Master’s Thesis – master Innovation Sciences

Shaping the emerging alternative service regime from a Technological Innovation System perspective: the case of decentralized water and sanitation in Bangalore

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Summary

Caused by the rapid urbanization of the city, Bangalore has been lacking to provide adequate water and sanitation services for its citizens. As the centralized water supply and sewerage network has been unable to meet this rapidly growing demand, Bangalore has been increasingly confronted with water shortages and lake pollution issues. In order to cover for these shortcomings, Bangalore has been pushing for decentralized water and sanitation technologies. However, due to the lack of coordination and guidance provided by the government and others, a large number of decentralized solutions were either sub-optimal for their context or became completely dysfunctional. Moreover, policy directives were poorly received by citizens, leading to the unsuccessful diffusion of many decentralized solutions.

The challenge for Bangalore was therefore to overcome these development and diffusion barriers in order for these technologies to be serving as a sustainable alternative to the centralized systems. In order to understand the mechanisms contributing to the shift towards more sustainable practices of basic services, innovation scholars have proposed the Technological Innovation System (TIS) framework. This study has adopted the TIS framework in order to analyse the mechanisms contributing to the development and diffusion of decentralized solutions in Bangalore. Due to the different development challenges and goals of these decentralized solutions, they have been developing in two sub-TISs. One is the water recycling sub-TIS and the other is the on-site sewage treatment plant (STP) sub-TIS. For these decentralized solutions to be serving as an alternative decentralized service regime (way of doing things), a better understanding of the development and alignment of these two sub-TISs is needed. Therefore, this study conducted a qualitative event analysis, based on a period of 15 years (2006-2020), in order to identify the key mechanisms contributing to the development and alignment of these sub-TISs.

Findings of this study indicate that particularly the (mis)alignment between shared visions, regulatory measures and user legitimation, contributed to the (un)sustainable development of both sub-TISs. As both sub-TISs have been insufficiently developed and have been emerging rather separately, they cannot serve as a fully functional alternative service regime to the centralized systems yet. However, when both these sub-TISs would be integrated more, the establishment of a decentralized urban water management service regime may start to emerge.

Table of Contents

Figures

Tables

1. Introduction

Rapid urbanization and rising social and environmental problems are among the main challenges for urban administrations in achieving sustainable growth (Keivani, 2010). While various cities in developing countries demand an increasingly dominant role in the global economy as centres of production and consumption, the development of basic infrastructure and services often lags behind. (Cohen, 2006; Welie, Cherunya, Truffer, & Murphy, 2018). One of the cities that faces these exact circumstances is the third-most populous city of India, i.e. Bangalore. Bangalore has the second fastest-growing economy in India and is often referred to as the 'Silicon Valley of India' due to its fast growing number of Information and Technology start-ups (Sudhira, Ramachandra, & Subrahmanya, 2007). The prosperous growth of Bangalore's economy however contrasts to the way in which basic services are developing within the city (JICA & NJS, 2017; Sudhira et al., 2007). To date, it has not been possible to expand urban infrastructures, that enable the provision of basic services at the same pace as the increase in demand (Chaplin, 2011). Unmet demands for the management of water and sanitation services have already resulted in water shortage, heavily polluted lakes, rivers and groundwater caused by untreated wastewater, and a multitude of unhygienic practices leading to various health problems (Chaplin, 2011; JICA & NJS, 2017).

Many innovative initiatives have been confronting these challenges, attempting to reconfigure local water and sanitation services towards more sustainable configurations (Schaefer, 2008). However, these innovations often failed to establish or scale up as entrepreneurs struggled to link their initiatives to institutional, financial and/or cultural means (Ahmed & Ali, 2006; Murphy, McBean, & Farahbakhsh, 2009; Ramani, SadreGhazi, & Duysters, 2012), while other innovations failed to be maintained and/or monitored properly (Carter, Tyrrel, & Howsam, 1999; Puttaswamaiah S, 2005). When local authorities started pushing for the adoption of decentralized water and sanitation solutions (e.g. on-site sewage treatment plants), instead of primarily leaning on the extension of centralized systems (e.g. networked piped sewerage systems), similar problems arose in Bangalore leading to major challenges in implementing and diffusing those decentralized solutions (Kuttuva, Lele, & Villalba Mendez, 2017). Local governments in developing countries are increasingly pushing for decentralized water and sanitation solutions as they proved to be more economical and environmental effective in difficult contexts such as poor site conditions (Kuttuva et al., 2017; Massoud, Tarhini, & Nasr, 2008).

A major turning point for Bangalore, in terms of pursuing a decentralized, was the moment when the Ministry of Environment, Forest and Climate Changes introduced a dedicated policy in 2006, directing all new large construction projects (built up area > 20.000 m²) such as residential apartment complexes, hotels, malls, to safely manage and treat their own wastewater (Klinger et al., 2019; MoEF, 2006). Policy measures like these triggered the installation of many decentralized wastewater systems in India, whereof an estimated 10-20% of wastewater produced in Bangalore, treated through such systems (Klinger et al., 2019). Although every state in India was allowed to define their own norms with regard to whom this directive applied, particularly Bangalore has set these norms more vigorously in comparison to other states and cities (Kuttuva et al., 2017; Reymond, Chandragiri, & Ulrich, 2020). Additionally, also rainwater harvesting systems (RWH) and groundwater recharging techniques were heavily driven by policy measures in Bangalore over the last two decades (Manasi & Umamani, 2013). However, due to various associated problems such as the lack of guidance, knowledge and skilled labours, many decentralized water and wastewater technologies were either slowly diffusing, sub-optimal for their contexts, or ended up dysfunctional (Klinger et al., 2019; Manasi & Umamani, 2013;

Reymond et al., 2020). This research therefore aims to get a better understanding of the blocking mechanisms and how they could be overcome.

As a result of these dedicated policies that push for the decentralization of services, an increased level of activity within the water and sanitation sector of Bangalore can be observed, where various actors advocate for different solutions they perceive ideal (Klinger et al., 2019; Kuttuva et al., 2017). Amid the above challenge, certain actors are pushing for well-functioning on-site sewage treatment plants, while others are promoting water recycling solutions, including rainwater harvesting and groundwater recharging (Mahapatra & Bhat, 2014; Manasi & Umamani, 2013). Because a decentralized approach for the treatment, recycling, and reusing of water and wastewater has not yet established and stabilized to serve as a reliable and sustainable alternative for the centralized approach, various actors are pursuing or pushing for different technological trajectories as solutions to the challenge (Klinger et al., 2019; Kuttuva et al., 2017).

Despite the wide variety of available technologies, decentralized solutions are not successfully developing and diffusing throughout Bangalore. In the field of transition studies, the Technological Innovation System (TIS) approach emerged to provide for an understanding of the innovation activities that are involved in development of technology, which may be a precondition for a transition. This study therefore adopted the TIS approach as it allows scholars to analyse the structural components, i.e. actors, institutions, interactions, infrastructures, and the functions (key processes) involved in the development, diffusion and use of a particular technology or technological field (Bergek, Jacobsson, & Sandén, 2008; Edquist, 1997; Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). Therefore, the TIS approach has often emphasized on the innovation activities contributing to the emergence of novel and sustainable socio-technical configurations (Hodson & Marvin, 2010; Markard, Raven, & Truffer, 2012; Smith, Stirling, & Berkhout, 2005). However, in the case of Bangalore, it is not necessarily a matter of stimulating the development of novel socio-technical configurations, but rather how these emerging socio-technical configurations could be contributing to a more sustainable water and sanitation sector in the future. Innovation scholars have therefore not only focused their research on the effective generation of innovation, but increasingly dealt with the direction of transformative change. Weber and Rohracher (2012) argue that societal challenges, such as sustainable development, cannot be fulfilled without shaping the 'directionality'. Shaping the directionality involves the proactive stimulation of specific innovation activities that contribute to the direction of long-term transformative change (Weber & Rohracher, 2012). In the water and sanitation sector of Bangalore, shaping the directionality is key in order for these decentralized solutions to be contributing to a more sustainable sector.

Innovation scholars have argued that in order to overcome an incumbent 'regime' of practices, an alternative 'service regime' (i.e. way of doing things) needs to gain momentum (Welie et al., 2018). A service regime encompasses an institutionalized combination of technologies and associated practices serving a particular user segment as of the 'sectoral regime' (the societal function it fulfils) (Welie et al., 2018). In the context of Bangalore, this study considers the sectoral regime as the whole water and sanitation sector of Bangalore, which includes two service regimes, i.e. the conventional centralized service regime and the alternative decentralized service regime. All of the decentralized solutions that are emerging in Bangalore are considered to be part of the alternative service regime. The ongoing challenge for Bangalore is whether the recently developed socio-technical configurations, including various decentralized solutions, could potentially integrate into an alternative new service regime. This study considers each socio-technical configuration as a separated TIS that together forms a larger TIS, hence they are called sub-TISs. In Bangalore, two sub-TISs are developing, namely, the water recycling sub-TIS and the on-site sewage treatment plant (STP) sub-TIS. The establishment and scale of the emerging service regime is heavily reliant on the alignment within and between these two sub-TIS (i.e. socio-technical configurations).

Because policy makers, planners and other technology strategists are eager to coordinate these two sub-TISs towards a well-established alternative service regime in Bangalore, it makes an interesting and crucial case to study the particular TIS processes contributing to the development and alignment of these two sub-TISs. In other words, by analysing these TIS processes over time, it helps to identify the key mechanisms driving the directionality towards the alternative decentralized service regime in Bangalore. By doing so, this study could contribute to the limited understanding of directionality in the TIS literature (Yap & Truffer, 2019). Based on this, the following research question has been formulated: *"How would the different socio-technical configurations of decentralized water and sanitation contribute to the development of a fully functional service regime in Bangalore?"*.

The main research question will be answered through the following sub-questions:

SQ1: What are the structural components contributing to the development of the two decentralized water and sanitation configurations in Bangalore, i.e. forming two sub-TISs?
SQ2: How do the functional components of the two sub-TISs change over time?
SQ3: How do the emerging sub-TISs contribute to the development of an alternative service regime in the water and sanitation sector of Bangalore?

The aforementioned questions will be answered by employing a qualitative case-study, based on news, journal and magazine articles obtained from the LexisNexis database and policy reports sourced through Google. The sub-TISs can be clearly delineated based on the structural and functional components identified. By analysing how the functional components of the TIS change over a period of 15 years (2006-2020), this study is able to distinguish the key innovation processes contributing to the development and integration of these two sub-TISs. In doing so, it sheds lights on how these processes have driven and might drive the directionality of an emerging alternative service regime in the future. As literature has treated all TIS processes as rather homogenous in influencing directionality (Bergek et al., 2008), this study contributes scientifically by identifying how the importance between TIS functions could differ in contributing to the establishment of an alternative service regime. Insights of this study may therefore help policy makers better understand the context of developing countries in dealing with societal challenges. In more specific terms, insights of this study can be used by the local government to stimulate the establishment of an alternative service regime, which could accelerate the provision of sustainable water and sanitation service throughout Bangalore

The remainder of this thesis is structured as followed, Chapter 2 will introduce the theory and associated concepts used for the analysis. After, Chapter 3 will give an outline of the methods used and data obtained. Chapter 4 presents the results of the data analysis. Chapter 5 provides a conclusion of the analysis and Chapter 6 ends with the theoretical contribution and limitations of the study.

2. Theoretical framework

This chapter presents an overview of the theory and associated concepts that will be used to get a better understanding of the present problem. Subsequently, it will be argued for how these theoretical foundations will help answer the concerning research questions. This research will empirically validate the concepts found in literature and additionally aims to contribute conceptually by providing insights on how different functions of a TIS affect the establishment of an alternative service regime.

Section 2.1 – Technological change

Innovation scholars have been researching technological change from mainly two analytical perspectives (Markard & Truffer, 2008). One perspective looks at technological change by focussing on the prospects and dynamics within a particular 'technological system' driving technological change (Bergek et al., 2008; Carlsson & Stankiewicz, 1991; Hekkert et al., 2007), while the other perspective looks at technological change from a more aggregated level, including broader transition processes in which a variety of innovations challenge the established 'technological regime' (Geels, 2002; Rip & Kemp, 1998). Both these perspectives build upon insights from Dosi (1982).

According to Dosi (1982), technological changes occur along a *technological trajectory*, stemming from a *technological paradigm*. A 'technological paradigm' can be defined as "model and pattern of solution of selected technological problems, based on selected principles derived from natural science and on selected material technologies" (Dosi, 1982, p.152). A technological paradigm, or a cluster of technologies, limits the directions in which technology develops, prescribing what direction of change to pursue and what to neglect (Dosi, 1982). The direction of technological change follows a 'technological trajectory', which is defined as: "the pattern of normal problem solving activity (i.e. of progress) on the ground of a technological paradigm" (Dosi, 1982, p.152). These concepts provide for an explanation of how technological development is bounded and may help to delineate the important aspects contributing to the direction of technological change.

However, as been pointed out by Kemp (1994), technological change moves beyond this rather 'engineering' perspective of improvements in costs and performance (Dosi, 1982), as these improvements are the result of a better understanding of users and the adaptability of the socio-economic environment to a particular technology (Kemp, 1994). In a similar vein, Bijker (1995) pointed out that various actor groups (e.g. users and policymakers), that have a special interest in a certain technology, are likely to contribute to the pathway of technological development (Bijker, 1995). This extended perspective on technological change have led innovation scholars to identify a multitude of socio-technical aspects, interacting in a system or embedded in a regime, that influence the development and direction of innovation and technological change (Carlsson & Stankiewicz, 1991; F. W. Geels, 2002; Rip & Kemp, 1998). For the remainder of this thesis, this study therefore adopted the notion of 'socio-technical configuration' to refer to the interrelated set of technologies and institutional elements, that are able to fulfil a specific societal need (Rip & Kemp, 1998).

The development pathway a particular technology or set of technologies is following is thus highly affected by the socio-technical context in which it is generated, diffused and utilized. In practical terms, this means that apart from engineering considerations, also fewer tangible aspects become important when aiming to understand technological development and directions of technological change (Murphy et al., 2009). In developing contexts, aspects such as the ability of the local community to operate and maintain the technology themselves, the encouragement of local participation, or the adaptability of the technology to the changing environment, are crucial (Murphy et al., 2009; Klinger et al., 2019). Other factors that play a particular decisive role in the development and direction of technological pathways, are the availability of financial and human resources, cultural aspects, and site specific characteristics such as soil quality and the availability of space (Klinger et al., 2019; Reymond, Chandragiri, & Ulrich, 2020; Singh, Kazmi, & Starkl, 2015). These socio-technical aspects may vary significantly within close spatial distances, making the development and diffusion of technologies highly context specific.

To account for the range of socio-technical aspects that could influence the development and direction of technological change, innovation scholars have often looked at the 'socio-technical system' surrounding a particular technology or set of technologies (Carlsson & Stankiewicz, 1991; Jacobsson & Bergek, 2004). Sustainability transitions literature has specifically emerged as a research field to study transformation processes through which the established 'socio-technical system' shifts towards more sustainable configurations (Markard et al., 2012). However, this perspective on socio-technical change has often been criticized for being too simplistic when studying heterogenous, complex and spatial uneven contexts, such as that of basic service sectors in developing countries (Geels, 2011; Welie et al., 2018).

To overcome the abovementioned issue, Welie et al. (2018) argue that a basic service sector consists of a diverse set of co-existing 'service regimes' that each serve a particular user segment, together forming and strengthening the 'sectoral regime'. A sectoral regime refers to the broader societal function it fulfils (i.e. water and sanitation service provisioning) (Welie et al., 2018). A 'service regime' forms around a "specific institutionalized combination of technologies, user routines and organizational forms providing a service" (Welie et al., 2018, p.260). Inspired by the service regime concept, this study argues that developing socio-technical configurations do not necessarily lead to the substitution of an entire sectoral regime, but instead could lead to the substitution of an established service regime or to the stabilization of a new service regime. Multiple socio-technical configurations may be part of the same service regime that could lead to different end-points of the transition (e.g. a better alignment in or between service regimes) (Welie et al., 2018). In a sum, the service regime concept provides for an explanation of the interrelatedness of particular socio-technical configurations and allows one to account for the heterogeneity of basic service sectors.

To get a better understanding of how the socio-technical configurations could scale up and lead to an alternative service regime, a more detailed analysis of the structures and processes contributing to the development and the alignment of these socio-technical configurations, is needed.

