;rhythm, cycles, lifecycles, frequency</td>
<td>P1: “MRA acknowledges different elements with different frequencies and rhythms. Cut these rhythms loose from each other.”&lt;br&gt;P7: “Planning and policies must account for multiple and nested temporal frames within a single planning timeline.”</td>
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<td>Drivers of Urban Change&lt;br&gt;drivers, technology, extreme, disruptions, catalysts, disasters, floods, politics, ageing, shared</td>
<td>P36: “For a rapidly urbanizing region...a vision for 20 years is too long given the speed of technology and climate change.”&lt;br&gt;P29: “MMR acknowledges the role of system-shocks and disasters in driving urban transformation.”</td>
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<td><strong>[Category 2]: Approaches/Tools to leverage an understanding of Urban Change &amp; Planning Perspectives on Urban Change</strong></td>
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<td>Approaches &amp; Tools&lt;br&gt;approaches, mechanisms, responses, tools incremental, transformative, forward-looking, land-use, landscape, layers, networks, evolution, metabolism, flow, circularity (pertaining to urban metabolism studies)</td>
<td>P8: “There are techniques to link (flood) return periods to planning storylines, but the future will evolve differently, but at least think of some catastrophic storylines.”&lt;br&gt;P33: “The more you are in reactive response mode, the lesser time and resources to devote for strategic thinking.”&lt;br&gt;P2: “Make an abstract vision for the future. Then it works out in different programs that can change so you can be flexible.”&lt;br&gt;P29: “Planning is Mechanical and restrictive.”&lt;br&gt;P36: “Development could be controlled using transit networks which offer a spatial structure for future growth...with long lifecycles”.&lt;br&gt;“P34: We need a multilevel framework for assessing (long-term) trade-offs for coastal roads, overhauling the drainage systems...”&lt;br&gt;“P35: Temporality of the informal landscape cannot be assessed using existing approaches as they cannot be fully regulated.”</td>
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<td>Perspectives, Challenges &amp; Gaps:&lt;br&gt;perception, challenges, institutional, issues, gaps, delays, process, update, regulation, renewal, maintain</td>
<td>P29: “Projects with long gestation periods are hard to implement as planners can’t even see beyond three years.”&lt;br&gt;P5: “Policies to implement climate norms will always be dated. How do you allow the policy design to respond and go beyond what is set in stone?”&lt;br&gt;P3: “Amsterdam’s Structurevision (2012) became outdated soon after its release as the city grew faster than expected.”&lt;br&gt;P37: “This lag in planning and implementation timelines cascades to day-to-day decision-making which then stretches to several months.”</td>
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The heterogeneous participants used different terminologies to describe similar concepts of planning and temporality. Table 1 enlists the coding categories, coding terms included under each category, along with representative quotations. We quantified the codes, dived into the associated quotations, and went back to the interviews to position them in the broader context of this research. We conduct a cross-case assessment to observe the similarities and differences in how the cases perceive and use temporal dynamics in decision-making.

**SOFTWARE**

Qualitative data analysis of interviews was conducted using software Atlas TI (Version 9).

**DATA AVAILABILITY**

All interview data in this study were collected through a GDPR-compliant framework and with approval from the Human Research Ethics Committee (HREC) at the parent institute. The publicly available datasets supporting the study’s findings may be accessed at DOI: 10.4121/22220398. Restrictions apply to the availability of the interview participants’ personal data per the consent received by all participants. Datasets containing personally identifiable
information are for verification and validation only; they may not be used for further research and are available upon request until March 2025, after which they will be deleted.

REFERENCES


ACKNOWLEDGMENTS
Removed from the anonymous version.

AUTHOR CONTRIBUTIONS
Removed from the anonymous version.

Appendix A: Interview Protocol
Each interview was approximately 60 minutes long and conducted online using Zoom/Teams calls due to Covid-19 related travel restrictions.
1. Experience in urban planning and climate space.
2. Perspectives on long-term thinking, uncertainty and approaches in urban planning.
3. Planning timeframes, speeds, updating and renewing plans, windows to integrate new information.
4. Spatial and temporal aspects of climate risks.
5. Long-term projects, sectoral focus, greenfield/ brownfield, public/private, other development models.
8. Issues with the current urbanization and planning.