Transformative leapfrogging in urban infrastructure – Learning from a de facto experiment with water reuse solutions in Bengaluru

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Abstract: Middle-income cities (MICs) are characterized by rapid urbanisation, expanding innovation capacities, and relatively weak path dependencies in their urban infrastructure systems. This could create unique opportunities for transformative leapfrogging – bypassing conventional infrastructure solutions in favour of novel, more sustainable approaches. Yet, most MICs tend to replicate global gold standards rather than embark on complex innovation trajectories. We argue that conventional urban planning and transitions concepts are ill-suited to address how to foster transformative leapfrogging in MICs and develop a novel analytical framework that combines socio-technical transitions theory with insights from innovation systems research. The framework highlights the creative problem-solving capacity of actors in dynamic MICs and specifies under what conditions experimentation with second-best solutions may lead to new transformative infrastructure templates. We apply the framework to a case study of how decentralized wastewater treatment and reuse systems have gained significance in Bengaluru (India). Drawing on 54 interviews, 23 site visits and 6 workshops, we show how regime-defying policies were introduced in response to development pressures and outline the factors triggering a de facto experimental space, in which actors could experiment with new solutions at scale. We then show that systemic barriers still hamper their maturing. We sketch an alternative approach to transformative leapfrogging in MICs that represents a shift from conventional planning logics and niche-focused transition models towards actively leveraging the ingenuity and problem-solving capacity generated within rapidly evolving urban contexts.

Keywords: urban infrastructure, transformative leapfrogging, innovation, water reuse, Bengaluru

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1 Introduction

Key urban infrastructure sectors like energy, water, or mobility need to be fundamentally transformed in the next decades to align with ambitious environmental and social policy targets. Most cities in high-income countries are deeply invested in old ways of providing infrastructure services and thus slow in transforming them. In contrast, many middle-income cities (MICs) possess promising conditions for leapfrogging into highly innovative infrastructure solutions: major urban centres located in rapidly developing middle-income countries often experience rapid urbanization, economic growth, and expanding technological capabilities, while struggling with addressing complex environmental and social challenges (Nagendra et al., 2018; Randolph and Storper, 2023). As their infrastructure systems are still under development, they exhibit weaker structural path dependencies and more space for experimentation with radical system alternatives. This situation opens considerable room for developing fundamentally new ways in which urban infrastructure service can be provided, beyond emulating global *gold standards* (Fuenfschilling and Binz, 2018; Wainaina and Truffer, 2024). Or put differently: MICs provide unique structural opportunities for engaging in *transformative leapfrogging*.

Transformative leapfrogging (Yap et al., 2022) is an innovation-based development strategy in which cities bypass conventional infrastructure paradigms and directly jump into novel, potentially more sustainable, (infrastructure) solutions. Transformative leapfrogging in MICs holds a very high potential to increase urban sustainability and should thus be a key policy priority. Yet, empirical evidence suggests that success cases remain scarce (Rock et al., 2009). In fact, when confronted with the challenge of building safe, reliable, and equitable infrastructure *from scratch,* decision makers in MICs tend to favour the global gold standard solutions (Fuenfschilling and Binz, 2018; Hansen et al., 2018; Wieczorek, 2018; Ghosh and Schot, 2019; Ghosh et al., 2021), rather than embarking on complex innovation trajectories with open-ended outcomes. As such, we still lack evidence on the structural conditions and processes that enable transformative leapfrogging in MICs (urban) infrastructures.

In this paper, we ask the question how the potential for transformative leapfrogging that is inherent in the dynamic contexts characterising MICs can be analysed and ultimately harnessed? We will argue that conventional urban planning concepts are ill-suited to address this question. Traditional expert-driven and technocratic planning processes, as well as market-led approaches that delegate infrastructure development to the private sector, have shown low effectiveness in inducing transformative leapfrogging in these contexts (Hansen et al., 2018; Ghosh and Schot, 2019; Groenewoudt and Romijn, 2022). In between these two generic approaches, frameworks from socio-technical transitions literature potentially provide a third route, which explores how transformative innovation may be fostered in protected *niche* spaces through strategic policy interventions (Kemp et al., 1998) or bottom-up grassroots experiments (Castán Broto and Bulkeley, 2013). However, these approaches do not translate seamlessly into the dynamic and fluid institutional context of MICs and tend to rather result in endless sequences of niche experiments than in coherent innovation scaling trajectories (Hansen et al., 2018; Raven, 2024).

We seek to further develop this third route by adapting it to the preconditions and policy environments prevalent in MIC contexts. By combining it with the literature on innovation system failures, we aim at developing a novel framework for conceptualizing and analysing how transformative leapfrogging may come about. We take as a starting point that actual infrastructure policies in MICs sometimes actively *defy* the prescription of global gold standards. We start by identifying the conditions under which such policies may open *de facto experimental spaces* that unleash innovation activities that specify novel and potentially transformative infrastructure templates. We then proceed with identifying the *systemic barriers* which hamper the scaling and maturing of these solutions (Woolthuis et al., 2005; Bergek et al., 2008; Weber and Rohracher, 2012) and elaborate on how supportive system structures may be actively constructed. Taken together, this constitutes an analytical framework for how transformative leapfrogging could be fostered by leveraging the creative problem-solving capacity of actors under the dynamic conditions prevailing in many MICs.

We apply the framework to a case study of an ongoing transformative leapfrogging trajectory in the urban water management sector in Bengaluru (Karnataka, India), which draws on 54 expert interviews, 23 site visits and 4 stakeholder workshops. Bengaluru has established a globally unique approach to urban water management, which depends on treating about 20% of its wastewater in decentralized wastewater treatment and reuse systems (DWTRS). However, many challenges with this novel infrastructure approach still prevail, making Bengaluru a paradigmatic case for studying the drivers and barriers of transformative leapfrogging in MICs. The analysis allows us to sketch the contours of an alternative perspective of transformative leapfrogging in MICs, that reverses the logic of conventional urban planning and transition models: away from the gradual upscaling of protected niche experiments towards a logic emphasizing the potential that lies in harvesting the ingenuity and innovativeness that may emerge endogenously through serendipitous events or as unintended by-products of broader infrastructure development policies.