Section 2.2 – Technological Innovation System

Over 30 years ago, scholars have acknowledged that innovation is not an isolated phenomenon, but rather occurs in a collective effort, influenced by various socio-technical aspects (Freeman, 1987; Kline, 1985). This acknowledgement led to a large number of studies emphasizing on the different contextual elements that deemed important for the emergence of innovation (Lundvall, 1988; Nelson, 1993). Innovation scholars have bundled these socio-technical elements as part of an Innovation System (IS) (Edquist, 1997). Originating from multiple disciplinary traditions such as evolutionary economics (Nelson & Winter, 1982), innovation systems became a prominent approach for the analysis of innovation development and diffusion. Moreover, innovation system analyses were often conducted to inform policy makers about the lacking aspects of the system (Hekkert et al., 2007; Jacobsson & Bergek, 2004). For analysis purposes, many variations of the IS concept have been proposed in literature, delineating the boundaries of an innovation system to a specific geographical, industrial or technological context (Cooke, 2001; Edquist & Lundvall, 1993; Hekkert et al., 2007; Malerba, 2002).

Studying the socio-technical context of a particular technology or technological field has proven to be valuable for a better understanding of how technology changes. In the field of transition studies, four major lines of research have emerged contributing to a better understanding of systemic change, namely; Transition Management, Strategic Niche management, Multi-Level Perspective and the Technological Innovation System framework (TIS) (Markard et al., 2012). While the former three lines of research aim to provide for a better understanding of how transitions unfolds, the latter line of inquiry particularly focuses on how socio-technical aspects and mechanisms contribute to the emergence of radically novel technologies or technological fields (Alkemade, Negro, Thompson, & Hekkert, 2011). The TIS framework deals more explicitly with the strategies of actors and their agency, thereby allowing for a better explanation of how different technological alternatives, embedded in the same regime, lead to different outcomes and successes (Alkemade et al., 2011). Therefore, this study argues that the TIS approach would be beneficial when aiming to understand the development of different socio-technical configurations and the way they contribute to the development or stabilization of a service regime.

The Technological Innovation System (TIS) is defined in literature as "a network of agents interacting in the economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology" (Carlsson & Stankiewicz, 1991, p. 111). In line with this definition, many innovation scholars have argued for the decisive role of various actor groups and institutions within the TIS (e.g Edquist, 1997; Smits & Kuhlmann, 2004). In addition, others have emphasized on the role of interactions between these actors and the physical or knowledge infrastructure, as important dimensions of the TIS (Geels & Raven, 2006; Smith, 1997). The four structural components and their types have been listed by Wieczorek & Hekkert (2012), see table 1 below.

Table 1 - Summary of the structural components of a TIS, derived from Wieczorek & Hekkert (2012)

Structural components	Description
Actors	Actors of a TIS can be categorised into individuals, organisations or networks that play a certain role in the economic activity, including: civil society, government, NGOs, firms (from start-up to multinationals), knowledge institutes (e.g. universities), and other parties such as legal and financial organisations, intermediaries and consultants
Institutions	Institutions are common habits, routines and belief, which are considered 'soft' institutions. Established rules, norms and laws are considered 'hard' institutions.
Interactions	Interactions are the relevant links between actors of a TIS occurring within networks or between individuals
Infrastructure	The infrastructure of a TIS that should be considered is either physical, knowledge or financial. Physical infrastructure are e.g. the roads, buildings, machines and instruments. The knowledge infrastructure encompasses the expertise, know-how and strategic information existent in the TIS. The financial infrastructure includes the grants, subsidies a financial program

Rather than merely considering the structural components, the TIS perspective allows for a more dynamical understanding of technical change (Bergek et al., 2008; Hekkert et al., 2007). That is why the TIS approach can be used for the analysis of regime change that contributes to sustainability transitions (Markard et al., 2012). To strengthen the analytical power of the TIS framework, next to the structural components, several key processes (functions) are proposed that drive the development, diffusion and use of new technologies within the TIS (Bergek et al., 2008; Hekkert et al., 2007). A dynamical understanding of socio-technical change can be obtained by mapping the seven functions determining the performance of a TIS, which are: *F1 entrepreneurial activities, F2 knowledge development, F3 knowledge diffusion, F4 guidance of the search, F5 market formation, F6 resource mobilization and F7 creation of legitimacy* (see table 2 for details). The interplay of these functions result in a particular direction of socio-technical change (Hekkert et al., 2007).

Table 2 - Summary of the functions of a TIS, derived from Hekkert et al. (2007)

System functions	Description
Function 1: entrepreneurial activities	The activities leading to new knowledge, networks or markets. Experiments are undertaken by entrepreneurs that are willing to take risk and able to cope with uncertainty inherent of these experiments.
Function 2: knowledge development	The development of knowledge through research and development activities and learning mechanisms.
Function 3: knowledge diffusion	The transfer or exchange of information through network activities such as workshops or conferences. Activities that result in 'learning by doing' and 'learning by using'.
Function 4: guidance of the search	Those activities that influence the selection processes of particular technological options. Activities that affects the wants of specific technology users.
Function 5: market formation	The creation of protected spaces or the creation of a competitive advantage for new technologies to be able to establish.
Function 6: resource mobilization	The financial and human capital resources available in the innovation system allowing the activities within the system to be carried out.
Function 7: creation of legitimacy	The activities causing new technologies to be more accepted or disregarded. These activities are considered as a form of lobbying.

It is important to understand that these functions interact and reinforce one another over time (Suurs, Hekkert, Kieboom, & Smits, 2010). In example, the activities and number of entrepreneurs (F1) are likely to influenced by the knowledge that is created (F2), which in turn is influenced by the availability of resources (F6) within the TIS. The reinforcement of functions, so called 'cumulative causations', can lead to a more rapid development of the TIS. These feedback cycles are either positively ('motors of innovation') or negatively ('vicious cycles') contributing to the development of the TIS (Suurs et al., 2010). The identification of these feedback loops may explain why a particular TIS is developing at a certain pace or towards a certain direction (Hekkert et al., 2007).

Section 2.3 – A better understanding of direction of technological change

In order to be able to understand how TIS functions contribute to directionality, this study will reflect on recent innovation systems literature and address several shortcomings of the TIS framework. Although the process-lens would be beneficial for a better understanding of the direction of technological change, the TIS approach comes with limitations. One of the limitations of TIS is that it is often used to analyse the emergence of one single dominant technology, neglecting important contextual structures such as the surrounding and related technologies (Bergek et al., 2015). Due to the heterogeneity of basic service sectors in developing contexts, the emergence of one dominant technology does usually not apply (Welie et al., 2018). Instead of analysing the emergence of one dominant technology or technological trajectory, a TIS analysis could also be extended to analyse the development of socio-technical configurations that encompass multiple co-existing technologies (De Oliveira & Negro, 2019).

To address the technology-centric perspective of the TIS, this study draws on insights from the 'valuation approach' introduced in the recently proposed Global Innovation System (GIS) framework. Binz and Truffer (2017) argue that a lot of research has focused on the supply of knowledge (knowledge-based technological innovation) when trying to understand technological development, but very little has been said about the demand of knowledge or technologies in this regard. Next to the supply-side of knowledge or technology, they introduce the 'valuation processes', inspired by several TIS functions, to more explicitly account for the demand related processes of technological development and adoption, which are; market formation, resource mobilization and technology legitimation (Binz & Truffer, 2017). These processes determine whether or not a product is valued by a particular user segment. Moreover, these valuation processes are considered to be of more decisive importance in industries introducing relatively novel technologies based on the local context, while technological advances (and thus technological variances) become less decisive (Binz & Truffer, 2017). Additionally, a more geographically sensitive approach gives hearing to another critique of the TIS approach, as the TIS approach has been predominantly used and developed in contexts of OECD-countries instead of in contexts of developing countries (Blum, Bening, & Schmidt, 2015; Gosens, Lu, & Coenen, 2015). Therefore, by making market formation, resource mobilization and technology legitimation processes central to this study, more emphasis is given to the local context in which a technology emerges and less emphasis on technological advances and variances. This extends the analytical scope of the TIS framework as emerging towards one dominant design, to a more general perspective of how a socio-technical configuration (including its technological varieties) is valuated by actors in the system.

However, something that is not addressed by the valuation approach is how 'guidance of the search' processes influence the development of socio-technical configurations, thereby shaping the directionality of the emerging alternative service regime. The valuation approach lacks to explain the role of visions and expectations, or how governance practices may shape the direction of socio-technical development. Yap & Truffer (2019) argue that the selection environment, to which a technology is exposed, is shaped by particular considerations and motivations, influencing the emergence and development of a socio-technical trajectory. Therefore, the mechanisms associated with the function 'guidance of the search' (GS) are arguably most directly related to shaping the selection environment, leading to a particular directionality of the TIS (Weber & Rohracher, 2012; Yap & Truffer, 2019). However, the proposed GS framework explains well for a case when there is a clear emergence of a single dominant technological trajectory. It remains unclear how the notion of GS will be when multiple technological trajectories co-exist as part of a socio-technical configuration. It is therefore relevant to analyse the meaning of the GS process in the water and sanitation sector of Bangalore.

In sum, it would be insightful to analyse the interplay between valuation aspects and guidance of the search in influencing the development of socio-technical configurations in underdeveloped contexts such as Bangalore. Using these insights will allow one to show how TIS functions contribute to directionality.

In the context of this case study, the two socio-technical configurations can therefore be analysed as part of the emerging alternative service regime, given that both the configurations share several structural components (i.e. actors, institutions, interactions and infrastructure) and a similar overarching goal. Subsequently, how the processes of knowledge or technological development, valuation and guidance of the search are co-evolving over time will give an indication of the importance of certain functions in driving the directionality towards an alternative service regime in Bangalore (RQ2/3). Figure 1 summarizes the conceptual approach used in this study in order to answer the proposed research question.

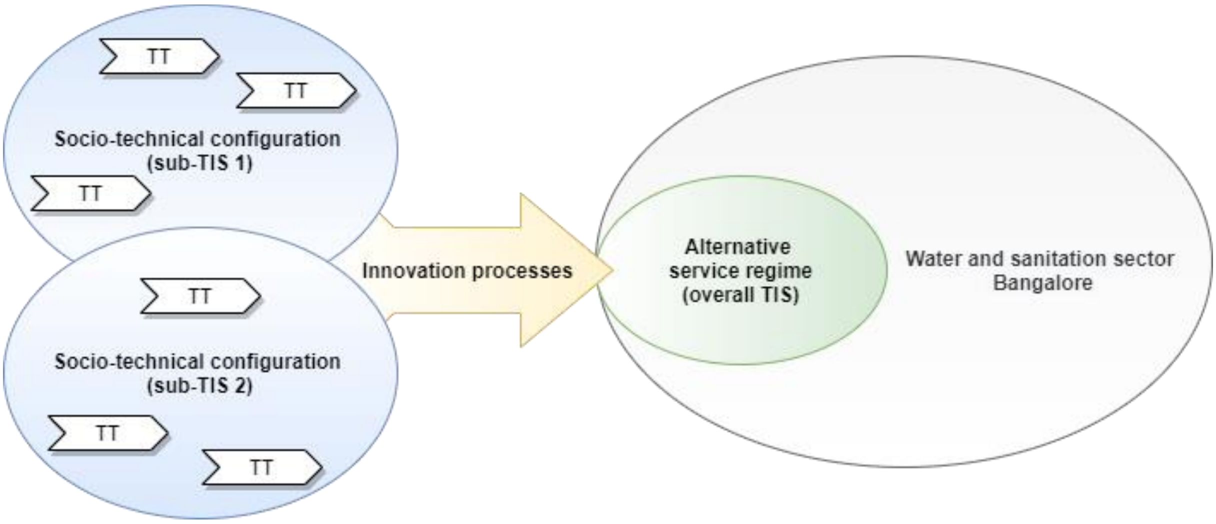

Figure 1 – Conceptual delineation of the water and sanitation sector of Bangalore [1]

[1] TT stands for Technological Trajectories (e.g. different kinds of technological options such as Membrane Bioreactor, Sequencing Batch Reactor or DEWATS).

3. Methodology

In this chapter, an overview of the selected methods will be given, and it will be argued for why these methods are considered appropriate for answering the research questions. Moreover, to provide for a contextual background of the study, a description and delineation of the selected case will be provided. Lastly, it will be argued for how the research quality will be ensured.

Section 3.1 – Research design

This study is based on both deductive and inductive principles, as existing concepts in literature were measured and additionally revised or complemented based on empirical findings. A qualitative case-study has been employed as it allows for a deeper understanding of the concepts being tested (Bryman, 2012). Furthermore, the decentralized water and sanitation segment of Bangalore is considered both an '*extreme*' and '*exemplifying*' case type (Bryman, 2012). This case is *extreme* given the dedicated policies put in place in Bangalore for the decentralization of practices, and is considered as *exemplifying* because Bangalore's question for an alternative service regime might serve as a learning example for other developing cities, which see limits to expand the centralized model to all its citizens.

Section 3.2 – Case description and boundaries

With a population size rising well above 10 million, Bangalore is one of the largest and fastest growing cities in India (Sudhira et al., 2007). Rapid and unsustainable urbanization pathways are causing significant inequalities within the city of Bangalore in terms of basic service provisioning (Saroj, Goli, Rana, & Choudhary, 2019). Basic service infrastructures, such as the availability and accessibility of water and sanitation, are unevenly distributed along socioeconomic, religion, and gender lines (Rajaraman, Travasso, & Heymann, 2013; Saroj et al., 2019; Welie et al., 2018). While almost all citizens in Bangalore have access to toilet facilities, only an approximate 62% of the produced wastewater is treated. The rest of the produced wastewater is left untreated or illegally dumped in open drains or lakes. (Eawag & CDD Society, 2019; JICA & NJS, 2017). Furthermore, in 2013, an approximate 93% of the citizens in Bangalore had access to safe drinking water, either supplied by the Cauvery river, extracted from (bore)wells or periodically supplied by water tankers (Raj, 2013). However, as the Cauvery water supply is restricted, the majority of wells went dry, and the supply of water through tankers appeared to be unreliable, Bangalore became short on water fast. Moreover, due to the alarming levels of sewage pollution and the unsustainable growth in number of citizens, the centralized way of water supply and sewage treatment appeared to be inadequate. Because of these various reasons, Bangalore is exploring a decentralized approach for the treatment, recycling and reuse of water and wastewater (JICA & NJS, 2017; Kuttuva et al., 2017; Manasi & Umamani, 2013; Raj, 2013).

A wide variety of decentralized water and sanitation technologies are advocated in Bangalore, each having different pros and cons depending on the context it is implemented (Singh, Kazmi, & Starkl, 2015). Particularly on-site STPs for the treatment of blackwater or a combination of black and grey water consists of many variants, including; nature based STPs (e.g. waste stabilization ponds, constructed wetlands), aerobic STPs (e.g. Extended Aeration Activated Sludge Process, Membrane Bioreactor, Moving Bed Biofilm Reactor, Sequential Bioreactor), or the combined anaerobic and anaerobic STPs such as DEWATS. In 2017, there were over 2.000 residential on-site STPs installed in Bangalore, of which the extended aeration activated sludge process (Kuttuva et al., 2017), sequencing batch reactors, and moving bed biofilm reactors were most prevalent (Klinger et al., 2019). Decentralized technologies for the catchment, recycling and reuse of water and rainwater, include

Greywater Treatment Plants, Rainwater Harvesting technologies (e.g. rooftop and runoff from landscapes, storm water drains, roads) and Groundwater Recharging (GR) methods. In 2013, over 25.000 households were equipped with a RWH system (Manasi & Umamani, 2013).

Section 3.2.1 – Case boundaries

The case boundaries can be delineated based on the structural and functional components of the TIS that have their presence or occur within the geographical boundaries of Bangalore. Some structural and functional components at the national or state level, which have a direct impact on the development of the TIS in Bangalore, are included in the analysis. For instance, national or state level components such as policies, actors or the general public discourses, that particularly influences the development and diffusion of decentralized solutions within Bangalore, are included. All structural and functional components that do not have their presence or influence the public discourse in Bangalore, are excluded for the analysis. However, it is assumed that most of the relevant processes occurring in India will resonate in or towards Bangalore due to the following three reasons; 1. Bangalore has been pushing on decentralized water and sanitation technologies most heavily in India, 2. Bangalore has the largest number of on-site STPs installed compared to other cities in India, and 3. half of the private sector actors in India that are involved in on-site STPs are located in Bangalore (Klinger et al., 2019).

Section 3.3 – Data collection

For this study, secondary data has been gathered from the LexisNexis database, which has been complemented and triangulated with a few semi-structured interviews. Prior to these interviews, two scoping study interviews were held with water and sanitation experts from Eawag (table 3). Through a process of trial-and-error (see appendix A), a total of 484 news articles and 53 magazines and journal articles were gathered from the LexisNexis database. From these, a total of 249 news articles were considered relevant and have been used for the analysis. These articles were published in the following nine English newspapers; New Indian Express (77), The Times of India (66), Mirror Publications (44), DNA (42), MINT (9), The Economic Times (5), The Hindu (4), Hindustan Times (3), The Financial Express (2). Out of the 53 magazine and journal articles, 20 articles were considered relevant for the analysis, including Business World (5), Realty Plus (3) Information Week India (2), Economic & Political Weekly (1), and others. Due to the poor documentation of decentralized water and sanitation technologies and associated processes (Klinger et al., 2019), news articles are considered to be a good source to capture the structural and functional components of the TIS within Bangalore. Moreover, as the focus of this study is not entirely on technological development, but more on issues such as societal acceptance and new regulations mostly applicable to the public citizens, many processes are likely to be captured by news articles. Moreover, other studies have shown that the identification of TIS dynamics, within developing contexts, could yield interesting findings from the analysis of news articles (De Oliveira & Negro, 2019; Edsand, 2017).

In order to triangulate and complement the findings of the secondary data analysis, semi-structured interviews were held with five water and sanitation experts located in Bangalore (see table 3). These interviewees were found through contacts of Eawag and through snowball sampling. These interviews were held digitally through Microsoft Teams with the use of an interview guide (see appendix B).

Table 3 – Interviewees

Scoping study interviewee	
Expert 1	Works at Eawag. (Swiss Federal Institute of Aquatic Science and Technology). Worked on the Small-Scale Sanitation Scaling-up (4S) project in India; focused on governance.
Expert 2	Works at Eawag. Expert in the 4S project.
Interviewee	
Expert 3	Representing Biome Environmental, Arghyam Foundation and Rainwater Club
Expert 4	Works at ATREE (Ashoka Trust for Research in Ecology and the Environment). ATREE is a non-profit organization focused on research and policy advocacy related to environmental conservation and sustainability.
Expert 5	Works at ATREE. Expert in Environmental Policy & Governance
Expert 6	Representing Ecotech and expert in decentralized STPs
Expert 7	Environmental engineer at CDD society. CDD society is a non-profit organization focused on research, policy advocacy, providing trainings and offering O&M support of on-site STPs.

The articles that were used for the data analysis were published between the year 2006 and 2020. This timeframe is taken as in 2006, an important and first of its kind amendment notification was issued by the Ministry of Environment and Forest (MoEF), directing all large construction projects to implement on-site sanitation systems (Klinger et al., 2019; MoEF, 2006). Moreover, in 2009, the Bangalore Water Supply and Sewerage Board (BWSSB) made rainwater harvesting compulsory for many households in Bangalore (Manasi & Umamani, 2013). Given the introduction of additional and more stringent policy measures in the years that followed, this timeframe will capture the majority of important processes leading to the development of the socio-technical configurations. This broader time frame of 15 years (2006-2020) allowed for the capturing of the relevant mechanisms contributing to the emergence of an alternative service regime over the years.

Section 3.4 – Data analysis and measurement of concepts

For the analysis of news articles retrieved from the LexisNexis database, an event-analysis is performed. A historical event-analysis, firstly introduced by Van de Ven & Poole (1990), allows for a systematic analysis of qualitative data, making it possible to measure the functions of a TIS over time (Kebede & Mitsufuji, 2017; Negro, Hekkert, & Smits, 2007; Suurs et al., 2010; Suurs, Hekkert, & Smits, 2009). For the coding of events, this study used an abductive approach. The events were deductively coded as the TIS framework has guided towards the relevant events for the analysis (Suurs et al., 2009). Subsequently, events were coded inductively by incorporating new elements that have been identified bottom up based on the news reported. These approaches alternated throughout the coding process. Each event that is coded is coupled to the year the article is published or to the date that has explicitly been mentioned. A chronological order of events was used to identify potential feedback cycles. The historical event-analysis has allowed for the capturing of important mechanisms influencing the development of the socio-technical configurations constituting the TIS (Hekkert et al., 2007).

The events are categorized into one of the seven TIS functions that fits the event best. When structural elements, such as *actors, institutions, interactions and infrastructure*, were found in these articles, they were coded and allocated to the appropriate structural component category. The identified structural components were used to distinguish the developing socio-technical configurations. The news, journal and magazine articles were analysed by the use of Nvivo software. Lastly, for triangulation purposes, seven interviews were conducted with local experts and coded accordingly using Nvivo.

Section 3.4.1 – Measurement of concepts

By using the indicators as derived from e.g. Negro, Hekkert, & Smits (2007) and Suurs & Hekkert (2009), relevant events were coded and subsequently allocated to either one of the systems structural and/or functional components (Table 4). However, as the proposed indicators are developed and often used for the analysis of innovation systems in western contexts, several indicators were added in order to get a grasp of the more informal processes in the water and sanitation TIS of Bangalore (e.g. learning from application [F2], open-houses [F3] and too high discharge standards [F5]). Every function has specific indicators for the coding of events that either positively or negatively influenced the development of a particular function (see 'value' in Table 4). Moreover, the coded events were also assigned to the particular socio-technical configuration it is associated with (see appendix C for coding scheme)

The functions entrepreneurial activity [F1], knowledge development [F2] and knowledge diffusion [F3] together capture the knowledge and technology supply dimension. Guidance of the Search [F4] is taken separately as it has a particular influence on the selection of options, the setting of priorities and the direction of changes. Market formation [F5], resource mobilization [F6] and Legitimation processes [F7] together capture the valuation dimension.

Table 4 – Indicators and measurement of concepts

Concepts	Indicators	Value
F1: Entrepreneurial activity	Project started. Portfolio expansion. Experimenting with new technology.	+1
	Project stopped.	-1
F2: Knowledge development	R&D projects. Investment in R&D. Learning from application. Learning from production.	+1
F3: Knowledge diffusion	Co-operation between actors. Organisation of workshops and conferences. Open houses for the sharing of knowledge.	+1
F4: Guidance of the search	Doubt and uncertainty	N/A
	Positive visions, expectations or believes. Outcome study positive (regarding the adoption of a particular technology or set of technologies), Articulation of demand by leading actors. Regulation favouring technology.	+1
	Negative visions, expectations or believes. Outcome study negative (regarding the adoption of a particular technology or set of technologies). Expressed lack of guidelines or standards.	-1
F5: Market formation	Tax exemption starts. Standards introduced. Too low standards introduced. Institutional incentives for market formation.	+1
	Tax exemption stops. Expressed lack of tax exemptions or standards. Too stringent standards introduced. Institutional barrier for market formation. Lack of enforcement.	-1
F6: Mobilisation of resources	Subsidies. Investment. Sufficient skilled labourers. Sufficient knowledge workers.	+1

	Expressed lack of subsidies or investments. Rejection of financial support. Lack of skilled labourers. Lack of knowledge workers.	-1
F7: Creation of legitimacy	Support by users, experts, industries, government or other key actors. Articulation of benefits. Awareness creation or call for action. Outcome study positive (related to compliance rate, water scarcity or pollution). Lobby or advice pro.	+1
	Expressed lack of support by users, experts, industries, government or other key actors. Articulation of disadvantages. Outcome study negative related to compliance rate, water scarcity or pollution. Lobby or advice contra.	-1

Section 3.5 – Quality of research

To ensure the quality of research, in this section, the reliability and validity of the methods used are argued for.

3.5.1 - Reliability

The reliability of research refers to the question whether the results of the study are replicable (Bryman, 2012). To ensure the reliability of this research, both the methods used to analyse the data, and the indicators used to measure the concepts, are derived from peer-reviewed articles, such as Hekkert et al. (2007), Negro et al. (2007) and Suurs et al. (2009). Moreover, as the coding process may be exposed to the researcher's interpretation of the data, the coding process and codes were frequently discussed with the supervisor to limit this effect. To ensure inter-coder reliability, several representative articles were individually coded by the supervisor and recommendations for the coding scheme were provided. Additionally, the coding scheme and the representative articles that were coded, were checked by one external researcher to strengthen the reliability of the coding process. The coding scheme was revised based on insights gained along the coding process. Furthermore, this study made notes detailing the systematic steps taken, coupled with attempts of trials and errors, that arrived at the final search string used (see Appendix A). Finally, as only seven experts were interviewed, one might argue that this would limit the representativeness of the sample. However, as multiple data sources were used for the analysis, only the findings that corresponded with the secondary data analysis, were considered.

3.5.2 - Validity

The validity of research refers to the measure accuracy of the used method, to what it is intended to measure (Bryman, 2012). Validity can be distinguished into internal validity, referring to the question whether the findings really explain the social phenomenon studied, and external validity, referring to the generalizability of the findings of the research (Bryman, 2012). Internal validity was ensured by process of triangulation and other internal validity improving efforts. First, this research was based on a number of studies done beforehand by experts at Eawag (e.g. Klinger et al., 2019; Reymond et al., 2020) which were spoken to throughout the research process. Moreover, the supervisor checked the coding process and revisions in the coding scheme were done accordingly (see appendix C for coding scheme). Lastly, different sources were used to study the social phenomena, namely: newspaper, journal and magazine articles, policy reports and a handful of experts were interviewed to both complement and triangulate the findings of the secondary data analysis. All of these efforts contribute to the internal validity of this study. The generalizability of this study is limited as the research focused on a single case. However, as this case embodies a broader category of issues often seen in other developing cities, this research could be tested to similar cases in order to see whether findings apply to or match with other cases.

4. Results

The following chapter presents the results of the data analysis. First, the boundaries of the socio-technical configurations and the service regime will be delineated, including the key actors and institutions. Thereafter, an overview of the TIS functions, per socio-technical configuration, over time will be presented from a period of 15 years (2006-2020). For each phase, a storyline will be presented that touches upon differences between knowledge supply [F1, F2, F3], guidance of the search [F4] and valuation processes [F5, F6, F7]. After each phase, a reflection will be given on the key processes influencing the development of the socio-technical configurations, triangulated with input from experts.

Section 4.1 – Delineation of system boundaries

Bangalore is aiming to establish a decentralized service regime through its dedicated policies regarding the diffusion of decentralized water and sanitation technologies (EX3, EX4 and EX5). A decentralized service regime can be considered established or stable when it provides for a sustainable alternative to centralized systems and when it is widely accepted by the various actors' groups in the system. The service regime focal to this study is defined as: 'all decentralized technologies and associated socio-technical aspects contributing to the way citizens of Bangalore treat, recycle or reuse water or wastewater'. Decentralized technologies are implemented on-site and are not connected to a central grid, including Sewage Treatment Plants (STPs), Greywater Treatment Plants (GTP), Rainwater Harvesting (RWH) and Groundwater Recharging (GR) technologies.

This study conceptualizes multiple decentralized solutions as one socio-technical configuration because in highly complex and heterogenous contexts such as basic service sectors of developing cities, multiple technological options could co-exist to meet particular user requirements (Welie et al., 2018). In example, both a Membrane Bioreactor (MBR) and a Sequencing Batch Reactor (SBR) are considered to be technological options of the on-site STP family. However, MBR is much more compact and for that reason more likely to be adopted by users that have limited space available. Several technological options may thus co-exist, indicating that the emergence of one dominant technological trajectory does not apply. Therefore, this study proposed to bundle these technological options together as one socio-technical configuration (or sub-TIS) in order to analyse the broader mechanism associated with the emergence of particular technology type/family.

Based on the differences in purpose and the development challenges of these decentralized solutions, this study distinguishes two sub-TISs. Sub-TIS 1 includes all technological solutions related to the catchment and reuse of greywater and rainwater (Water recycling sub-TIS), and sub-TIS 2 includes all technological solutions related to the treatment and reuse of wastewater (On-site STP sub-TIS). Both sub-TISs have the goal to provide for an alternative source of water, while the latter sub-TIS also includes the goal of preventing sewage pollution. Together, the two socio-technical configurations (i.e. sub-TISs) would form an alternative service regime that can be understood as the decentralized Urban Water Management (UWM) service regime. This emerging decentralized UWM service regime is considered as the main TIS including both sub-TISs (see figure 2 below).

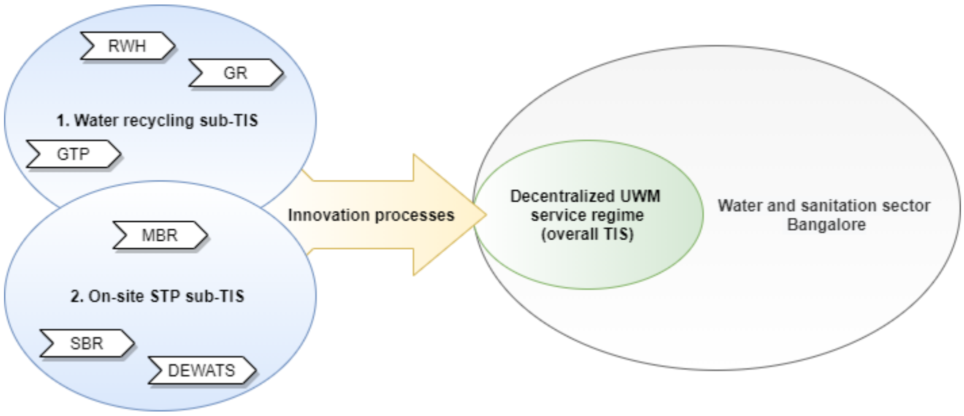

Figure 2 – Conceptual illustration system boundaries

Section 4.2 – Structural system components

To get a grasp of the technologies, actors and institutions part of the socio-technical configurations focal to this study, an overview is given of the key structural components of the TIS. The given overview does not intend to include all existing actors and institutions part of the system, but rather aims to give an overview of the most important ones.

Section 4.2.1 – Socio-technical configuration 1: Water recycling sub-TIS

The technological solutions involved in this configuration include various RWH technologies that enable the collection, storage and purification of rainwater, greywater treatment plants, and groundwater recharging techniques such as the soak pits or pipeline constructions to open wells. Moreover, the actor groups that have a determining influence on the development of the water recycling sub-TIS are users, governmental agencies, commercial organizations, knowledge institutes, NGOs and activists. Additionally, to a lesser extent, industry associations, consultants, designers and manufacturers, played a role in the development of this sub-TIS (see table 5 for details). Finally, the critical hard institutions that particularly influenced the development of this sub-TIS are given in figure 3 below. More detailed modifications of these institutions are discussed in section 4.3.

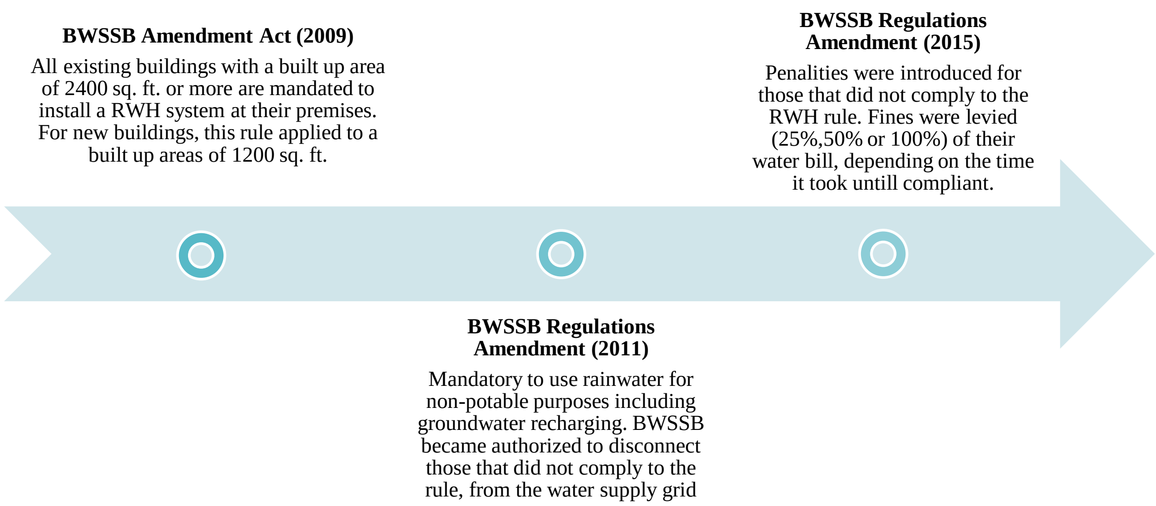

Figure 3 - Hard institutions over time (water recycling sub-TIS)

Soft institutions that play an critical role in the development of this sub-TIS are: the little sense of urgency to comply to measures, citizens often need to be faced with water shortage or pollution issues first before they are willing to take action. Also, there seems to be a mentality of ‘it is somebody else’s problem’. Lastly, the sense of urgency to protect local water bodies increased over time. Most of these soft institutions have changed over time, which will be further explained in the functional analysis below.