2 Conceptualizing transformative infrastructure leapfrogging in MICs

The global gold standards in infrastructure provision like car-based urban mobility, centralized water systems, or fossil-fuel based heating and power solutions, were originally designed to target the key development challenges of European and North American cities in the early 20th century (Randolph and Storper, 2023). This almost by definition makes them ill-adapted to today's sustainability challenges in quickly growing MICs. Nevertheless, empirical evidence shows that local governments tasked with developing urban infrastructure often look for *quick fixes* and *best practices* borrowed from elsewhere, rather than developing novel (and context-sensitive) solutions *from scratch* (Rock et al., 2009; Nilsson, 2016; Fuenfschilling and Binz, 2018; Miorner et al., 2025). Many sectors has a strong *global regime,* i.e., a dominant configuration of technologies, standards, practices and actors, which exerts strong influence on the aspirations of decision makers in planning departments and utilities (Fuenfschilling and Binz, 2018), despite solutions being disadvantageous or even dysfunctional in the specific context of MICs. A case in point are the promises by planners in many MICs to develop universal access to large-scale centralized water and sanitation infrastructures, which consistently fail to reach quickly expanding urban areas or informal settlements (Nilsson, 2016; Mara and Evans, 2018; van Welie et al., 2019).

Engaging in transformative leapfrogging trajectories, in contrast, is often constrained by limited financial resources, insufficient regulatory capacity, and a lack of locally adapted solutions in MICs (Binz et al., 2016; Reymond et al., 2020). When promising approaches emerge locally, they are often not pursued with a long-term strategy due to all sorts of resource deficits that prevent them from maturing and eventually scaling (van Welie et al., 2019). Existing planning frameworks typically do not consider the option of transformative leapfrogging and provide very limited analytical guidance on how MICs could leverage their structural conditions that would in principle be conducive to transformative leapfrogging (Hansen et al., 2018; Van Welie et al., 2018; Wieczorek, 2018; Ghosh and Schot, 2019; Ghosh et al., 2021).

2.1 A critical reflection on existing frameworks

Existing urban planning and transition frameworks broadly fall into three categories: those which emphasise state-led and technocratic planning processes, those which suggest delegating infrastructure development to the market, and those which focus on fostering innovation dynamics in protected niches. We argue that all three approaches show limitations in properly conceptualizing transformative leapfrogging in MICs.

First, state-led planning approaches in theory promise the most equitable outcomes, as the state is equipped with a political mandate to provide universal infrastructure services. But evidence shows that state-led planning processes in MICs are often captured by global regime actors (Fuenfschilling and Binz, 2018), which makes them overlook local context conditions in favour of infrastructure solutions that draw legitimacy from seeming success cases *far away* (Wainaina et al., 2023). This tendency is understandable, given that urban expansion in many MICs outpaces infrastructure planning and stretches administrative capacities. Governments are often tasked with managing rapid urban expansion in many interrelated infrastructure fields, thus leaving limited time and capacity to venture into developing new infrastructure templates (cf. Monstadt and Coutard, 2019).

Given these challenges, a second ideal-type approach, which is often promoted by economists and large development banks, has been to delegate the responsibility for infrastructure development and provision to private actors (Jensen and Wu, 2017; Hansen et al., 2018; Ghosh and Schot, 2019; Groenewoudt and Romijn, 2022). This approach has been justified with the higher technological capabilities, substantive financial resources, and the efficiency in project delivery that private firms and consultants can mobilize. Yet, market-driven infrastructure development programs in MICs have also been criticised for reproducing structural inequalities and having prioritized financial gains over environmental and social benefits (Bombaerts et al., 2020; Groenewoudt and Romijn, 2022).

Transition studies offer a third approach, which leverages a socio-technical, innovation oriented perspective (Wainaina et al., 2023). This approach conceptualizes urban infrastructures as being provided by *socio-technical configurations:* alignments of technologies, institutions and actors that provide a societal function (e.g., energy, water, food, or transport) in a specific way. Socio-technical configurations align supply- and demand-side dynamics and lock-ins are reflected in the co-evolution between different elements. This means that leapfrogging cannot be achieved by simply introducing new technologies but rather requires the co-development of new business models, regulative frameworks, financial investments, and legitimizing storylines (Yap et al. 2022). The Strategic Niche Management (SNM) literature (Kemp et al., 1998; Hoogma et al., 2002) posits that these co-development processes can be coordinated by nurturing *niches,* which shield the new socio-technical configurations from mainstream selection pressures. Niches can be fostered by inducing experiments with transformative innovation *top-down*, in policy-induced pilot initiatives or living labs (for a recent review, see Raven, 2024). Or they can be fostered bottom-up as *grassroots innovations*, typically in community initiatives that operate under informal governance structures for building up hyperlocal solutions (Harms and Truffer, 1999). In these collaborative modes of experimental governance, the responsibility for coordinating niche development processes is extended from local governments and firms, to grassroots organizations, NGOs, research organizations and user groups (Seyfang and Haxeltine, 2012). Reflecting *messy governmentalities* (Castán Broto, 2020), this form of networked coordination has become a prevalent feature of studies zooming in on transitions in the Global South (see Wieczorek, 2018), assuming that groups of actors rooted in civil society should take responsibility for coordinating local experiments with transformative infrastructure solutions where local governments and private actors fall short (Castán Broto and Bulkeley, 2013).

The application of these ideas to transformative leapfrogging in MICs, however, still has limited analytical purchase. Under conditions of skyrocketing urbanization, SNM-based gradual experimenting may simply not be possible or too slow (Yap et al., 2022; Wainaina et al., 2023; Wainaina and Truffer, 2024). It is also questionable how successful grassroots approaches can be beyond the very early stages of experimentation. Solutions that depend on reciprocal social ties and trust are very hard to scale across and beyond their original contexts (Bauwens et al., 2022). In a recent review, Raven (2024) notice that several scholars have warned that experiments may often not "expand, diffuse or 'add up' to broader systemic change" (Sengers et al., 2021, pp. 1149–1150). These bottlenecks tend to be exacerbated in MICs (Rock et al., 2009), where bottom-up initiatives often operate independently in a very dynamic context, leading to fragmented efforts that lack strategic alignment (van Welie et al., 2019).

To summarize, traditional state-led, market-based, and transition approaches all show significant limitations in the context of MICs. The question that looms large, then, is what alternative model could conceivably support transformative leapfrogging trajectories in MICs.

2.2 Towards an alternative approach

How may then the ingenuity of actors in MICs be leveraged, while acknowledging that planners, companies and civil society will not be able to assume the role of a strategic niche manager? Our starting point is to scrutinize actual developments that result from implementing policies that –

intentionally, or not – *defy* global regime standards. Such policies typically result from imminent crises that policymakers must react to, like droughts, environmental disasters, disease outbreaks, traffic infarcts, or other sudden breakdowns in service provision. Under certain conditions, these policy interventions may open windows of opportunity for experimentation with radical system alternatives (Ghosh and Schot, 2019; Wainaina and Truffer, 2024). Innovating actors will (temporarily) get more leeway in developing solutions with context-adapted performance and cost characteristics to serve market segments in which new infrastructure solutions can mature and scale, despite being initially considered *second-best* in terms of service delivery.