Section 4.2.2 – Socio-technical configuration 2: On-site STP sub-TIS

The technological solutions involved in this configuration include a wide variety of on-site Sewage Treatment Plants (STPs), of which the most prevalent; (extended aeration) Activated Sludge Process, nature-based DEWATS, Sequencing Batch Reactor, Membrane Bioreactor, Moving Bed Biofilm Reactors, and other less prevalent ones. These technologies may differ with regard to the investment’s costs, operation and management costs, electricity consumption and the quality of treated wastewater they produce. The actor groups that have a determining influence on the development of the on-site STP sub-TIS are users, governmental agencies, industry associations and commercial organizations, such as manufacturers, builders, consultants, designers and architects. Additionally, to a lesser extent, citizens, NGOs, activists and knowledge institutes, played a role in the development of this sub-TIS (see table 5 for details). The policy measures that particularly influenced the development of this sub-TIS are given in figure 4 below. Other institutions, such as discharge standards, are discussed in section 4.3.

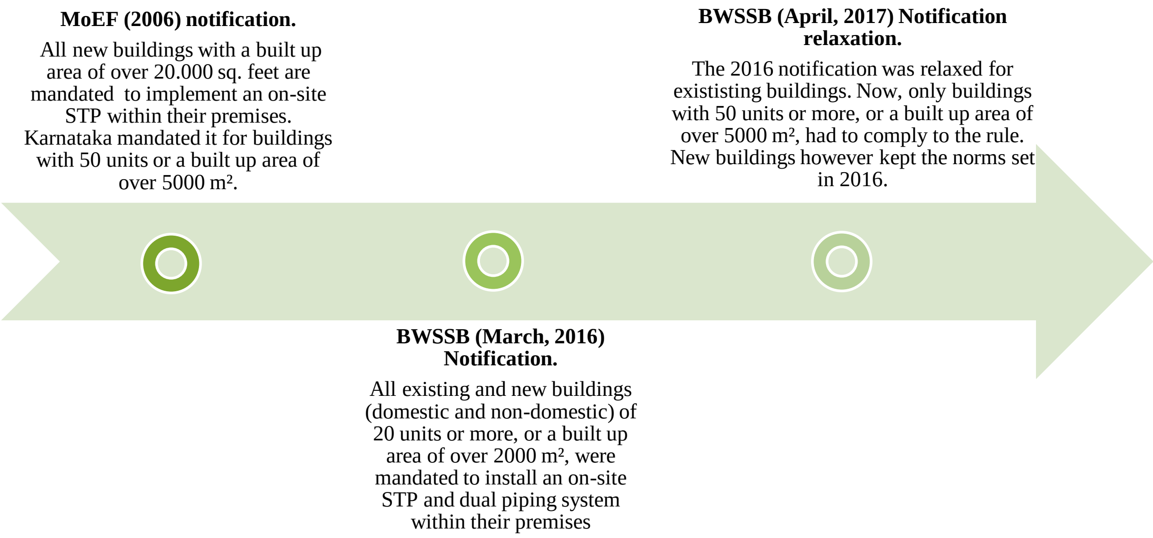

Figure 4 - Hard institutions over time (on-site STP sub-TIS)

Soft institutions that play an critical role in the development of this sub-TIS are: the lack of trust in governmental agencies, the lack of awareness about the actual impact of sewage pollution, the psychological barrier for the reuse of wastewater, the lack of interest by citizens in sewage generally (i.e. ‘something the government has to take care of’ mentality), and citizens tend to blame others frequently for the mess they created themselves. Most of these soft institutions changed over time and will likewise be further explained in the functional analysis below.

Table 5 below provides an overview of the most relevant actors contributing to the development of the TIS. After each actor group, a description is given about the role they play in the development of the TIS. Subsequently, it is marked to which sub-TIS the particular actor contributes (see column 4 (ST1) and 5 (ST2)). This table shows that most of the actors are involved in the development of both these sub-TISs. However, as explained earlier, there are differences to what extent they are influencing the development of each sub-TIS. The differences in actors relate mostly to the commercial actors manufacturing the various technological solutions or those offering a related service. Moreover, while several knowledge institutes and NGOs were involved in the development of the on-site STP sub-TIS (ST2), almost all were involved the water recycling sub-TIS (ST1).

Table 5 - Actor groups and their key players

Actor groups	Who	Role	ST1	ST2
Users	All residential, commercial and governmental buildings (those meeting the requirements of the notification)	+/- 40.000 mandated to have an on-site STP and dual-pipeline system.		x
	All residential, commercial and governmental buildings (those meeting the requirements of the notification)	+/- 195.000 (2018) were mandated to adopt a RWH system and use the water for the recharging of the groundwater.	x	
Governmental agencies	Ministry of Environment and Forest (MoEF)	Policy setting		x
	Bangalore Water Supply and Sewerage Board (BWSSB)	Policy setting, enforcing law	x	x
	The Karnataka State Pollution Control Board (KSPCB)	Monitoring environmental related issues and setting of discharge standards	x	x
	The Bruhat Bengaluru Mahanagara Palike (BBMP)	Enforcing law, take action against offenders	x	x
	Bangalore Development Authority (BDA)	Enforcing law, take action against offenders	x	x
	Karnataka State Council for Science and Technology (KSCST)	Formulating policies, advising the government	x	x
	National Green Tribunal (NGT)	Dedicated jurisdiction in environmental issues. Improving the effectiveness of local bodies derelict in performing their duty.	x	x
Industry associations	Bangalore Apartment Federation (BAF)	Representing and protecting the interest of apartment owners and residents	x	x
	Residence Welfare Association (RWA)			
	Bangalore Political Action Committee (B.PAC)	Aims to improve governance in Bangalore by policy advocacy and campaigns	x	x
	Bangalore Chamber of Industry and Commerce (BCIC)	Representing large and medium industries	x	x
	The Confederation of Real Estate Developers' Associations of India (CREDAI) Bengaluru	Representing private real estate developers in Bangalore	x	x
Commercial organizations	Manufacturers	Enviro India, Eco Tech Engineering Consultancy, Murali Sesh Enviro Engineers Pvt. Ltd., Aqua Chem India Pvt. Ltd., Green Enviro Polestar, Aquatech, Bisineer, and many more.		x
		Wipro Ecoenergy	x	x
	Builders	TZED, *Builders often remained anonyms in news articles		x

	Consultants	Eco Tech Engineering Consultancy, Ecoparadigm, Hydro Drops Aqua Solutions, Seamak Group, CDD society, and many more.		x
		Frogg.in, Bangalore Rainwater Club	x	
	Architects/Designers	Biome Environmental Solutions, Biodiversity Conservation India Ltd (BCIL), Inspiration, Eco Tech Engineering Consultancy, Daksha Greentech International, Bisineer, Xtreme Private Limited, and many more.		x
		Biodiversity Conservation India Ltd, Patel Realty India Ltd.	x	x
	Operation & Management	Aqua Chem India Pvt. Ltd., Environ India, Green Enviro Polestar, Aquatech, and many more.		x
Knowledge Institutes	Research Institutes	Indian Institute of Science (IISc)	x	x
		Energy and Wetlands Research Group (EWRG)		x
		Environmental Information Systems (ENVIS)	x	x
		The Energy Research Institute (TERI)	x	x
		Centre for Ecological Sciences (CES)		x
		Environmental Management Policy & Research Institute (EMPRI)	x	x
		Karnataka State Council for Science and Technology (KSCST)	x	
		Bangalore University	x	
	Think tanks	Public Affairs Centre (PAC)	x	x
		Advanced Centre for Integrated Water Resources Management (ACIWRM)	x	x
		Centre of Science and Environment (CSE)	x	x
		Sensing Local	x	x
		The Centre for Public Policy (CPP), part of the Indian Institute of Management Bangalore (IIMB)	x	x
Non-profits/ NGOs	Consortium for DEWATS dissemination Society (CDD Society)	Policy advocacy, conducting or financing research, educating citizens about recycling and reusing practices, organizing awareness campaigns and action calling.	x	x
	Ashoka Trust for Research in Ecology and the Environment (ATREE)		x	x
	Araghyam Trust		x	
	Biome Environmental Trust		x	x
	United Way of Bengaluru		x	
	Art of Living		x	
	Bangalore Association for Science Education (BASE)			
	Technology Informatics Design Endeavour (TIDE)			
	Round Table India (Bangalore)		x	x
	Bangalore Environmental Trust		x	
Activists		Policy advocacy, frontrunners in technology adoption, spreading awareness	x	x
Citizens		Grassroots initiatives, pioneering technology adoption	x	x

Section 4.3 – Functional analysis

Before the results of the functional analysis will be presented, a brief overview of the water and sanitation sector before 2006 will be given. The water and sanitation sector of Bangalore before 2006 primarily consisted of centralized piped systems covering the city centre and decentralized technologies, such as septic-tanks and the usage of water wells, in the peripheral areas of the city. Those that were connected to the centralized network received water from the Cauvery River, while sewerage lines were connected to large sewage treatment plants (treating 50 to 250 million litres per day per unit). Those that were not connected to the centralized sewerage network relied on 'honey suckers' that emptied their septic tanks every once in a while. However, rapid urbanization trends caused these centralized and decentralized technologies to be overused. This led to the overflow of sewage in both sewerage pipelines and STPs, while groundwater levels dropped massively due to the overexploitation of groundwater. This unsustainable model of water supply and sewage treatment led Bangalore to search for alternative solutions. More specifically, Bangalore increasingly acknowledged the benefits of using advanced decentralized technologies and methods for the treatment of sewage, and the need to recycle and reuse water in order to combat water scarcity.

The search for alternative and sustainable solutions, in combination with the introduction of the nation-wide on-site STP mandate in 2006 (MoEF, 2006), resulted in a period with many development and advocacy processes regarding the wide variety of decentralized water and sanitation technologies since then. Many events took place that particularly stimulated or hampered the development and diffusion of decentralized water and sanitation services within the city of Bangalore (see figure 5).

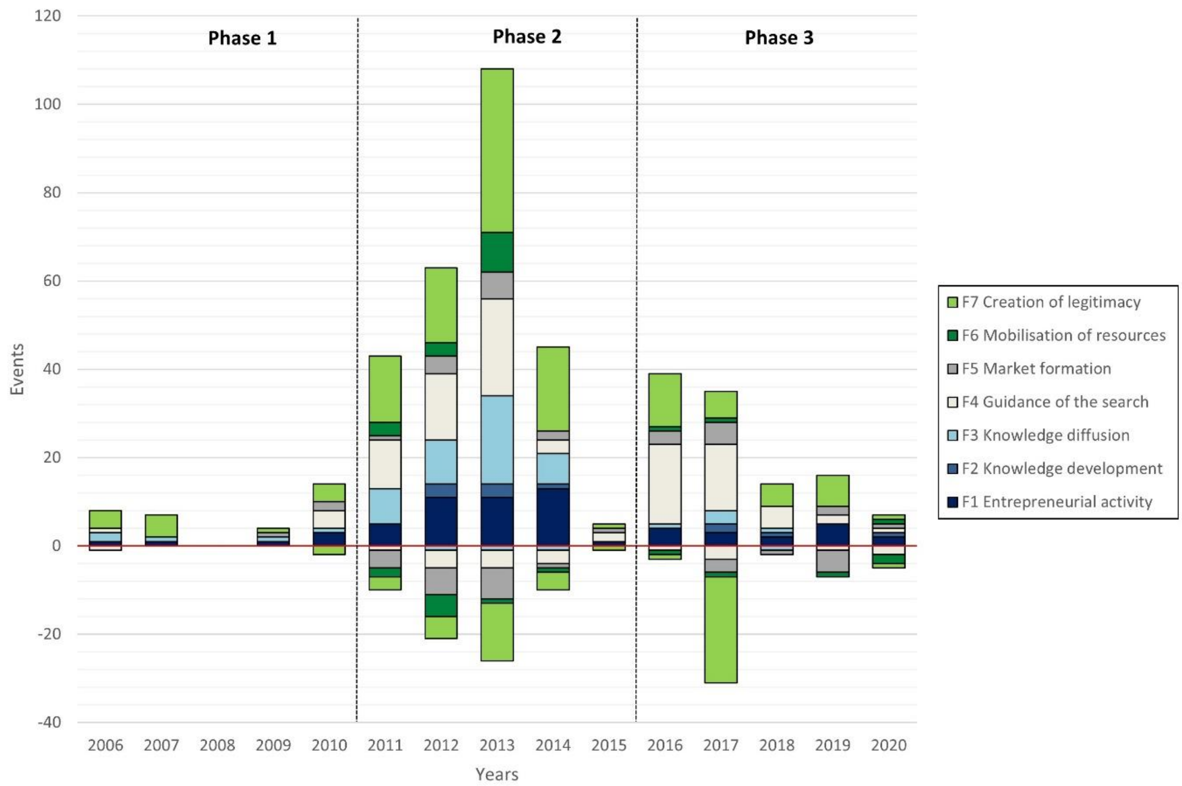

Figure 5 - TIS functions over time (2006-2020)

When looking at the function fulfilment of the Technological Innovation System over time, it is possible to distinguish three development phases. These three phases can be distinguished based on the abrupt fluctuation of processes and by specific events characterizing the particular phase. The first development phase (2006-2010) can be characterized as a phase in which decentralized services were gradually introduced. Most citizens still had nothing to do with these technologies, but policy advocacy processes were slowly emerging. The second develop phase (2011-2015) can be characterized by a huge increase in events caused by the increasing shortage of water and pollution issues. These events resulted in the exploration of alternative water and sanitation solutions. The third development phase (2016-2020) can be characterized as a phase in which the majority of citizens became aware of the water and sanitation crisis of the city. Moreover, various actors were increasingly wiling to participate in the city's fight against pollution and water shortage.

Based on the concepts described in the theory section, figure 6 gives an overview of the development of function over time, categorized into the three dimensions of knowledge and technological development, valuation and guidance of the search. These dimensions are discussed per phase in the following sections (section 4.3.1 – 4.3.3). Additionally, the future prospects of the sector are discussed in section 4.3.4. All details presented in the following sections are drawn from the coding of news articles. After each event, the function is marked (e.g. [F4] referring to the 'guidance of the search' function) and valued (e.g. either [F4] referring to the positive effect and [F4-] referring to the negative effect on the development of the TIS). Whenever the findings are supported or triangulated by one of the interviewed experts, the expert was cited (e.g. EX1 to refer to expert 1).

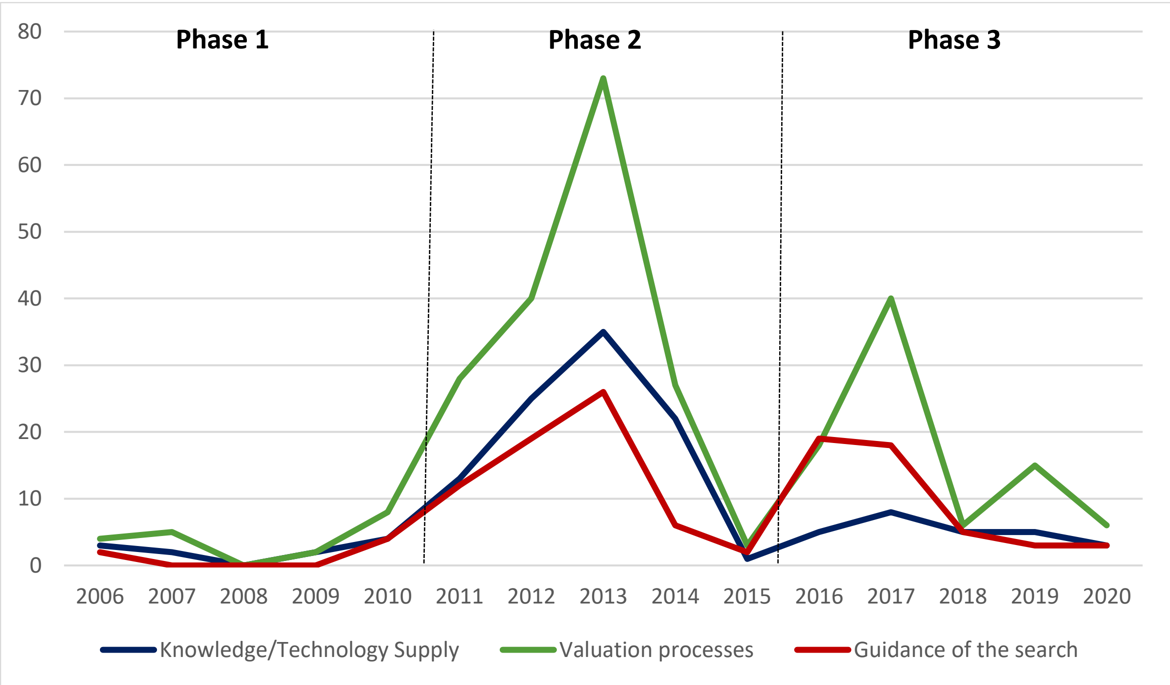

Figure 6 - Function fulfilment over time per dimension

Section 4.3.1 – Phase 1: Early dynamics (2006 – 2010)

In the first development phase of the TIS, very few dynamics can be observed regarding the development or advocacy of decentralized water and sanitation technologies. Both these sub-TISs were gradually gaining the attention of environmental oriented actors in the system.

Section 4.3.1.1 – Knowledge or technological developments

During this phase, a handful of social/environmental activists and private sector actors started experimenting with water and wastewater recycling technologies. Several environmental conscious private sector actors, such as Frogg.in, the Bangalore Rainwater Club and Wipro Ecoenergy, offered consultation and solutions for water harvesting and wastewater treatment [F1].

Water recycling sub-TIS: A few activists adopted Rainwater Harvesting (RWH) systems in their home and started showcasing it to others with the intention to share practicalities [F1, F3]. Furthermore, several actors believed that in order to make citizens more aware of the water issues that Bangalore faced, efforts should be made to inspire the youth. While urban planners requested the BWSSB to educate children in schools about the need to conserve water, Coca Cola India partnered up with the Energy Research Institute to facilitate RWH systems in schools across Bangalore [F1, F3].

On-site STP sub-TIS: Actor groups that primarily experimenting with the recycling of wastewater were luxury hotels and ecological oriented building companies initiating the idea of 'green buildings' in Bangalore. These green buildings included multiple recycling and recharging technologies [F1].

Section 4.3.1.2 – Guidance of the search processes

During this phase, the main actors that were sharing visions and expectations were the Karnataka State Council for Science and Technology (KSCST) and the Agenda for Bengaluru Infrastructure Development (ABIDe) task force. Both these institutes acknowledge the need to explore alternative sources of water and considered the Cauvery river as an unsustainable source for the future [F4].

Water recycling sub-TIS: Both the KSCST and the ABIDe believed that the rising water demand should be met through the recycling of water, harvesting of rainwater and the creation of sink pits, to recharge the groundwater [F4]. Several policy and regulatory measurements were introduced to stimulate the decentralization of water catchment, treatment and reuse. Particularly the introduction of the RWH mandate in 2009, directing a huge number of citizens to install a RWH system within their premises, had an impact. Furthermore, the BWSSB requested homeowners to store their harvested rainwater (20 litre per m^2) for later use or for the recharge of groundwater through soak pits [F4].

On-site STP sub-TIS: After a nation-wide push for on-site STPs, which was mandated by the MoEF in 2006, several issues that were associated with this mandate, shed to light. Due to the lack of proper hand-over procedures between the builder, who is responsible of the implementation of an on-site STP, and the Residents Welfare Association (RWA), many buildings did not have a proper on-site STP installed within their premises [F4-] (EX4). The KSPCB filed cases against the RWA's of these violating buildings, while the actual violator (the builder) escaped unpunished. These builders were often referred to as 'night-flyers' (EX3). In 2010, the KSPCB were formulating procedures to make builders accountable for not installing on-site STPs when constructing new buildings [F4].

Section 4.3.1.3 – Valuation processes

Signs of an increasing water shortage could already be observed in the first development phase of the system. Multiple rallies were organized by the BWSSB and the Bangalore Jalamandali Abhiyantarara Sangha (engineering association of the government) that were focused on water conservation and awareness creation, with the call to citizens to make water conservation their attitude [F7].

Water recycling sub-TIS: Several non-profit organizations (e.g. Akshara Foundation, Pratham Books, Arghyam Trust, Biome Environmental Trust) started advocating for an integrated water management approach, including RWH systems and Groundwater Recharging (GR) methods, expressing their negative perspective on the current centralized water supplying model [F7]. In 2010, the BWSSB articulated that they considered RWH as the best solution to mitigate water shortage in Bangalore [F7]. However, although RWH technologies were heavily advocated by non-profits and the BWSSB, over 8000 citizens have written to the BWSSB and asked for an extension of the given deadline [F7-]. Citizens feared that the BWSSB would disconnect them from their water supply and sewerage connection, if they did not adhere to the 2009 mandate in time. The resistance of these citizens led the BWSSB to extend the deadline [F5-].

According to newspapers and experts, there are several reasons why the diffusion of RWH technologies, after the 2009 mandate, happened relatively slow. One of the reasons is due to the lack of incentives for homeowners to adopt such a technology, as they often received clean centralized piped water or water from a (bore)well nearby [F5-] (EX7). Hence, as the RWH policy got introduced first, without making it mandatory to store or reuse for groundwater recharging purposes, people were confused about what was actually mandated. Rainwater was already running off their roof into open drains anyway [F4-] (EX4 and EX5). Moreover, several citizens complained about the lack of financial resources available to install such a technology in a short period of time, while other expressed the lack of available plumbers [F6-] (EX3 and EX5). Other reasons that resulted in the slow adoption of RWH systems were caused by the lack of success stories (that could convince people of the benefits) [F7-] (EX3), but also the lack of human capacity of the government to check whether a RWH system within their premises [F6-] (EX4 and EX5).

On-site STP sub-TIS: When the KSPCB started filing cases against those that violated the STP mandate of 2006, it became clear that there were many buildings that either got a dysfunctional on-site STP installed or not one at all [F7-]. As hand-over procedures were not monitored and guided properly, builders often installed on-site STPs that were either of very low quality or required very high operational costs (such as energy or O&M costs) while the investment costs were small. The real estate owners were reluctant in making expenses for the operations and maintenance of these on-site STPs, which leaded to the dumping of untreated sewage in lakes and other surfaces [F7-]. This was later confirmed by a study by the KSPCB, who published that water contamination levels have been increasing which was primarily caused by a large number of industries and apartments that were discharging untreated wastewater into open drains (despite being directed to install an effluent treatment plant) [F7-].

Section 4.3.1.4 – Reflection phase 1

In the first development phase of the innovation system, both sub-TISs remain rather underdeveloped. Although several actors articulated their vision related to the need for Bangalore to explore alternative sources of water, both sub-TISs developed rather separately. Moreover, both sub-TISs were pushed and visioned by governmental agencies and non profits, as a potential good and sustainable alternative for centralized systems. However, the related policy directives were badly received by citizens. While the RWH mandate was publicly contested by many citizens of Bangalore, issues associated with on-site STPs stayed more ‘off the radar’. Nonetheless, these on-site STPS were also poorly adopted due to inadequate regulations and a lack of monitoring by the government. In contrast to on-site STPs, the benefits of adopting a RWH system was directly felt by citizens when harvested rainwater was for purposes such as gardening. However, the merits of adopting an on-site STP were unknown by most of the citizens (EX3). Due to the lack of incentives for citizens to adopt a RWH system and lack of available plumbers, RWH systems were slowly diffusion within the innovation system (see table 6 for a summary of the inducement/blocking mechanisms). However, as the shortage of water was increasingly felt by citizens and multiple actors started advocating for the implementation of RWH and groundwater recharging techniques, the water recycling sub-TIS gradually gained momentum. On the contrary, there were no visions articulated by governmental agencies or other actors in the system, with respect to growth expectation and believes that could stimulate the on-site STP sub-TIS. Policies were poorly picked up and in combination with the lack of monitoring capacity of the government, nobody seemed to care either.

Section 4.3.2 – Phase 2: The increasingly pressing water scarcity (2011 – 2015)

In the second development phase of the TIS, there is a significant growth in events related to the recycling and reusing of water and wastewater (figure 6). In wait for the completion of the Cauvery Water Supply Scheme Stage IV Phase II, which was expected finish in 2012, water scarcity became increasingly pressing during the second phase. Moreover, as many waterbodies dried up and multiple lakes got heavily polluted by sewage, multiple actors started exploring alternative sources of water and sewage treatment.

Section 4.3.2.1 – Knowledge or technological developments

To stimulate the exchange of knowledge and the development of technology, the BWSSB signed a Memorandum of Understanding (MoU) with both the Singapore government in 2012, and with the San Francisco (US) city government in 2013. These arrangements were made to share technical expertise on wastewater treatment and reusing, to learn about the formulation of policies to conserve and recharge groundwater, and to learn how stakeholders could be better involved in the creation of public acceptance towards the reuse of treated wastewater [F2, F3]. Additionally, several engineering projects of Bangalore universities were sponsored by the KSCST to boost innovation, while other universities tied up with NGOs to allow students to familiarize with water recycling and groundwater recharging technologies and methods [F2, F3].

Water recycling sub-TIS: Due to the increasing water scarcity during this period, multiple workshops, campaigns and programmes, such as the Bangalore Water Famine 2020, RighStep Conclave 2013, Catch Every Drop, and more, were organized by governmental agencies, NGOs and active citizens [F3]. These events were particularly focussed on the creation of awareness and the sharing of knowledge regarding RWH, GR, lake rejuvenation, grey water recycling, and the catchment, recycling and reuse of water in general [F3]. Meanwhile, to enhance the diffusion of RWH technologies within the city, the BWSSB built a RWH theme park that showcased several RWH designs for people to get inspired by. This theme park was meant to share knowledge on how to properly install a RWH system, where people could be buying such a system, and what the costs would be [F3]. Likewise, to encourage public interaction on RWH, a project was executed in a joint effort of several NGOs, such as the Bangalore Association for Science Educations (BASE) and Technology Informatics Design Endeavour (TIDE) [F3]. Furthermore, multiple smaller projects were executed, in which local communities and environmental conscious citizens worked on local recycling and recharging projects. For instance, one grassroot initiative focused on the digging of RWH recharge wells across Bangalore [F1].

On-site STP sub-TIS: During the second development phase, more and more private and public sector actors (e.g. Mindtree, GE India, IIMB, BCIL Zed, Infosys, HCCBPL, etc.) became aware of the city's water and pollution reality. These organizations started experimenting with decentralised STPs and implemented zero-discharging measures related to the recycling and reusing of water and wastewater [F1]. During the same period, India's first green township was built in Bangalore which included various integrated RWH systems and on-site STPs for the treatment, recycling and reusing of water and wastewater [F1].

Section 4.3.2.2 – Guidance of the search processes

During this phase, visions and believes started to shift from 'it would be good to explore alternative sources of water' towards expressing the need for Bangalore to take action now, with regards to the recycle and reusing of water and wastewater. Both the director of the BWSSB and the director of the Centre for Science and Environment (CSE) visioned this in the news [F4]. However, head of the NGO Round Table, among other activists, expressed the lack of visions and a comprehensive plan to solve Bangalore's water crisis [F4-]. Many actor groups (from NGOs to citizens) expressed their dissatisfaction with the government, as they felt that these measures were not part of a more comprehensive plan and were rather taken ad hoc and not well thought out [F4-].

Water recycling sub-TIS: The pressing water scarcity led to the over-exploitation of groundwater in Bangalore. To improve this situation, the BWSSB set the deadline for properties to install a RWH system to the end of 2011, specifically for all properties measuring 2400 square feet (730 m^2), i.e. about 55.000 RWH systems at that point in time. However, the BWSSB made it clear that all residential properties, irrespective of size, would be directed to install a RWH in the near future [F4]. Additionally, the guidelines of the BWSSB mandated (instead of the previous request) a minimum storage capacity of 20 litres per square meter. Moreover, it was made mandatory to use this stored water for the recharging of groundwater or for own use throughout the year [F4]. With the amendment of Karnataka Gazette Notification, the BWSSB was empowered to disconnect citizens from the centralized water and sewerage connection if they failed to adhere to the RWH mandate before the given deadline [F4].

On-site STP sub-TIS: The Minister of Urban Development, Law and Parliamentary Affairs, among others, expressed that the drinking of treated wastewater would soon become reality in Bangalore, believing that the Cauvery river will not be an infinite water source for the future [F4]. By effect of the Cauvery Water Tribunal Agreement, Bangalore was restricted to pump unlimited water from the Cauvery river [F4]. Moreover, the minister expected wastewater recycling and zero discharge systems to become increasingly popular in India, as new housing projects in Bangalore would not get any drainage facilities from the government [F4]. In parallel to these expectations, a study published in 2011 showed that 2.2 million Bangaloreans were currently facing acute water shortage. This study suggested the city to take water conservation measures and to reuse treated sewage for both domestic and drinking purposes, in order to combat water shortage [F4]. Therefore, in an effort to improve the quality of treated wastewater, the Karnataka State Pollution Control Board (KSPCB) increased the quality standards, applicable to domestic STPs, to India's drinking standards (BIS-10500) in 2013 [F4]. In order to meet these standards, high-end technologies were required (e.g. membrane bioreactor (MBR)). However, following the findings from a study conducted in 2013, only an Extended Aeration Activated Sludge (EAAS) STP could be considered as a viable option for apartments of about 150 units or more [F4].

Furthermore, as lake health became an important topic during this phase, the BWSSB introduced the Lake Policy (2011) in an effort to prevent the inflow of sewage into the lakes of Bangalore. This policy gave power to the BBMP and the BDA to take action against violators that were dumping untreated sewage into the lakes of Bangalore. Additionally, by effects of this policy, builders of new large housing projects were obligated to install STPs on-site. This policy thus prevented builders from handing-over constructions that did not had an on-site STP implemented [F4].

Section 4.3.2.3 – Valuation processes

During the second development phase of the innovation system, a lot of attention was headed towards lake health, which particularly boosted the development of both sub-TISs. As a result of the unchecked inflow of untreated sewage water, lakes started to foam and froth, eventually leading to the Bellandur lake catching fire in 2015. Specifically, the latter event created a lot of attention, both nationally and internationally, towards lake health [F7]. Because of this, many citizens of Bangalore felt the need to do something about the inflow of untreated wastewater into the lakes of Bangalore [F7] (EX3, EX4, EX6).

Furthermore, the Confederation of Indian Industry (CII) released a report discussing the worsening water scenario of Bangalore [F7]. As Bangalore has reached the maximum amount of Cauvery water (1450 MLD) that they could receive (following the Cauvery Water Tribunal Agreement), the gap between water demand and supply was expected to increase. To mitigate these problems, the CII proposed a number of Integrated Urban Water Management (IUWM) strategies in 2014, specifically focussed on the stimulation of water and wastewater recycling and reusing measures through on-site STPs, RWH, and the formulation of a comprehensive groundwater plan [F7]. For the first time in Bangalore, the integration of both sub-TISs was advocated and thus contributing to the establishment of a decentralized UWM service regime [F7].

Water recycling sub-TIS: One of the key functions of lakes is to recharge the groundwater. However, as many lakes either got polluted by sewage or dried up due to over-exploitation of groundwater through borewells, the groundwater level of Bangalore hit rock bottom [F7]. Borewells had to be dug over a thousand feet to be able to extract water, while older wells were completely dried up. However, according to the director of the Karnataka Urban Water Supply and Drainage Board (KUWS & DB), most people were oblivious about the value of water and therefore continued to over-exploit the groundwater [F7-]. Other problems were expressed by the director of the Indian Institute of Science (IISc), among several activists, as they argued that the water problems of Bangalore were primarily caused by the lack of communication and cooperation between stakeholders and civic bodies [F5-]. For instance, civic bodies were increasingly willing to cooperate with governmental agencies (i.e. the BBMP) to build soak pits that could be used for public use. However, civic bodies were either not able to get in contact or got rejected after several months waiting.

Although the groundwater levels in Bangalore dropped down, the adoption of RWH systems went up rapidly during this phase. The RWH theme park was received well by the citizens, resulting in the adoption percentage of about 80% (that were mandated to implement one) [F7]. The BWSSB stimulated the rapid diffusion of RWH systems by training over a thousand people, registering over 600 new plumbers and added multiple architects to their reference list [F6].

On-site STP sub-TIS: The pollution of lakes particularly boosted the interest in decentralized STPs, as evidence showed that the inflow of untreated sewage was primarily coming from residential and industrial sewage that was generated nearby [F7]. The director of the Centre for Policies and Practices

(CPP) articulated his concerns in the news about the lack of law enforcement, arguing that governmental agencies (i.e. the KSPCB) had to take more severe action against industries and apartments that were polluting the environment [F5-].

Despite the clear interest and need for Bangalore to improve regulatory loopholes related to on-site STPs, both citizens and governmental agencies showed little effort in making this happen. Although reports of the KSPCB showed that the 600 on-site STPs in Bangalore could treat over 800 million litres per day (MLD) of wastewater, less than 20% of that potential was reached because the majority of on-site STPs functioned either sub-optimal or was completely dysfunctional [F7-]. Additionally, most of the treated wastewater went down the drain, as people were only able to reuse a small part of the treated wastewater themselves for purposes such as toilet flushing and gardening [F7-]. Although there was a huge demand for treated wastewater from agricultural segment (EX3), there was no demand that allowed people to sell the surplus of treated wastewater in urban areas [F5-] (EX3, EX4, EX5 and EX7).