This type of innovation activity is actually a recurring phenomenon in many MICs (cf., frugal-, shanzai-, and jugaad innovation). Experimental spaces are often generated organically and endogenously, sometimes even haphazardly, as an unintended consequence of urgent and problem-oriented policy interventions. Yet not all policy initiatives will do equally well in creating consistent incentives for experimentation. Weakly designed policies will often lead to limited service provision and no innovation, when circumventing regulatory pressure is an option. To unleash ingenuity and innovation, such policies would ideally need to be combined with incentive structures for different actors to engage conjointly in transformative innovation. The task of policymaking is therefore maximizing the potential for experimentation and tinkering in the *right direction*. Compared to the conventional SNM approach, this will lead to a situation where *de facto experimental spaces* that emerge haphazardly in cites that are then mobilized by innovative local actors, while not assuming full foresight and heroic capacity on the side of the policy makers or any other strategic niche manager.

However, existing evidence vividly illustrates that even the most fertile ground fails to scale transformative innovations if innovation activities remain scattered and disconnected from each other in an institutional and policy environment that is quickly evolving and prone with uncertainty. A key question then is how to foster the transformative potential that can be unleashed in de facto experimental spaces. To this end, transition scholars have argued that developing a well-functioning *innovation system* (Bergek et al., 2008) supports the alignment of different socio-technical elements into configurations that "could work", as well as gradually minimizing the tensions between new solutions and the local selection environment (cf. Smith and Raven, 2012). An innovation system supports reflexive learning trajectories and the formation and curation of innovation processes that contribute with key resources, such as knowledge and skills, markets, financial investments, and legitimacy (Bergek et al., 2008).

Innovation systems do not grow automatically out of experimental activities but require active system building and coordination efforts (Musiolik et al., 2012). Developing innovation systems therefore often requires establishing new intermediary actors, developing education programs, creating new or adapted regulatory frameworks, or mobilizing public and private funding. The innovation system lens is instructive for detecting early signs of self-organization around an emerging infrastructure solution. It is also particularly useful for identifying systemic barriers that hinder a novel solution from working well and scaling up. The well-established literature on *system failures* can be mobilized for this purpose (Weber and Rohracher, 2012). The literature broadly distinguishes between two types of barriers that may appear in innovation systems (see Table 1). The first type refers to static *structural barriers* (Woolthuis et al., 2005), i.e., a lack of coordination between different actors, as well as missing skills, knowledge and expertise or a mismatch with relevant institutions in a sector. The second type refers to a lack of dynamic capabilities for transforming pre-existing ways of doing things, i.e., dynamic *transformation barriers* (Weber and Rohracher, 2012; Grillitsch et al., 2019). This includes a lack of a shared vision, a lack of feedback loops between different parts of the value chain, as well as barriers related to monitoring and reflexively adapting innovation activities and policies.

Table 1: Types of system failures

Systemic barriers		Examples
Static structural barriers	Infrastructure failures	Lacking R&D and education infrastructure; poor transportation- and communication networks
	Institutional failures	Inappropriate or missing policies, regulations, norms, standards etc.
	Network failures	Too weak or too strong networks between actors
	Capability failures	Insufficient skills, knowledge and expertise
Dynamic transformation barriers	Directionality failures	Lack of a shared vision that establish clear goals among actors
	Demand articulation failures	Lack of feedback loops between planners, technology suppliers and users, hampering iterative improvement of the solution
	Reflexivity failures	Lack of ability to monitor and involve actors in interactive learning
	Policy coordination failures	Lack of coordination between different policy areas and inappropriate policy mixes

Source: Own summary of Woolthuis et al. (2005) and Weber and Rohracher (2012)

2.3 Outline of the analytical framework

We may now purport an analytical framework for assessing transformative leapfrogging trajectories that rest on three consecutive analytical steps (Figure 1). The first step (1) revolves around identifying regime-defying policies that are developed in response to pressing environmental or social challenges. The starting hypothesis here is that in dynamic development contexts, regime-defying policies are quite often implemented. However, most of them do not lead to a sustained and strategic leapfrogging trajectory, but rather temporal *quick fixes* that are later abandoned in favor of global regime solutions. A key analytical question then revolves around mapping endogenous or exogenous transformation pressures and analyzing policy responses that clearly contradict global gold standards. If such a policy is introduced and sustained for some time, the structural seed for a potential leapfrogging trajectory arguably exists that can be exploited by visionary entrepreneurial actors.

The second analytical step (2) is about identifying whether incentive structures emerge that push local actors to innovate on the new infrastructure approach and coordinate their strategies to some degree in a new direction. If such dynamics can be observed, the simple regime defying policy maybe "endogenized" by local innovators (Yap and Truffer, 2019) and be turned into a *de facto experimental space*. This second step includes mapping innovation activities and the emergence of market segments with particularly high quality or performance requirements, as well as whether new business models, policies, or use contexts emerge, and if new actors enter the innovation field. If these activities in the de facto experimental space reach a certain critical mass, the leapfrogging trajectory might switch yet again into a next phase, in which the innovation process gets more strategic and coordinated.

The third analytical step (3), is concerned with applying the system failure framework outlined above to analyze the bottlenecks that prevent the broader maturing and scaling of the new infrastructure template. If the ecosystem of business and policy entrepreneurs reaches a certain density, the leapfrogging trajectory can be pushed endogenously by improving system-level coordination and proactively identifying and tackling system failures. This might relate to missing actors, institutions and technologies, but also to broader structural and transformation barriers that impede the build-up of a well-functioning innovation system that pushes the leapfrogging trajectory forward.

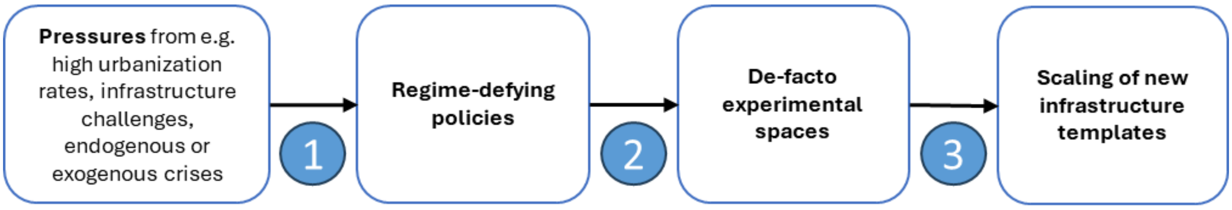

Figure 1: Analytical framework. Source: own elaboration.

3 Case selection and research design

To illustrate and validate the analytical framework, we draw on the analysis of a *paradigmatic case* which helps to establish a pattern by which other cases can be understood, by highlighting general principles from case-specific insights. The case in point is the urban water management (UWM) sector in Bengaluru (India), which represents one of the rare cases globally in which a MIC is endogenously leapfrogging into a radically new infrastructure paradigm focused on decentralized water reuse. Bengaluru has experienced strong economic growth over several decades, driven by quickly expanding IT, biotechnology and aerospace industries. The metropolitan area has an estimated population of approximately 14 million and has experienced an average annual growth rate of 4% over the past 20 years. This dynamic urban expansion implies that is very hard to plan and implement conventional centralized water infrastructure in a strategic way (cf. Maurer, 2009). Consequently, from the early 2000s the city mandates all new residential and commercial developments above a certain size to install and run Decentralized Wastewater Treatment and Reuse Systems (DWTRS) on their premises. Over the last 20 years, more than 3 500 such plants have been constructed, cumulatively treating approximately 20% of the city's total generated wastewater (Klinger et al., 2020; Nath et al., 2022). Bengaluru thus represents one among very few cities worldwide in which buildings are equipped with individual treatment plants and reusing their water on-site or in the immediate neighbourhood.

The empirical analysis is based on 54 semi-structured interviews with stakeholders in the UWM field in Bengaluru, encompassing firms, policymakers, intermediaries, researchers, and residents (see Appendix A). The duration of the interviews ranged from 20 to 120 min. The semi-structured format allowed for the exploration of unexpected discoveries during the interviews, which are crucial in developing a broad understanding of a case that has not been extensively covered in previous research. We selected interviewees based on desk research and snowball sampling. Moreover, the research was enriched by 23 site-visits to DWTRS plants in Bengaluru, and by participation in four stakeholder workshops organised by research institutes and the local apartment owner's federation (see Appendix A). Key systemic barriers and ways to overcome them were furthermore discussed with local stakeholders in two additional workshops organized by the authors and colleagues.

The data collection period spanned from 2022 to 2025. Findings were triangulated with insights from a comprehensive review of secondary sources (academic papers, grey literature, newspaper articles, and official documents such as mandates, government memos, and meeting minutes). To analyse the empirical material, we employed a qualitative coding approach, which were used to reconstruct a timeline, triangulate narratives about how the leapfrogging trajectory in Bengaluru came about, and to reconstruct the key mechanisms that enabled it. The results are illustrated with direct quotes from the interviews indicated by Q# in parentheses throughout the text (referring to Appendix B).

4 Results

In the early 2000s, the Karnataka state government started mandating the installation of small-scale wastewater treatment plants in all new residential and commercial buildings above a certain size (Kuttuva et al., 2018). The rationale for this policy intervention was an increasing realization that expanding Bengaluru's centralized sewer system could not keep pace with the rapid growth of new apartment complexes at the city's outskirts (Q1-2). The initial mandates were complemented by additional regulations and guidelines in 2014-2016, targeting concerns over environmental protection and water security. In 2014, the Karnataka State Pollution Control Board (KSPCB) introduced a *Zero Liquid Discharge* (ZLD) mandate, prohibiting the discharge of wastewater (treated or untreated) into storm drains. They also required all treated wastewater to be reused locally for non-potable purposes, such as toilet flushing, cleaning and irrigation/gardening. In 2016-2018, the mandates were extended to include existing buildings over a certain size, referred to as the *retrofit mandate*, and more stringent treatment requirements were specified. Sewage regulations were also amended to more clearly specify which buildings were required to install on-site wastewater treatment plants. In 2021, the KSPCB furthermore released a memorandum specifying design and operation guidelines for treatment plants (Nath et al., 2022). Moreover, due to increasing water stress in early 2024, the state government released a directive that allows residents to sell 50% of their treated wastewater to nearby industries. Finally, in early 2025 the local water utility issued an order banning the use of fresh water for non-essential purposes like car washing, construction or irrigation.

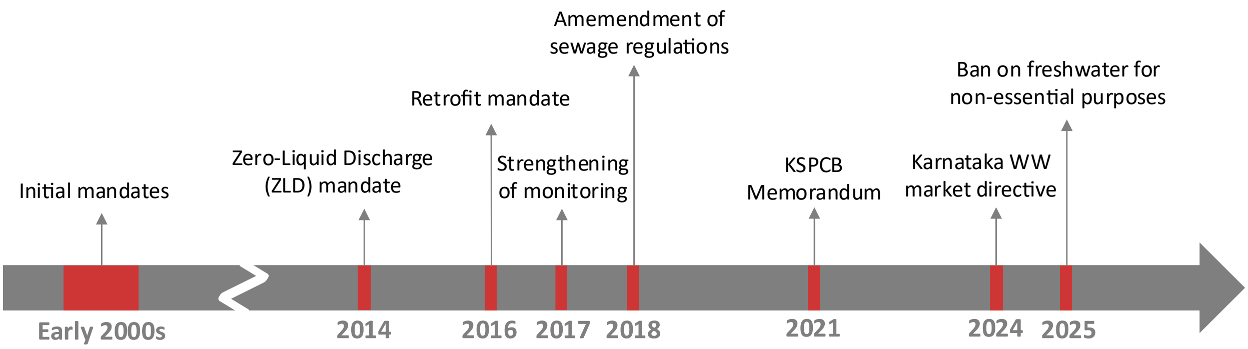

Figure 2: Timeline of policies, mandates and regulations. Own elaboration.

In the following subsections, we will analyse how these pragmatic, yet regime-defying, policies created novel market opportunities for the local DWTRS industry, how the unregulated market was gradually turned into a de-facto experimental space for actors developing transformative innovation, and finally how distributed, yet increasingly dense innovation activities started to accumulate into recognizable innovation system structures aimed at supporting the ongoing transformative leapfrogging trajectory.

4.1 Regime-defying policies

The original DWTRS mandate was experienced as a major shock for construction- and real estate companies in Bangalore (Q3). Technology vendors, often without previous experience in wastewater management, offered treatment plants based on technology from a range domestic and international equipment providers (Q4), and sold their solutions to real estate developers (Q5). After finishing the construction of an apartment complex, the responsibility for the plant is handed over to a Resident Welfare Association (RWA), a legal entity made up of residents, that owns and manages the shared spaces and infrastructures of the apartment complex.