One of the reasons why there was a lack of demand for treated wastewater in urban areas, is due to the huge psychological barrier of citizens for the reuse of treated wastewater (both for potable and non-potable purposes) [F7-] (EX5). To enhance the use of treated wastewater, the KSPCB increased the quality standards of treated wastewater produced by domestic STPs, to 'Urban Reuse Standards' (Indian drinking standards). However, instead of stimulating the diffusion of high-end STPs, the quality standards were perceived as too high, causing it to be a disincentive for people to improve STP quality or the operations and maintenance, instead [F5-]. Governmental agencies lacked the capacity to check apartments and industries as whether the installed STP actually met these quality standards or whether the STP was actually well-operated and maintained in the first place [F6-].

Another important barrier for the development of this sub-TIS was the issue of corruption. Both the builders and several governmental agencies were accused of corruption prior the building and during the hand-over process of real estate (EX3, EX4 and EX7). Both a Consent for Establishment (CFE) and a Consent for Operation (CFO) needed to be obtained respectively prior the building of the apartment and prior the handing-over of new apartments or other industries. Builders often bought these certificates from governmental agencies, allowing them to install poor quality, improperly designed and cheap on-site STPs [F7-, F5-].

Section 4.3.2.4 – Reflection phase 2

In the second development phase of the innovation system, a clear difference in development can be observed between the two sub-TISs. While the development of both sub-TISs were stimulated by the increasing water scarcity and the effects of lake pollution, the development of the on-site STP sub-TIS had to overcome many blocking mechanisms (see table 6 for a summary).

One of the main reasons why the water recycling sub-TIS is developing better in comparison to the on-site STP sub-TIS, was due to the favouring valuation processes. Actors of the sub-TIS such as the users, governmental agencies, NGOs and knowledge institutes, shared the same vision and believe that the implementation of RWH systems and groundwater recharging measures were needed to combat water scarcity in Bangalore. The shortage of water was something most citizens directly felt, while sewage pollution was something citizens increasingly cared about, but which remained a 'far from their bed show' (EX3 and EX5). Both the legitimation processes (i.e. favouring RWH and groundwater recharging technologies/measures) and mobilization of resources, (i.e. available skilled plumbers), were in line with the visions and expectations shared, and the regulatory measures taken.

When taking a closer look at the development of the on-site STP sub-TIS, although visions, expectations and several regulatory measures were in favour of the development of the sub-TIS, the valuation processes were not well-aligned with these 'guidance of the search' processes. On-site STPs were increasingly visioned as an important solution for the prevention of lake pollution and in addition seen as an alternative solution to Bangalore's water needs. However, as governmental agencies lacked the capacity to monitor the adoption and discharge quality of on-site STPs, the discharge standards were considered to be too high and financial incentives were missing, on-site STPs were not perceived as a legitimate solution to Bangalore's water and sanitation problem. Because of the lack of shared visions, and the misalignment of these regulatory measures with the valuation processes, the on-site STP sub-TIS developed slowly.

However, even though the water recycling sub-TIS developed better compared to the on-site STP sub-TIS, during this development phase, both sub-TISs were considered to be a potential interesting alternative solution to Bangalore's water needs. Several leading actors within the innovation system therefore advocated that these decentralized solutions should be integrated and pushed as part of an Integrated Urban Water Management (IUWM) plan. Synergies of these sub-TISs give an early indication that the decentralized UWM service regime is slowly starting to emerge.

To conclude, as been argued above, the alignment of visions and regulatory measures, with the valuation processes spread across various actor groups, seemed to be important for the development of both these sub-TISs. Moreover, the sharing of knowledge was very much linked to the legitimation of technology, as the willingness of citizens (within local communities) to adopt decentralized solutions was highly dependent on the best practices that were showcased within the neighbourhood.

Section 4.3.3 – Phase 3: Translating thoughts into inappropriate action (2016 – now)

In the third development phase (see figure 6), rigorous measures were taken by the government regarding the diffusion of RWH systems, groundwater recharging techniques, and especially on-site STPs. The introduction of such regulatory measures resulted in a lot of resistance from both citizens and experts. This has led governmental agencies to questioning whether the decentralized direction of development is the right direction for Bangalore.

Section 4.3.3.1 – Knowledge or technological developments

The importance of data was increasingly acknowledged during this development phase. In order to take targeted measures for the depletion of groundwater and pollution of lakes, governmental agencies and NGOs pointed to the lack of available data on i.e. the number of (bore)wells, how much water was consumed and how much water was leaking. To overcome this issue, organizations such as IBM Bangalore and NextDrop Technologies (NGO) were working on sensors and meters to quantify this data [F1].

Water recycling sub-TIS: As the city's water demand growing at an alarming pace, multiple entrepreneurial activities were initiated by a wide variety of actor groups within the city. While the BWSSB engaged in a Singapore based agency to prepare a rainwater reuse action plan for the northern part of Bangalore, several commercial organizations, such as the Karnataka State Cricket Association and Ingersoll Rand, made efforts to reduce their water consumption and implemented RWH systems and groundwater recharging soak pits within their premises [F1]. Moreover, Biome Environmental Trust (NGO) initiated a project called 'A million Recharge Wells' aiming to revive the city's water wells with the help of the traditional well-digging community [F1]. On the household level, a principal investigator at the IISc has made his entire house running on harvested rainwater with the use of a pop-up filter he patented [F1, F2]. He argued that more people should become self-sufficient and that people should learn from others that are self-sufficient within their neighbourhood [F3].

On-site STP sub-TIS: Caused by the continuing foaming and frothing of lakes in Bangalore, local communities, private sector actors (using Corporate Social Responsibility funds (EX3)) and governmental agencies, launched several projects in order to built on-site STPs next to lakes (e.g. Iblur lake, Bellandur lake, Vurthur lake) [F1]. By doing so, inflowing water would first be processed before entered into these lakes.

By looking at the entrepreneurial activities and organizations entering Bangalore, the city is heading towards the adoption of more advanced STPs. All major global MBR players are now located in India of which several in Bangalore (GE, Degremont Ltd), of which a large one (GE Zenon) has been treating municipal sewage water in Bangalore (Cobbonpark). Moreover, several entrepreneurial initiatives were focused on decreasing the wide gap between the supply and demand of drinking water. For instance, the BWSSB initiated a project called 'Spoorthi' aiming to bottle treated wastewater that could be sold as drinking water [F1]. Similarly, a start-up called Openwaters developed a fully automated STP that could treat wastewater to drinking water standards with minimal energy consumption and operate and management efforts [F1, F2].

Section 4.3.3.2 – Guidance of the search processes

During this third development phase, both RWH systems and on-site STPs were advocated heavily. However, head of the Biome Environmental Trust (NGO), among other activists, pointed out that the efforts that were made were too fragmented and that there was a lack of institutional coordination that resulted in these water problems in Bangalore. They advocated for an Integrated Urban Water Management strategy in which data could be translated into targeted measures [F4]. In a similar line, a report of the Public Affairs Centre (PAC) argued that the different governmental agencies lacked coordination, as citizens that were willing to participate in water and sanitation projects missed an established framework allowing them to cooperate with civic bodies [F4-].

Water recycling sub-TIS: Research institutes have published several reports highlighting the potential that could be captured by adopting decentralized water and wastewater recycling and reusing technologies [F4]. According to findings of a study published by Environment Information System (ENVIS), 73% of the required water in Bangalore could be met by rainwater alone, while findings of another study ('One more Cauvery') showed that the supply of the Cauvery river could be doubled by efficiently implementing RWH technologies, dual-pipelines in new flats, groundwater recharging methods and by the improve lake health and other water sheds [F4]. These claims were further strengthened by an analysis of the Bangalore Political Action Committee (B.PAC) [F4]. Another study stressed that Bangalore was expected to run dry, estimating that about 200.000 million litres of groundwater was extracted per year, while only 80.000 million litres was being recharged each year. This study argued that a wide-spread implementation of groundwater recharging technologies was needed [F4]. All these studies specifically directed on the diffusion of technologies in this sub-TIS.

In line with the insights from these studies, BWSSB was heavily pushing on the adoption of RWH systems. Empowered by the Draft Gazette Notification in 2015 (see section 4.3.2.2), from February 2016, the BWSSB started issuing penalties to those that did not comply to the mandatory directive of the government. Out of the circa 195.000 buildings that were mandated to have a RWH system, about 83.000 were penalized for non-compliance [F4].

On-site STP sub-TIS: In March 2016, the BWSSB issued a notification directing all existing and new buildings (either domestical and non-domestical) consisting of 20 units or more, or with a built up area of 2000 m² or more, to adopt an on-site STP or a Greywater Treatment Plant (GTP). In addition, the installation of a dual-piping system to allow for the reuse of recycled water/wastewater (for e.g. toilet flushing) was also made mandatory [F4]. Buildings that failed to install an on-site STP before July were said to be penalized. After a lot of resistance, the deadline was extended from July to the end of October. For non-compliance, domestic buildings had to pay a fine of 25% on top of their water bill in the first three months and 50% after. For non-domestic buildings, a fine of 50% on top of their water bill was levied in the first three months and 100% after [F4].

However, a notification was issued in 2017 by the BWSSB making on-site STPs and dual-piping systems only mandatory for existing buildings that had 50 units or more, or a build up area over 5000 m², instead of 20 units or 2000 m² issued in 2016 [F4]. For new buildings, the norms remained on 20 units, or a build up area over 2000 m², following the 2016 notification. The BWSSB expressed that they would penalize those that failed to comply before the end of 2017 [F4]

Next to the fines that were being levied, the National Green Tribunal (NGT) directed governmental agencies such as the KSPCB, the BWSSB and the Bangalore Development Authority (BDA) to check apartments and industries, particularly around lakes, whether they installed an STP in time. If this was not done, the NGT told these agencies to cut off the electricity and water supply of homeowners [F4]. In 2020, the KSPCB reported that they slapped notices on almost 500 apartments that did not meet the prescribed discharge standards for their on-site STPs [F4]. However, one of the important reasons why these discharge standards were not met, were caused by the lack of available or effective guidelines in terms of design and operation & maintenance (EX3, EX4, EX6 and EX7). Moreover, most of the technological options (e.g. SBR, MBR, MBBR) were not appropriate for such small complexes (below 150 units) as they could not handle peak loads very well [F4-] (EX7).

Section 4.3.3.3 – Valuation processes

During this development phase, many valuation processes could be observed that particularly hampered the development of these two sub-TISs. However, several signs of an increasing awareness among citizens and organizations could be noticed as well and various actors were increasingly involved in the plans of the government [F7]. Moreover, according to reports of the KSPCB in 2016, the pollution of sewage had been declining in the last five years, showing that the situation of Bangalore is improving [F7].

Water recycling sub-TIS: The overall awareness of water conservation and the need to recycle water by adopting RWH systems is increasingly noticed by several NGOs and activists [F7]. However, although many citizens did already implement a RWH system, many only followed when the BWSSB started enforcing the mandate with penalties [F7-]. From the roughly 70.000 RWH systems that were installed before the penalty notification, over 40.000 followed within several months after. Several citizens were still hesitating to invest due to the low water tariffs (seven rupees per thousand litres of Cauvery water). Moreover, the Bangalore Apartment Federation, supported by several activists, argued that more citizens should be mandated to install a RWH system. Even if all citizens that were mandated to install a RWH system would have one, it would generate only a small fraction of the actual water demand of the city. Therefore, these actors advocate for the implementation of RWH systems at a much larger scale (e.g. by runoff/stormwater harvesting systems) [F7-]. Furthermore, according to them, the government lacked to create sufficient awareness and lacked to enforce the rules more strictly [F7-, F5-]

On-site STP sub-TIS: To improve lake health, governmental agencies often expressed that this was due to the lack of financial resources available [F6-]. Therefore, with the help of CSR funds, several private sector actors got involved in the improvement of lake health by financing and managing the installation of on-site STPs next to lakes [F7] (EX1). Moreover, many actor groups, from governmental entities to commercial firms, started to advocate for a more decentralized and scalable options for the treatment and recycling of sewage [F7].

However, citizens, on the other hand, were less positive about the prospects and usage of on-site STPs in Bangalore [F7-]. When the BWSSB issued the on-site STP notification in 2016, many apartment owners and industries, supported by the Bangalore Apartments' Federation (BAF) and several Residence Welfare Associations (RWA), posed huge resistance to the mandate [F7-]. In a series of protest, over 10.000 citizens hit the streets expressing their opposition to the mandatory move of the BWSSB. Considering that over 80 per cent of the existing STPs in Bangalore were dysfunctional before this mandate, many people questioned why the BWSSB issued this notification, as it would probably lead to more dysfunctional STPs. Moreover, apartments that were already connected to the centralized piped sewerage system were also mandated to install an STP, making people even more outraged [F7-]

The BAF claimed that the mandatory directive of the BWSSB was neither economically nor practically feasible, as existing buildings would not have the physical space to implement an on-site STP. Hence, for retrofitting of dual-piping systems walls needed to be broken down [F7-]. Furthermore, apart from the lack of financial resources (both investment and expensive O&M) and the practical difficulties (EX3-EX7), many other problems were associated with it. First, most on-site STPs were already poorly designed when they got approved by the KSPCB [F5-] (EX3, EX4, EX6 and EX7). Second, there were limited available skilled labourers to design, operate and manage on-site STPs [F6-] (EX4-EX6). Third, the retrofitting of dual-pipelines brings safety issues to the building [F7-] (EX4 and EX7). Finally, there has been no consultation with experts, apartment owners or others, prior to the introduction of the mandate [F7-] (EX5 and EX7).

As a result of these problems, the BAF and several apartment groups filed petitions against the BWSSB for the mandate to retrofit on-site STPs and dual-piping systems in apartments of 20 units or more, or a built up area of 2000 m² or more. Although this mandate was relaxed in 2017 to 50 units or more, many protests continued to happen as the retrospective implementation was considered to be the problem, not the number of units. Moreover, many citizens felt that these rules were 'dumped' on them as the BWSSB failed in its duty to supply water and treat wastewater centrally [F7-] (EX5). In response to these complaints, the BWSSB expressed that there was no chance of withdrawing the mandate for 50 units or more and explained that the STP directive was needed to combat the pollution of lakes and groundwaters in Bangalore [F7]. However, due to the limited human capacity, the KSPCB and other governmental agencies were not able to check whether the implementation was done right [F6-] (EX3, EX4, EX7).

In the last two years, things started to look brighter with respect to the development of both sub-TISs. In 2019, multiple awareness campaigns were organized by the KSPCB regarding sewage pollution and with the help of the Environment Management Policy & Research Institute (EMPRI), the KSCPB started training operators of STPs as well [F7, F6]. Moreover, with a public statement in the news, the BAF expressed their support with regard to the implementation of RWH systems, encouragement of recharging wells, and the use of on-site STPs, for all apartments in the city of Bangalore [F7]. However, the employment of unskilled sanitary workers remained a big problem, leading to various reports stating that sanitary workers died while cleaning an on-site STP caused by asphyxiation [F7-]. Although regulations were being formulated by the BWSSB to stop the employment of unskilled labourers without proper safety gear, this remained a habit of many [F6-].

Section 4.3.3.4 – Reflection phase 3

In the third development phase, both sub-TISs were slowly developing due to several associated blocking mechanisms (see table 6 for a summary). Both sub-TISs continued to develop separately despite the increased interest in the establishment of a decentralized UWM service regime.

The water recycling sub-TIS has developed gradually during this phase, as there was a shared vision among governmental agencies, scientists and citizens, that a city-wide adoption for RWH systems and groundwater recharging methods would be beneficial and a good alternative for the limited supply of the Cauvery river. However, although more people, across different actor groups, got aware of the water situation in Bangalore and the means to combat this, the number of citizens installing a RWH only increased when they got threatened to be penalized. This particularly shows that without strict enforcement of the law, the shared believe in the technologies and the sufficient availability of technicians and technology suppliers, were not decisive for the development and diffusion of the technologies part of the water recycling sub-TIS. Guidance of the search processes (e.g. policy directives and the monitoring of implementation) and legitimation processes showed to be essential for the development and adoption of technologies of the water recycling sub-TIS.

For the on-site STP sub-TIS, the misalignment between guidance of the search processes and valuation processes are considered to be the main blocking mechanism resulting in the unsustainable development of the sub-TIS. Although extreme measures are taken to increase the adoption of on-site STPs, the lack of guidelines, the quality standards being too high, the lack of available skilled workers, the corruption issues and the lack of trust in the government, resulted in the limited adoption and compliance to the mandate. Even worse, due to these negative valuation processes, many on-site STPs became dysfunctional which led to an even greater mess.

To conclude, the water recycling sub-TIS is developing into a more promising direction as the technological solutions part of the water recycling sub-TIS were more widely supported by various actor-groups. However, despite the widespread legitimacy, experts argue that with the number of RWH systems that have now been implemented, only a small fraction of the city’s water demand could be covered by the catchment of rainwater. Therefore, the scale has to increase in order for it to serve as a sustainable alternative to the centralized supply of water. The on-site STP sub-TIS is clearly less developed and thus not ready to serve as an alternative for the centralized treatment of sewage. Due to existing psychological barriers for the reuse of wastewater, this trajectory is far from serving as an alternative source of water. As both sub-TISs face different blocking mechanisms and are unevenly well established, they have not yet emerged into a decentralized UWM service regime.

Section 4.4 – Summary and Future Prospects

In the table 6 below, a summary is given on the inducement and blocking mechanisms contributing to the development of the two sub-TISs over time. This table shows that the water recycling sub-TIS primarily faced development challenges in the early phases and was able to overcome a majority of these challenges relatively fast. On the contrary, the on-site STP sub-TIS was increasingly faced with development challenges over time and still has to overcome many challenges in order to be serving as a sustainable alternative to the centralized systems. Based on the inducement and blocking mechanisms contributing to the development of both sub-TISs over the last 15 years, it is expected that both sub-TISs will continue to develop into a more sustainable and reliable alternative service regime for the centralized systems. As the water recycling sub-TIS is relatively well established, through a better law enforcement and monitoring, the scale of diffusion is going to increase in time. Moreover, the on-site STP sub-TIS will overcome several development challenges (e.g. the psychological barrier to reuse treated wastewater) soon as more high-quality manufacturers enter the market and discharge standards will be monitored by interference of the National Green Tribunal.

Table 6 - Inducement and Blocking mechanisms sub-TISs

	Sub-TIS	Inducement mechanisms	Blocking mechanisms
Phase 1	**Water recycling**	• Policy introduction RWH [F4] • NGOs advocacy on RWH and groundwater recharging [F7]	• Lack of policy related to the reuse of rainwater [F4] • Lack of reason to install a RWH system as many citizens received high-quality water from a (bore)well nearby [F5] • Lack of financial resources available to install a RWH system [F6] • Lack of available plumbers to install a RWH system [F6] • Lack of human capacity to check whether the citizens adhered to the policy directive [F6] • Resistance to the given deadline by 8000 citizens [F7] • Lack of success stories spread [F7]
	On-site STP	• Policy introduction on-site STP [F4]	• Lack of proper hand-over procedures between builder and RWA [F4] • A high rate of non-compliance to the policy directive, while other on-site STPs were semi-functional or dysfunctional [F7]
Phase 2	**Water recycling**	• Multiple water awareness creation and knowledge sharing campaigns and workshops were held [F3, F7] • RWH theme park [F3, F7] • Recycling and reusing rainwater and greywater was being visioned by governmental agencies and knowledge institutes [F4] • Storage and reuse of rainwater was made mandatory [F4] • Training of thousand people, registering over 600 new plumbers and several architects [F6] • Over-exploitation of groundwater enhanced the legitimacy of RWH systems and groundwater recharging techniques [F7]	• Policy directives were merely ad hoc and lacked a comprehensive plan [F4] • Lack of communication and cooperation between stakeholders and civic bodies that were willing to contribute by building i.e. soak pits for public use [F5]
	On-site STP	• Many organizations started experimenting with on-site STPs [F1]	• Too high discharge standards disincentivised citizens to improve the quality and O&M of on-site STPs [F5]

		• Recycling and reusing wastewater was being visioned by governmental agencies and knowledge institutes [F4] • Studies showed the need to reuse treated wastewater [F4] • Wastewater discharge standards were set at BIS-10500 (Indian drinking standard) [F4] • Policy introduced regarding the accountability of builders to install an on-site STP [F4] • Foaming and frothing of lakes enhanced the legitimacy of on-site STPs [F7]	• No urban demand in order to sell the surplus of treated wastewater [F5] • Lack of capacity by the government to check whether people met the standards or implemented an on-site STP [F6] • Corruption issues related to the handing over of on-site STPs and the buying of CFEs and CFOs [F5] • Corruption cases spread through the news leading to the distrust in the government and the lack of compliance to the policy directives [F7]
Phase 3	**Water recycling**	• Several high-profile studies were published arguing for the need to adopt RWH systems for recharging purposes (as groundwaters were over-exploited) [F4] • Penalties were levied (83.000 were penalized) [F4] • Widespread awareness for the need to recycle water and adopt RWH systems [F7]	• Policy directives were fragmented and there was a lack of institutional coordination to solve Bangalore's water problems [F4] • Lacking capacity to monitor the adoption of RWH systems and groundwater recharging measures [F6] • The RWH policy directive lacked the scale to have impact [F7] • Many citizens only complied to the rule when the government started to levy penalties [F7]
	On-site STP	• Several entrepreneurial initiatives stimulating the reuse of high-quality treated wastewater [F1] • Policy introduction on-site STP [F4] • Interference of the National Green Tribunal stimulating the enforcement of regulations [F4] • Governmental agencies and commercial organizations advocated for the adoption of on-site STPs [F7]	• Lack of guidelines available [F4] • Poorly designed on-site STPs were being approved by the KSPCB [F5] • The availability of skilled labourers to design, operate and manage on-site STPs [F6] • Small apartment complexes lacked the financial resources to install and operate an on-site STP [F6] • The lack of human capacity to monitor the implementation of on-site STPs • Huge resistance from citizens, leading to protests and non-compliance [F7] • Lack of communication and consultation with all stakeholders (from experts to citizens) [F7] • Distrust in the government [F7] • Unskilled sanitary workers were often employed leading to safety issues and even death cases [F6, F7]

Based on the prospects of experts, the market for water and sanitation technologies in Bangalore is expected to mature within the next 5 years (EX3). Most of the unreliable actors and 'fly-by-night operators' are believed to be rooted out already, which will stimulate the sustainable development of the on-site STP sub-TIS (EX3). Additionally, the awareness of citizens is increasing which could result in the increased adoption of high-quality on-site STPs and the willingness to invest in a good service contract (EX3 and EX4). It is believed that when the apartment buyer will be starting to drive up the pressure (e.g. by asking the builder what the quality of treatment is and which technology will be adopted), the market will start to respond in a positive fashion resulting in more professional organization to come in (EX3). Furthermore, as more and more well-known international organizations, such as GE Zenon and Degrémont ltd, that can produce high-quality STPs, are entering Bangalore, it is expected that high-end on-site STPS (e.g. MBR) will be implemented more in Bangalore. Additionally, expert 3 and 7 argue that MBR technology specifically is gaining momentum, and therefore considered to be the technology for the near future (after 5 years or so). Moreover, as more commercial organizations are learning about the revenue that can be created by installing a high-quality on-site STP, more organizations are expected to use their CSR budget for the implementation of high-quality STPs (EX3). As water becomes scarcer and the water tariffs increase, the demand for treated wastewater will grow and more people will consider treated wastewater as an essential water source for the future (EX3 and EX6).

Based on the last developments in these two sub-TISs and on the prospects of the interviews, it becomes clear that these sub-TISs are slowly getting integrated (EX3-EX6). As one expert has put it: "*I think at least that there will be a larger sort of policy package where these trajectories* (meaning sub-TISs) *become part of the overall plan of Bangalore*". Moreover, one expert argued that new water policies are coming up that particularly relate to the integrated water management approach, including multiple decentralized technologies (EX6). Also, the monitoring efforts and effectiveness of regulatory measures are expected to improve because of the National Green Tribunal who is starting to interfere heavily now regarding the adoption of decentralized technologies (EX7).

However, several experts also express their doubts whether decentralized technologies are considered to be a lasting solution, as there seems to be a political gravity towards centralized systems. One expert has put it; "*There is no public money spent on people doing RWH for example, or much less; just some technical support*". Decentralized water and sanitation technologies are frequently considered as an intermediate solution and believed to exist only up until the centralized system infrastructure reaches their homes (EX3 and EX5).

5. Conclusion

The focal aim of this study was to obtain a better understanding of how the different socio-technical configurations could contribute to the establishment of an alternative decentralized service regime in the water and sanitation sector of Bangalore. For two decades, the provision of water and sanitation services has been falling short due to rapid urbanization of the city, resulting in heavily polluted lakes and an increasingly pressing water shortage. For that reason, Bangalore started to explore and push for decentralized technologies that could provide for a sustainable alternative to the centralized provisioning of water and sanitation services. As many actors advocated or pushed for different decentralized technologies, they perceived ideal, a wide variety of decentralized solutions are emerging in Bangalore. For this study, all these decentralized solutions are bundled into one TIS as they are together framed as an emerging alternative service regime to the existing centralized one. However, due to the varying structural components and development challenges of these decentralized solutions, two sub-TIS can be distinguished; water recycling sub-TIS and the on-site STP sub-TIS. By investigating the mechanisms contributing to the development of the two sub-TISs over the course of 15 years (2006-2020), this study posed to get a better understanding of how an alternative service regime could be established in the water and sanitation sector of Bangalore. Therefore, this study has proposed to give an answer to the following research question: *"How would the different socio-technical configurations of decentralized water and sanitation contribute to the development of a fully functional service regime in Bangalore?"*. In order to answer this overarching research question, the Technological Innovation System framework is used to analyse the various structural and functional components fostering the development of the alternative service regime. These structural and functional components of the TIS were captured by analysing 249 newspaper articles and 20 journal or magazine articles. Additionally, 7 experts were interviewed to scope, complement and triangulate the findings of the secondary data analysis. The main research question is answered through the following three sub-questions:

Sub-question 1: *What are the structural components contributing to the development of the two decentralized water and sanitation configurations in Bangalore, i.e. forming two sub-TISs?*

Based on the actors and institutions involved in the system, it can be concluded that the whole decentralized water and sanitation TIS of Bangalore consists of two sub-TISs. The water recycling sub-TIS involves technological solutions related to the catchment and reuse of greywater and rainwater, including greywater treatment plants, rainwater harvesting systems and groundwater recharging techniques. The on-site STP sub-TIS involves technological solutions related to the treatment and reuse of wastewater, including various kinds of on-site sewage treatment plants. Based on the structural components of the TIS, this study shows that the development of both sub-TISs were particularly influenced by governmental agencies, introducing dedicated policy measures regarding the adoption of technologies, and the willingness and awareness of users in their decision to adopt these technologies. However, while knowledge institutes and NGOs played a more prominent role in the development of the water recycling sub-TIS, commercial organizations such as technology suppliers, consultants and designers played a more decisive role in the development of the on-site STP sub-TIS. Particularly the differences in the involvement of various actor-groups caused the on-site STP sub-TIS to develop more slowly compared to the water recycling sub-TIS. More specifically, the self-interest of commercial organizations has often led to problems such the willingness of builders to cut costs, the recommendation of poorly designed STPs, and the selection of technological options that are sub-optimal for the particular context. In comparison, actors-groups such as NGOs and knowledge institutes particularly stimulated the development of the water recycling sub-TIS by organizing awareness campaigns, encouraging public interaction and by providing trainings to plumbers. Moreover, while the government allowed for the water recycling sub-TIS to develop gradually over the years before starting to penalize users for non-compliance, regulatory measures in the on-site STP sub-TIS were put in place more vigorously and enforced quite recklessly without the consideration of physical and financial constraints. This is considered as one of the main reasons why users were more reluctant to adhere to new regulations in the on-site STP sub-TIS, compared to the water recycling sub-TIS.

Sub-question 2: *How do the functional components of the two sub-TISs change over time?*

Based on the functional analysis over time, it can be concluded that particularly guidance of the search and valuation processes played a decisive role in the development of both sub-TISs. While a significant increase in processes related to knowledge and technology supply could be observed in the second development phase of the TIS (2010-2020), this was mainly due to knowledge sharing activities aiming to improve people's water awareness. Awareness campaigns, technical workshops and other knowledge sharing initiatives (e.g. RWH theme park) are considered to be closely associated with legitimation processes, as they contribute to the willingness of citizens to adopt a technology. Meanwhile, while most processes remained within the spatial boundaries of the TIS in Bangalore, it was particularly the technological knowledge and designs that could be sourced through global linkages. For instance, the signing of multiple Memorandum of Understandings to obtain knowledge from Singapore or the United Stated, and attracting global manufacturers of high-end on-site STPs, such as General Electrics and Degrémont Ltd.

In contrast, guidance of the search processes and valuation processes were merely observed within the spatial boundaries of Bangalore. In order to encourage the development of both sub-TISs, policy directives were issued before the innovation system was sufficiently established, leading to the unsuccessful and unsustainable diffusion of decentralized technologies. Moreover, it was particularly the shared vision across different actor groups and the alignment between these visions and the valuation processes, that allowed for the policy directives to be adhered. More specifically, in both sub-TISs, regulatory measures got introduced to enhance the diffusion of decentralized technological solutions across Bangalore. However, the development of the water recycling sub-TIS went more rapidly and towards a more sustainable direction, compared to the development of the on-site STP sub-TIS. One of the key reasons why both these sub-TISs develop differently is caused by the shared visions across various actor groups. Visions related to the need to recycle and reuse greywater and rainwater was shared among governmental agencies, NGOs, knowledge institutes first, and at a certain moment by citizens as well.

As citizens could more easily feel the impact of water shortage and the benefits of using a RWH system or recharging the groundwater, visions got in line more easily, which resulted in a faster development of sub-the water recycling sub-TIS. Meanwhile, while some actor-groups in the on-site STP sub-TIS started visioning the recycling and reuse of wastewater for potable and non-potable purposes, it were especially the citizens, among other actor groups, that did not share the visions articulated by the government. Citizens were not able to relate to sewage treatment as much as they could related to water conservation or rainwater catchment, while the psychological barrier to reuse treated wastewater and the particular high discharge standards caused even more aversion.

The negative legitimation processes were slowly dissolved by the increasingly pressing water scarcity, water awareness creation efforts, knowledge sharing activities, improved guidelines and an increased availability of skilled plumbers in the water recycling sub-TIS. In contrast, in the on-site STP sub-TIS, the negative legitimation processes increased over time, caused by the lack of guidelines, lack of skilled service providers, lack of urban demand for treated wastewater, too high discharge standards and corruption practices. It can therefore be concluded that the alignment of visions across different actor groups and the alignment of regulatory measures with these visions, could be considered to be important for the emergence of both sub-TISs. Furthermore, the establishment and alignment of valuation processes (particularly legitimation processes) with that of the guidance of the search processes (e.g. visions, mandates, guidelines and standards), show to be decisive for the sustainable development of both sub-TISs.

Sub-question 3: *How do the sub-TISs contribute to the development of an alternative service regime in the water and sanitation sector in Bangalore?*

Primarily the visioning and advocacy processes contributed to the alignment of the two sub-TISs. Leading actors such as the Confederation of Indian Industry, NGOs and knowledge institutes visioned and advocated for a more comprehensive plan in which multiple decentralized water and sanitation solutions are coordinated in an integrated manner. Moreover, policy directives were received poorly by citizens as they felt that these measures were ad hoc, fragmented and not part of a comprehensive plan, in order for it to make a real impact. These legitimation processes of citizens were therefore also contributing to the advocacy for a more integrated decentralized urban water management strategy.

To conclude, although the water recycling sub-TIS is developing relatively better in comparison to the on-site STP sub-TIS, the former sub-TIS lacks the actual scale to serve as a sustainable alternative to the centralized supply of water. The development of the on-site STP sub-TIS, on the contrary, is developing in a particular unsustainable fashion due to the many difficulties that are listed above. Although improvements are made related to the prevention of sewage pollution, this sub-TIS is far from serving as an alternative source for the centralized supply of water, used for both non-potable purposes, but especially not for drinking purposes. However, when both of these sub-TISs continue to be incorporated and pushed in an integrated urban water management service regime, visions become more aligned across several actor groups, and several legitimation issues are overcome, a decentralized service regime could start to stabilize in time and serve as an alterative sustainable source for centralized configurations.

6. Discussion

This chapter gives a reflection on the theoretical contributions and limitations of this study. First, the theoretical implications are discussed. After, several policy implications are proposed that aim to stimulate the development of the decentralized service regime in Bangalore. Finally, a critical reflection is given on the limitations of the methods used and future research avenues are proposed.

Section 6.1 – Theoretical implications

This study aims to make a theoretical contribution by providing for a better understanding of how the directionality of transformative change comes about. Although there have been studies showing how directionality lead to the emergence of a dominant socio-technical configuration (Yap & Truffer, 2019), it remains unclear what the broader processes are that influence directionality in the context of multiple co-existing configurations. In line with Bergek et al. (2008), who argues that the interplay of TIS functions leads to the directionality of the TIS, this research shows that the alignment within and between socio-technical configurations could lead towards an alternative decentralized service regime in the sector. Therefore, this research has specifically focused on how the various TIS functions contribute to the development of the two socio-technical configurations. By analysing the key mechanisms contributing to the development of these two socio-technical configurations, it can be argued for how the importance between TIS functions may differ in their contribution to the emerging directionality of the sector.