Studies have shown that a vast majority (up to 85%) of the plants installed in this first phase did not work properly (Klinger et al., 2020; Nath et al., 2022). Inappropriate technology designs coupled with cost-cutting among vendors, consultants and real estate developers, left most RWAs with plants that were very expensive to operate (Q5-Q8). RWAs had few means of solving the problems of poorly designed plants and lacked the competences to negotiate with vendors. As a result, many tried to cut costs by delegating the responsibility for O&M to in-house staff, e.g., security guards or parking attendants, or outsourcing operations and maintenance to firms without the necessary competence or resources (Q9). With a lack of accountability between suppliers and end-users and real estate developers focusing on reducing capital expenditures, innovation was disincentivized. *Nightflyer firms* (Mulder, 2020) without the knowledge and skills required to implement proper plant designs exploited the situation by providing cheap, yet poorly designed, DWTRSs and then quickly moving out of business (Q10).

From the perspective of the local government, DWTRS was at this point mainly a pragmatic solution to deal with the challenge of rapid urban expansion. The local government largely lacked the resources and capabilities to effectively and stringently enforce the new mandates, let alone guarantee a baseline quality of the installed plants and their O&M. Several interviewees highlighted that regular inspections were unusual, and lenient when they did happen.

Enforcement took place mainly at the end of the construction phase, when the builder needed approval for the design of the DWTRS prior to starting operation, and through renewing these permits every five years. This approach did not take into account the capacity of the RWA to subsequently operate and maintain the plant.

This led to a situation where DWTRS increasingly malfunctioned and contributed to adverse environmental outcomes, with untreated or partially treated wastewater being released into storm drains, ending up in Bengaluru's expansive system of interconnected lakes (Q11). Disastrous environmental pollution events with pictures of white foam flowing into lakeside neighbourhoods, lakes catching fire and dead fish floating on their surface have attracted local, national and even global media coverage (see National Geographic, 2018). While poorly functioning DWTRSs were not the only source of lake pollution, they had an important overall contribution (Ulrich et al., 2021).

4.2 Unleashing innovation in a city-wide de-facto experimental space

As a reaction to these high-profile pollution events, the zero liquid discharge (ZLD) was introduced to explicitly ban the release of DWTRS effluent into storm drains. This new policy put pressure on RWAs to reuse water for toilet flushing, irrigation and cleaning. It was a key turning point of the leapfrogging trajectory as it spawned more ambitious local innovation activities. DWTRS turned from a peripheral nuisance for residents to a key concern, as they now started to experience bad smell from toilet flushing water and felt the financial impact of having to transport excess treated water away with tankers. As homebuyers became more aware of the adverse impacts of poorly designed DWTRSs, they started inquiring about DWTRS during home inspections, leading real estate developers to pay more attention to them (Q12-13). This dynamic was further strengthened in the most recent period, in which recurring droughts are pushing water reuse high on residents' agendas (Q14).

Some local firms realized early on that this situation represented new business opportunities and started experimenting with technologies and business models for higher quality DWTRS solutions. While not overstating the radicality of the scale or scope of these innovation activities – most of the DWTRS industry continued business-as-usual practices (Q15) – a small subset of dedicated entrepreneurs started tinkering with better performing DWTRS solutions. These ranged from incremental innovations focused on rectifying defunct existing plants, to more radical innovations in plant design and technology aimed at providing more ambitious products and services.

For example, some local firms developed new business models focusing on DWTRS rehabilitation (Q16). They offered to refurbish existing DWTRSs with proper treatment technologies and then operate them with long-term O&M contracts using skilled personnel. While increasing the O&M costs up to three times, this model enabled the RWAs to strongly increase water reuse and fulfil the ZLD mandate, which often also provided a net financial benefit as they could substitute expensive tanker water supplies with a cheaper local water source. Variants of this model also appeared, with vendors taking over malfunctioning plants from RWAs, rehabilitating them, and operating them for a fixed fee, under the condition that they owned the produced water which they could sell later. While not becoming explicitly allowed until 2024, business models for matching residential supply of treated wastewater with industrial water customers in the neighbourhood such as laundries, cooling towers, construction, sites, etc., started to emerge in this period. One local actor even created a logistics system, which matched treated wastewater from its DWTRS with local demand, mostly construction sites, through deliveries with tanker trucks (Q17).

As examples of more radical innovations, some entrepreneurs focused on treating wastewater to near-potable quality to enable a broader set of reuse applications for the RWAs, like using the water in swimming pools. One firm started offering container-sized add-ons to existing DWTRSs that treated wastewater to near potable quality using a series of filters, reverse osmosis, and chemical disinfection. They covered all installation and O&M costs, paid rent to the RWA for the space used for the container and resold the treated water back to the RWA or to nearby industrial water users like laundries, or cooling towers (Q18) at a long-term, fixed fee. Advocates of these solutions started to push the narrative that RWAs may potentially own a *drought resilient* water source that would make them independent from increasing local water scarcity (Q19).

Moreover, innovation also started to emerge among end users. For example, highly skilled residents, often retirees with an engineering degree, started tinkering with their own plants. There are examples of residents without prior knowledge in wastewater treatment having rectified malfunctioning plants by relying on instructions from YouTube and knowledge exchanges with other RWAs (Q20). In some cases, these *prosumers* even turned into entrepreneurs that established new technology suppliers and DWTRS operation firms (Q21). In one RWA, residents connected pumps and blowers in the DWTRS to a self-developed online platform that allowed them to constantly monitor system performance, energy use, and O&M procedures. The software was then sold to more than 100 other RWAs (Q22-23).

Some RWAs also started to experiment with advanced water reuse, beyond what was mandated by law. In a few exceptional cases residents early on started to push towards reusing the water for swimming pools and in two systems even for producing potable water (Deccan Herald, 2015). One apartment complex that we visited had been reusing virtually all their wastewater on-site since 2012, also for cooking and bathing (Q24). These RWAs, however, were often intent on keeping themselves under the radar and their solutions were rarely showcased beyond informal knowledge exchange with other RWAs.

Taken together, the pivot induced by the ZLD mandate and subsequent policies led to a city-wide *de facto experimental space* that induced strong innovation dynamics both at a supplier and demand side. A distinct qualitative shift thus happened compared to the activities in the first phase, which were characterised by “pure” market-driven and often rent-seeking business practices. However, scaling the innovative, but in terms of market shares still limited, new business models and harnessing their full transformative potential has proven very hard in a next phase and remains a key challenge until today.

4.3 Emergence of an embryonic innovation system structure

Up until the most recent period (2023-2025) several innovative approaches emerged which were opening up some early, but rather insignificant, niche markets. The typical firm that offered innovative DWTRS solutions was small, often with an elaborate business plan on how to further scale their market. But barriers for further growth have proven significant. Mostly, firms suffer from uncertain regulatory contexts, lacking expertise in complementary technologies, lacking problem awareness by end-users, still face price competition from nightflyer firms and incumbent actors, including the water tanker industry. The empirical analysis made clear that a high number of these barriers had a systemic quality, i.e., they could only be overcome by conjoint action to establish the field of DWTRS as a potential solution for the immense water challenges of the city.

In terms of *structural barriers*, initially no shared knowledge infrastructures, such as university-industry platforms or applied R&D organizations existed, that supported the generation, storage and dissemination of knowledge related to DWTRS. Firms entering the market had to invest in internal learning, often using standard engineering textbooks or information from the internet (Q25), and were faced with a severe lack of experienced and skilled operators (Q26). Many local innovators thus had to actively retrain engineering graduates to the particularities of DWTRS (Q27). In the broader institutional environment, standards, certification schemes or labels to guide technology choices or identify high-quality products and services were also largely missing. So were enforcement mechanisms to ensure the long-term functionality of the installed systems (Q28). Finally, interviewees pointed out that collaboration was prevented by a strong culture of avoiding interactions with competitors, even when faced by industry-wide barriers (Q30).

In the most recent phase of development, actors have started to identify, acknowledge and act to try to overcome some of these structural systemic barriers. For example, high-end DWTRS vendors and service providers have initiated training programs for operators and organised consumer awareness activities directed to RWAs and real estate developers (Q31). In parallel, RWAs developed informal platforms to exchange knowledge on DWTRS operation and maintenance. These were loosely organized social networks between individual residents and RWA board members (Q32). Local NGOs and research institutes, such as ATREE, Well Labs and Biome Environmental Trust, further engaged in activities that targeted some structural barriers, especially related to regulation, legitimation, and capacity building. More recently, the Bangalore Apartments' Federation (BAF) – an association of RWAs that organizes more than one million individual households across the city – have, together with Well Labs, acted to support the creation of platforms for discussion among vendors and RWAs. There have also been discussions between research institutes, NGOs, vendors and state authorities about establishing training- and certification schemes at the state level (Q33).

However, our analysis also shows that systemic *transformation barriers* are still significantly impeding a transformative leapfrogging trajectory. We have previously touched upon barriers related to *demand articulation*, vividly illustrated by the lack of accountability between technology suppliers and end users in the DWTRS value chain. In terms of *reflexivity*, many actors in the DWTRS industry did not monitor even the most basic performance indicators of their plants and thus missed opportunities for interactive learning with residents and their water customers (Q34). Similarly, policymakers were reflexive on their own interventions only in terms of targeting the most fundamental DWTRS issues with ad-hoc actions when pressured to do so by the public or environmental disasters. There were no systematic measures in place to monitor, anticipate, evaluate and assess the impact of policies, which would provide a forward-looking basis for "ratcheting up" policy support. *Policy coordination* and appropriate policy mixes were largely missing along the development trajectory, illustrated by the ad-hoc layering of mandates and regulations over the last 20 years. Most importantly, there was a lack of clear, balanced and well-enforced fit-for-purpose water quality standards for onsite and offsite reuse respectively, and a lack of coherence between, for example, water policies at local to national levels, as well as urban water policies and policies in the construction sector (Ulrich et al., 2021). Finally, *directionality* was weak in terms of lack of guidance on what sort of problems ought to be addressed and what directions innovation activities in the sector should take. Other than aiming to fulfil mandates, there was a lack of shared visions which established goals among actors across private and public sectors, for example about promising innovation trajectories, and their likely contribution to ease the increasingly daunting water scarcity problem of the city.

In the case of UWM in Bengaluru, it remains a future challenge among stakeholders to address these transformation barriers. It is likely that water crises combined with an increasing awareness about the potential of DWTRS among residents and real estate developers will propel the leapfrogging trajectory forward. There are active attempts among local research institutes to coordination innovation system build-up and venture capital firms have shown increasing interest in supporting the most innovative local players. For example, local stakeholder workshops resulted in a vision of establishing a *Bengaluru Water Reuse Coalition*, which is envisioned as a network of local actors focusing on systemic issues related to capacity building, technology and governance. Taken together, even though the jury is still out on whether the more innovative DWTRS solutions will prevail in the mid-term future, there are increasing signs of system building and coordination that target transformation barriers identified in our analysis.

5 Contours of an alternative approach to transformative leapfrogging

Our results illustrate that the transformative leapfrogging trajectory in Bengaluru follows an iterative, tinkering-based and emergent trajectory, rather than a pre-designed strategic niche management process. The observed trajectory differs fundamentally from conventional state- and market-led approaches to infrastructure development, as well as provides a new twist on the *third route* found in transition studies. The key proposition emerging from our case is that transformative leapfrogging in MICs may not exclusively start form developing novel infrastructure solutions in protected and nurtured in well-managed niches. Instead, leapfrogging may start with a (initially unintentional) push for *second-best* options that feature many imperfections and uncertainties, but may iteratively develop into a transformative innovation trajectory over time. Based on the three analytical steps outlined in section 2.3 and informed by our empirical analysis, we can now further tease out the risks and opportunities of such an approach, including insights on how to harness the potential of experimenting with second-best solutions without falling into the trap of *forever fragmented* and suboptimal service delivery.

First, regime-defying policies, regulations and other socio-institutional conditions may have a widely underestimated potential to spawn transformative innovation activities. In Bengaluru, the set of initial DWTRS mandates allowed a second-best solution to be implemented at a city-wide scale, despite being fraught with imperfections and major performance issues. In this first stage of development, creating a *novel market opportunity* was the main mechanism that induced the leapfrogging trajectory. Yet, *innovating and experimenting* to improve the installed solutions was not a high priority among local actors. This led to poor performance and glaring environmental impacts. This initial situation was thus very far from a conscious pre-designed planning approach, but still the crucial seedbed for subsequent leapfrogging dynamics. Future research should map out and analyse such policies in other cities and infrastructure sectors, to systematically understand how regime defying policies pan out across different regional contexts and under which conditions they may give rise to promising innovation trajectories, instead of turning into failure stories (cf. Ghosh and Schot, 2019).

Second, a critical inflection point in our leapfrogging model is when policies and other context conditions coalesce in a way that incentivize local actors to more systematically innovate on the new solution and experiment with improving its performance. In Bengaluru, this inflection point was arguably the implementation of the ZLD mandate, which triggered feedback between suppliers of solutions and end-users, who were suddenly exposed to treated wastewater in their homes, e.g. when flushing their toilets. The pattern of development thus got reversed if compared to other infrastructure development models: radically novel solutions were first implemented *everywhere* and only later improved in restricted *niche markets* with more demanding quality requirements. A key factor that enabled the leapfrogging trajectory to reach this inflection point was that the local government consistently sticked with supporting the second-best solution and exercised forgiveness in relation to subpar system performance in early phases. It is important to note that the ZLD policy was not consciously introduced to induce an experimental space. But the policy together with increasing water scarcity problems in the city created an incentive structure that made some local actors perceive new business opportunities and endogenize them through their own innovation activities. This stands in stark contrast to developments in other contexts. For example, in Beijing, similar policies was largely abandoned in favour of expanding centralized water infrastructures after performance issues with DWTRS solutions got increasingly evident (Binz et al., 2016). A key future endeavour will be to cross-compare similar developments in other contexts, to identify the structural conditions and mechanisms that turn regime defying policies into de-facto experimental spaces.

Third, another key inflection point is reached when distributed and disjoint innovation processes in a de facto experimental space get more coordinated and connected to a strategic development direction for the ecosystem of innovative actors in the city. By analysing the sum of the identified activities and initiatives in Bengaluru through an innovation system lens, we identified the main barriers that need to be overcome in order to move from loosely coordinated experimental activities to a more coherent innovation system that give clearer direction to the transformative leapfrogging trajectory. In Bengaluru, different business models emerged that reflected particularities in how the socio-technical configuration ought to be set up to function properly. For example, knowledge and skills were missing and financial investments were still directed towards fulfilling policy mandates rather than developing more well-functioning solutions. This related to *structural barriers* in the innovation system. However, it is *transformation barriers* that still impede the transformative leapfrogging trajectory in Bengaluru's UWM sector. Future research will have to explore how system building could look like in contexts with fragmented top-down coordination capacity. A key concern in this regard is to imagine system coordination addressing transformation barriers, without assuming the emergence of a heroic system intermediary of sorts. Conceptual and empirical work will have to explore and substantiate how innovation system coordination in MICs may rely on networked and distributed forms of governance.

6 Conclusion

This paper has examined how transformative leapfrogging in middle-income cities (MICs) may emerge not through conventional state-led planning, free ranging market forces, or strategic niche management, but through large-scale *de facto* experimental spaces. Using the case of Bengaluru's urban water management sector, we illustrated how *second-best* infrastructure solutions were triggered by regulatory mandates and implemented at scale in response to rapid urbanization pressures. While these developments were initially characterized by poor performance and limited coordination, they inadvertently created fertile ground for experimentation towards a transformative infrastructure solution.

Over time, evolving policies and shifting user demand enabled a pivot toward more sophisticated forms of experimentation and innovation by local firms and residents. However, the broader transformative potential continues to be hampered by persistent systemic barriers, especially the lack of coordination and systemic agency across local actors. Rather than supporting the gradual upscaling of pre-selected pilot projects, our analysis suggests that transformative infrastructure leapfrogging MICs might rest on a fundamentally different sequences of mechanisms than what is commonly assumed in urban planning and transition studies. A key challenge of this model is coordinating innovation with ongoing, city-wide implementation of new solutions.

To this end, we have sketched out an alternative approach to leverage policies for transformative leapfrogging, grounded in innovation system thinking and calibrated to the realities of MICs. This model emphasizes leveraging the ingenuity that emerges endogenously in experimental spaces, while dynamically identifying and addressing system failures that hinder scaling. It moves beyond the assumption of centralized control, instead highlighting how coordination can emerge ex post through strategic engagement with real-world experimentation. While based on a single case study, our findings provide analytically generalizable findings that open new avenues for research into how MICs can develop more context-sensitive, sustainable and transformative infrastructure solutions.

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Appendix A: Summary of empirical data

Interviews

Type of actor	Description	Mode	No. of interviews
Traditional DWTRS vendor	Representatives of DWTRS vendors focusing on traditional treatment technologies and solutions. Most interviewed firms were considered, by peers and experts, as delivering well-functioning solutions but their innovation activities were typically limited to incremental improvements of existing products and services.	Face-to-face	7
		Online	1
Real estate developer	Representatives of real estate developers, typically in the high-end segment. Firms were identified by being known by peers or experts as paying attention to the wastewater management systems installed in their projects. This category also includes architects that work as subcontractors to real estate developers and facility management firms.	Face-to-face	10
UWM expert	Individuals with deep and long-term knowledge about the urban water management sector in Bengaluru. Typically works or have worked at research institutes or in state agencies but express their individual views.	Face-to-face	4
Innovative DWTRS vendor	Representatives of DWTRS vendors that stand out by developing and/or supplying highly innovative solutions, e.g. related to new treatment technologies or water reuse systems. This category also includes actors developing additional products and services to complement treatment systems, such as membranes, water tanker transport solutions, sensors and IoT solutions.	Face-to-face	14
		Online	3
RWA	Representatives of Resident Welfare Associations. Interviewees were identified on an individual basis. Most were with RWAs that have either had issues with their DWTRS or have worked with vendors to co-develop new solutions that worked in their context. Most interviews were with individuals holding elected positions in their RWAs, e.g. board members. This category also includes interviews with representatives of associations of RWAs.	Face-to-face	5
		Online	1
RWH technology provider	Representatives of firms supplying solutions for rainwater harvesting to RWAs.	Face-to-face	2
Policy actor	Representatives of city and state authorities, e.g. the Bangalore Water Supply and Sewerage Board (BWSSB) and the Karnataka State Pollution Control Board (KSPCB)	Face-to-face	1
Researcher	Individual researchers or researchers holding positions at research institutes or academic institutions.	Face-to-face	3
Industrial water users	Firms that use water in their industrial processes and, for example, express interest in or already use DWTRS to reuse water.	Face-to-face	3
			54

Site visits

Type of site	No. of sites
DWTRS with traditional treatment technologies	8
DWTRS with water reuse enabled	6
Centralized treatment plants	3
DWTRS with innovative technologies but without water reuse	2
Industrial end-users of reused water	2
Rainwater harvesting systems	2
	23

Stakeholder workshops and other events

Year	Type of event	Description	Stakeholders
2019	Workshop	Workshop connected to the 4S project at Eawag, focusing on small-scale sanitation solutions in India. Xiao-Shan Yap from Eawag attended the workshop and generously shared her notes.	Policymakers, Researchers
2022	Workshop	Workshop organized by ATREE in collaboration with Eawag, before the commencement of the WaterReuseLab project. Participation by the authors.	Policymakers, Firms, Researchers, Intermediaries
2023	Workshop	Workshop organised by WELL Labs and BAF. Participation by the authors.	Firms, Resident Welfare Associations
2024	Online workshop	Online workshop organised by BAF, primarily targeting Resident Welfare Associations. The authors participated and shared preliminary results from the project.	Resident Welfare Associations, Firms
2024	Scenario workshop 1	Workshop organised as part of the project. Focusing on formulating future scenarios for UWM in Bengaluru. Organised by the authors together with WELL Labs and BAF.	Policymakers, Firms, Researchers, Intermediaries, Resident Welfare Associations
2025	Scenario workshop 2	Workshop organised as part of the project. Focusing on formulating future scenarios for UWM in Bengaluru. Organised by the authors together with WELL Labs and BAF.	Policymakers, Firms, Researchers, Intermediaries, Resident Welfare Associations

Appendix B: List of Quotes

1. “The city area has grown too much – there is no space for a centralized system. [..] Decentralized wastewater treatment is the only possibility.” (UWM expert)
2. “Extending the pipe network to 100% coverage is not feasible in a city like Bengaluru. Instead of laying pipelines, decentralized approaches are much more efficient when the city is growing.” (UWM expert)
3. “the new rules came and everyone needed [plants]. The market became huge [..] and everyone wanted to get in.” (DWTRS vendor)
4. “So they have done their own reading and YouTube and this and that, [and have become] knowledgeable about the basics of wastewater treatment.” (UWM expert)
5. "There are consultants that are mainly commission agents. So, it is not only your technical competence which will get you the job, but also how much you're willing to pay.” (DWTRS vendor)
6. “I have nothing against the technologies, excellent technologies, but then they have been forced fitted into the wrong side and that make them to not work.” (DWTRS vendor)
7. “See, the builder is a man who expects the profit only. He least bothered about the environment, he least bothered about the quality, he least bothered about anything. [..] Only for the sake of government orders, he will put some STP. [..] Not all builders are like this, some care about the environment, but many are.” (STP provider)
8. “So, ultimately these dysfunctional STPs fall into the hands of these poor residents. And they suffer a lot. They see a dysfunctional STP not working. So, why throw good money after bad - their mindset is: let us not work this STP at all and they're not getting any return from it, so why you

spend money on this. [..] And that is the reason you have heard about the pollution the lakes in Bangalore for the last 10 years. There has been no action taken against these STPs which cannot work." (DWTRS vendor)

9. The apartments may sometimes not hire professionals. They try to manage themselves, not to spend money, and give the task to [unqualified] staff at the complex." (DWTRS vendor)
10. "There are large companies that do a good job but they are expensive. So 90% of the STP market is controlled by small mom-and-pop shops. So they buy the motor from somewhere, the pump from somewhere, copy another system and put it together. [..] This rarely works." (DWTRS vendor)
11. "all along Bangalore everywhere they put [treated water] into storm water drains, which actually take this water back to the lakes" (DWTRS vendor)
12. "People are becoming more and more conscious that they need to take care of certain things. [..] They have become more interested in the STP when they buy a home." (RWA representative)
13. "Most of the builders only looked at the price, but more and more have started to look also at the technology. They want a system that works and that is sustainable for residents, to compete for home buyers." (DWTRS vendor)
14. "A major problem is the smell [from the plant and the treated water]. This leads residents to not feel good about their water, and wanting to do something about it." (RWA representative)
15. "a clear majority are still building plants that are not working properly" (UWM expert)
16. "We revive defunct STPs, there are so many that are not at all working. We fix them and then do long term contracts for operating and maintaining the plants. We know how to make the orchestra work. That piece is very often missing." (DWTRS vendor)
17. "My team is [..] mapping the plants with extra water, [the] availability and quality, and then we tell them what we are willing to pay. All of this gets onboarded onto our platform." (DWTRS vendor)
18. "We take [one or two] car parking spaces, set up our equipment there, pay rent [to the RWA], take all their excess treated water and convert it to [high] quality, and transport it via tankers to an [nearby] industry" (DWTRS vendor)
19. "if they install a proper plant, they will not have any problems in the next drought. [...] They have experienced it once, and now they want to make changes to avoid the tanker prices next time". (DWTRS vendor)
20. "The residents have realized that they cannot depend on vendors and suppliers anymore, [..] but have become very knowledgeable about the basics of wastewater treatment, by interacting with each other." (RWA representative)
21. "I live in [an apartment complex] and we have a micro sewage treatment plant, which was not up to the mark or not meeting the required compliance standards. [..] We went to the market but [could not find] any vendors. They don't know what they are doing, or they are too expensive. [..] So I asked my neighbour, who had STP experience, and he fixed the STP in three days. Then other neighbours started to ask for help. We decided to start this company." (DWTRS vendor and service provider)
22. "It's basically a SaaS company. [..] We use sensors, which will monitor the bore well operation, along with the water flow. [..] And we monitor the pumps and electricity use in the STP. And many other things. [..] any overflow or any alarms in your bore wells or whatever, it gives you an alarm." (Entrepreneur)
23. "some facility management committee companies have subscribed to [our solution] to get a whole handle of things by their backend team, and they are able to give some benefits back to the customers, and get more business." (Entrepreneur)
24. "What we do is, from the wastewater, we treat that water. And then, we mix it with the fresh ground water. And then give it for treatment and [use] it directly. So, our treated water does not get into the drain at all. It comes back to our inflow system." (RWA representative)

25. “And today, thanks to what we have by way of internet, we can sit down and learn a lot of things ourselves. We don't need a teacher to come and tell us, we can learn a lot of things. Now this water management is not rocket science. […] And there are good textbooks available for STP design as well.” (DWTRS vendor)
26. “There is no guidance provided. [..] we have [asked] the government to set up some sort of a training where you certify that these guys are capable of running and maintaining an DWTRS”. (Real estate developer)
27. “It is not possible to hire an engineer straight from college. The knowledge can’t be transferred to the small scale. […] There is no university in India which teaches you how to design a [DWTRS].” (DWTRS vendor)
28. “[The city] was not able to manage the switch. This was a quick-fix. They realized that ‘okay, let's take it off our books - let's make communities responsible for their own sewage’. [..] But no one told them how to do it.” (UWM expert)
29. “We're going to depend on vendors, and we have not been given any guidance for finding good vendors we can go to, neither to buy the product nor to run the system.” (Real estate developer)
30. “There is never a true collaboration. I'm not going to open my heart and speak to you about the problems that I have […]. It is generally a situation that we probably don't see it happen in India very easily.” (DWTRS vendor)
31. “[We] are working to form an alliance or association, and on one side support enforcement, on the other side educate the residents.” (DWTRS vendor)
32. “The residents have realized that they cannot depend on vendors and suppliers anymore, [..] but have become very knowledgeable about the basics of wastewater treatment, by interacting with each other.” (RWA representative)
33. “There is no guidance provided. [..] we have [asked] the government to set up some sort of a training where you certify that these guys are capable of running and maintaining an DWTRS”. (Real estate developer)
34. “There are very, very few, actually, that are responsible in the long term. [Retracted] is one that I know of, but most of them are generally trying to provide and forget.” (UWM expert)

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