Firstly, in contrast to most conventional TIS studies, this study uses a different approach to analyse the various TIS functions contributing to the development of the socio-technical configurations. By dividing the various TIS functions into broader categories including; 'knowledge and technology supply processes', 'guidance of the search processes' and 'valuation processes', this study shows that a clear distinction can be made into what type of functions matter with regards to the emerging directionality of the sector. For instance, in developing contexts, to avoid making huge expenses on the R&D of new technologies, existing technologies are often sourced from outside of the country (i.e. China or Germany). Therefore, it is likely that the processes influencing the demand for a certain technology have more influence on the directionality of the TIS, in comparison to the processes related to the supply of knowledge and technology. This is in line with Binz & Truffer (2017) which distinguished the valuation dimension from the knowledge dimension. In a similar vein, Gosens et al. (2015) have argued that in domestic industries, not all TIS functions need to be developed in order for a TIS to mature, as the weakly performing functions of the domestic TIS could be relying on the global TIS. This is also in line with Binz & Truffer (2017) which argues for a multi-scalar (spatially open) perspective on the two different dimensions. In line with these studies, it can be argued that processes related to knowledge and technological development matter on a global level, while guidance of the search and valuation processes are of more decisive importance when trying to understand the development and thus the directionality of the local TIS. Therefore, dividing the different TIS function into the broader dimensions (as explained above) has allowed for reflection of development differences between these function-groups over time. The results of this case study show that particularly the 'valuation processes' and 'guidance of the search processes' were considered to have a decisive role in the development of the two socio-technical configurations, which in turn, shape the directionality towards an alternative decentralized service regime.

Second, this study provided a novel way of delineating the boundaries of a TIS. As emphasized earlier, the TIS approach has often been criticized for its little emphasis on the surrounding contexts, such as other TISs, influencing the emergence of the TIS (Bergek et al., 2015). Many ways have been proposed to delineate the boundaries of a TIS, which in essence comes down to analytical choice and interest of the researcher. For this study, the delineation of TIS boundaries is inspired by the service regime concept introduced by Welie et al. (2018). This concept bundles several technological solutions together based on the goal and user segment they share, and the way they deliver a service (Welie et al., 2018). It is therefore likely that the included technological solutions are closely related and could therefore benefit from a combined analysis. The results of this study confirm this assumption as the developing socio-technical configurations, including different technological solutions, proved to have many overlapping structural and functional components. More specifically, i.e. the share of visions or the creation of legitimacy has contributed to the development of both sub-TISs and thus to multiple decentralized solutions.

Section 6.2 – Policy implications

Based on the results of this study, several policy implications are set forth in this section according to the carrot and stick principles. These principles mean that the proposed policy implications are focused on both increasing the acceptance of users and other actors to adopt and enhance the sustainable development of the two socio-technical configurations, and on improving the compliance rate by limiting the regulatory loopholes.

First and foremost, there is a lack of trust and a feeling of being 'dumped' with water and sanitation problems that the government could not solve itself. Therefore, stricter law enforcement and monitoring efforts will not necessarily enhance a sustainable development in the early phase of the developing sub-TISs. Rather, these measures should be considered in a later stage, when the innovation system is sufficiently established but the diffusion of technologies is lacking behind. For the early phase, an arguably better approach would be to refine policy measures and improve the valuation dimension of the TIS, specifically around the adoption of on-site STPs, through incentivising citizens to adopt a technology rather than enforcing it. This could be done by facilitating more and higher-quality trainings for all stakeholders in the value chain. Particularly designers, service providers and RWA's need to be educated on what a good design is, where to look for when selecting one, why good operations and maintenance is required, and where to find organizations that could provide these products and services. Moreover, a better understanding of the benefits of a well-functioning STP (apart from avoiding penalties), need to be made clearer. The second policy implication relates to the stimulation of working with reliable service providers. As the results of this study have showed, many on-site STPs became dysfunctional due to the poor operations and maintenance services provided. Similar to what have happened to improve the RWH ecosystem, governmental agencies could certify those designers, consultants and O&M providers that prove to be reliable and skilled. In order to provide better guidance, these service providers could be listed and recommended on official governmental websites. Third, to ensure the provision of proper operations and maintenance services for all on-site STP, a service contract could be made mandatory for those buying a new on-site STP. By doing so, the responsibilities shift from the buyer of the on-site STP to the supplier. This could be beneficial as suppliers could be held more easily accountable and deleted from the list of reliable service providers certified by the government.

Furthermore, when regulatory measures are refined and positive valuation processes are in place, law enforcement becomes much more realistic and needed for a widespread diffusion of decentralized water and sanitation technologies. A fourth policy implication could therefore be pointed towards increase in human capacity to monitor and control the implementation of decentralized water and sanitation technologies, the reuse of treated wastewater or filtered rainwater, and whether discharging standards are met. Moreover, a dedicated unit of the KSPCB and/or the BWSSB could be held accountable for the execution of these tasks. This may help governmental agencies to priorities the development of decentralized solutions more.

Section 6.3 – Limitations

Due to the qualitative focus of this research, one could argue that this may reduce the reliability of the research. From the secondary data analysis, a total of 426 events were coded and categorized into one of the seven TIS functions. Although the use of large amounts of data could affect the consistency of the coding process, a coding scheme was used to minimize this risk (see appendix C). Furthermore, as inter-coder reliability was ensured and the coding scheme was adapted accordingly, this effect is considered minor.

Another limitation of this research has to do with the selected articles used for the analysis. Only the English written newspapers were selected for the analysis which could potentially lead to the missing of relevant events. However, as nine different English newspapers were selected for the analysis and the findings were triangulated with local experts, this limitation is expected to have limited effect on the results of this study. In addition, another limitation relates to the particular content written in newspaper articles. Although the systematic process of trial and error have led to a search string that provides for a relevant list of articles, one might argue that newspapers write more frequently about legitimation processes or the introduction of policy measures affecting citizens, rather than writing about the creation of knowledge via R&D projects. However, as been argued, technology development is not the core aspect of the analysis, as for the case of Bangalore, the successful emergence of the alternative service regime does not depend on this. Rather, it is the problem of valuation and guidance of the search processes that particularly affects the emergence of the alternative service regime in Bangalore. Additionally, by adding more informal indicators for the identification of TIS functions and by triangulating the findings with local experts, this effect could be minimized. Furthermore, news articles can give a distorted picture of reality as the extreme cases are often featured in the news, or as one expert puts it; "*The media narrative gets into an environment romanticism very easily, their skin is not in the game*". Even though this could affect the internal validity of this study, by triangulating the results with local experts, most of the gained insights obtained from the news articles corresponded well with the expert's take on the sector. Finally, as the focus of this study is on a single case, the findings may not be directly applicable to other cases. However, as primarily broad development processes are identified, one might observe similar development patterns in other cities in India or other developing countries. In order to reckon the effects of the listed limitations better, future studies could use other data sources, methods or cases to study the mechanisms contributing to the establishment of an alternative service regime in a city. By doing so, insights of these studies could be compared which could strengthen the validity and generalizability of the study (see next section).

Section 6.4 – Potential research avenues

A potentially interesting research direction could be to study how the conventional and the alternative service regimes, that make up Bangalore's water and sanitation sector, interact. For instance, this study showed that there is still a political gravity towards advocacy of centralized systems over that of decentralized systems. It may be interesting and important to investigate these interactions in order to evaluate its effect on the development of the entire whole sector. Another suggestion for further research is to compare these results with other cases studies, with similar contextual aspects, to see how these findings correspond. These results could then be translated into policy advice for other cities facing similar problems.

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Appendix

Appendix A – Trial and Error LexisNexis

Initial: 390	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household) PRE/2 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater) PRE/2 (recycling OR reuse OR treatment OR infrastructure OR management or system)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater) PRE/1 (recycling OR reuse OR harvesting))
Adjustment 1: No harvesting 78	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household) PRE/2 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater) PRE/2 (recycling OR reuse OR treatment OR infrastructure OR management or system)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater) PRE/1 (recycling OR reuse))
Adjustment 2: With groundwater and recharging 446	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household) PRE/2 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR groundwater) PRE/2 (recycling OR reuse OR treatment OR infrastructure OR management OR system OR recharging)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR groundwater) PRE/1 (recycling OR reuse OR harvesting OR recharging))
Adjustment 3 PRE/5 instead of 2 405	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household) PRE/5 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater) PRE/5 (recycling OR reuse OR treatment OR infrastructure OR management or system)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater) PRE/1 (recycling OR reuse OR harvesting))
Adjustment 4 PRE/5 instead of 2	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household) PRE/5 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR groundwater) PRE/5 (recycling OR reuse OR

Add groundwater and recharging 462	treatment OR infrastructure OR management OR system OR recharging)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR groundwater) PRE/1 (recycling OR reuse OR harvesting OR recharging))
Adjustment 5 Add in-house	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household OR in-house) PRE/2 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater) PRE/2 (recycling OR reuse OR treatment OR infrastructure OR management or system)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater) PRE/1 (recycling OR reuse OR harvesting)) OR (STP)
Adjustment 6 (591 articles) Near/2 instead of Pre/2, Add groundwater recharging, Add in-house	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household OR in-house) NEAR/2 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater) NEAR/2 (recycling OR reuse OR treatment OR infrastructure OR management or system)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR groundwater) NEAR/1 (recycling OR reuse OR harvesting OR recharging))
Adjustment 7 (734 articles) Same as 6, plus STP	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household OR in-house) NEAR/2 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater) NEAR/2 (recycling OR reuse OR treatment OR infrastructure OR management or system)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR groundwater) NEAR/1 (recycling OR reuse OR harvesting OR recharging)) OR (STP)
Adjustment 8 Add domestic!	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household OR in-house OR domestic!) NEAR/3 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater) NEAR/3 (recycling OR reuse OR treatment OR infrastructure OR management or system)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR groundwater) NEAR/1 (recycling OR reuse OR harvesting OR recharging))
Adjustment 9 (272 articles)	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household OR in-house OR domestic!) NEAR/3 (water OR

Leave out harvesting, adding in-house, domestic, groundwater and recharging, rainwater, Change PRE/2 to NEAR/3	sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater) NEAR/3 (recycling OR reuse OR treatment OR infrastructure OR management or system)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR groundwater OR rainwater) NEAR/1 (recycling OR reuse OR recharging))
Adjustment 10 Add STP!	atleast2 (Bangalore) and ((small-scale OR building-scale OR on-site OR onsite OR non-grid OR nongrid OR decentral! OR modular OR distributed OR integrated OR household OR in-house OR domestic!) NEAR/3 (water OR sanitation OR faecal sludge OR sewage OR sewerage OR wastewater OR blackwater OR greywater OR graywater OR stormwater) NEAR/3 (recycling OR reuse OR treatment OR infrastructure OR management OR system)) OR ((water OR sanitation OR faecal sludge OR wastewater OR blackwater OR greywater OR graywater OR stormwater OR groundwater OR rainwater) NEAR/1 (recycling OR reuse OR recharging)) OR (STP!)

Appendix B – Semi-structured Interview Guide

Hi, thank you for finding the time to talk with me. My name is Matthijs, I am a master's student at the Utrecht University studying Innovation Sciences. I am currently writing my master's thesis on the water and sanitation sector of Bangalore, with a specific focus on the innovation processes leading to the adoption of multiple decentralized technologies. For my research, I performed a media analysis. This allowed me to map the multiple technological trajectories (or development options or directions) that are emerging in Bangalore (with a focus on decentralized technologies).

In the water and sanitation sector of Bangalore, diverging technological trajectories can be observed, all with the goal to tackle water scarcity and/or pollution issues in Bangalore. However, as these trajectories are diverging and multiple technologies are pushed individually, the development and adoption of these decentralized water and sanitation related technologies is ineffective (e.g. leading to dysfunctional or semi-functional On-site Sewage Treatment Plants, legitimation issues (such as protests and loopholes), lack of regulation, expertise and financial resources). The research aims to get a better understanding of the processes leading to the emergence of particular technological trajectories or co-existence of multiple trajectories in the water and sanitation sector in Bangalore.

From the media analysis, next to infrastructural developments of the centralized system, such as piped/connected sewerage systems, two decentralized technological trajectories can be observed in Bangalore. One trajectory is the Decentralized (on-site) Sewage Treatment Plants, either for new buildings or implemented retrospectively in existing buildings, including dual piping. Another trajectory is the Integrated Urban Water Management (IUWM) trajectory, which includes Rainwater Harvesting technologies, Groundwater Recharging methods, and Grey Water Recycling (GWR) for primarily non-potable purposes such as washing and landscaping. This trajectory often includes decentralized (on-site) STPs as well. The latter thus also includes the former.

Socio-technical trajectories – Sectoral overview

1. Do you recognize these two decentralized development directions (e.g. socio-technical trajectories) emerging in the water and sanitation sector of Bangalore?
2. Do you feel like these two trajectories are linked together or are they developing more separately? Do you think one of these two is more dominant? Why?
3. Are there other decentralized development directions (socio-technical trajectories) emerging in the sector that you know of?
4. Would you say that decentralized water and sanitation technologies are now preferred over that of centralized development, in Bangalore? Why?
5. Are you, or is your organization, involved in the development and scaling-up of one of these socio-technical trajectories? Which one? What is it that you do?
6. Do you or does your organization, favour one of these trajectories over the other? Why?
7. Do you or does your organization, actively advocate one of these socio-technical trajectories? How?
8. Do you or does your organization actively advocate or express a preference for a particular technological option (e.g. ASP, DEWATS, MBR, SBR, etc.), when it comes to decentralized sanitation technologies in Bangalore?
9. Do you or does your organization actively pose resistance to particular socio-technical trajectories or developments in the sector? How? Why?
    a. And to particular technological options?
10. Can you think of any striking event in the past two decade that particularly boosted or hampered the development of one or multiple technological trajectories?
11. Can you think of any striking events in the past two decade that particularly boosted or hampered the development of one or multiple technological options?
    a. Decentralized sanitation technologies?
    b. Decentralized water technologies?
12. Are there different actors involved in the development and advocacy of a particular technological trajectory? Can you distinguish them?
13. To what extent do you think these actors are able to steer the direction in which the water and sanitation sector is developing? Why?

Innovation dynamics

The following questions are based on findings from the secondary data analysis that has been conducted. The media analysis included a total number of 350 news articles that were published between the year 2006 and 2020. These news articles had something to do with decentralized or on-site water and sanitation technologies and wastewater recycling and reuse in general, with a specific focus on Bangalore.

1. Many articles have been published between the year 2011 and 2014. Can you think of any particular reason why in these years a lot of media attention is given towards these kinds of issues?
    a. Can you think of any event or multiple events that took place during that period that made this increased media attention happen?
2. From 2013 onwards, greywater recycling became a more prominent topic in the media. Can you think of any reason why this is? What triggered this attention?

3. Both the introduction of the Rainwater Harvesting (RWH) mandate in 2009 and the on-site STP (including dual piping) mandate in 2016 were contested heavily. Can you explain what the main factors are why the on-site STP mandate was contested more heavily compared to the RWH mandate? Please elaborate.

Decentralized STPs and Dual Piping systems

4. Focussing on the STP with dual piping mandate in 2016:
    a. Which actors do you think that were driving the introduction of such a mandate?
    b. Can you tell me which actors were causing resistance to the STP and the Dual Piping mandate in 2016 and why they posed resistance?
    c. A lot of resistance towards the on-site STP and dual piping mandate in 2016 has been opposed in 2016 and 2017. Do you know why in the years after, little to no resistance towards this mandate can be found?
    d. Are there particular events that took place that could explain why regulations were introduced for decentralized STPs and dual piping in 2016/2017 specifically? Why in these years and not sooner/later?
    e. Could you explain whether this mandate boosted or hampered the creation of
5. Many decentralized STPs are dysfunctional in Bangalore. From your point of view, why do you think this happened?
    a. Do you think the government should take a more prominent role during the process? In what part of the process and in what way? Think of technology selection, operation and management, monitoring, hand-over procedures, guidelines, etc.
    b. What decentralized STP technologies are most prevalent in Bangalore? Why?
    c. Can you see a shift in the technological choice for decentralized (or on-site) STPs over time in Bangalore?
        i. What technological choice has been most prevalent in Bangalore?
        ii. What technological choice is gaining momentum now? What are the main reasons for this?
        iii. What technological choice do you foresee to be implemented more often in Bangalore?
6. In which parts of the city are decentralized STPs most prevalent? Why?
    a. Can you give an estimation of the share of citizens reliant on decentralized STPs for their sewage treatment?
    b. Has this changed over time?

Integrated Urban Water Management

7. Do you know when, or in what point of time, the integrated urban water management approach started to emergence in the water and sanitation sector of Bangalore?
    a. What triggered the emergence of this approach? Why at this moment?
    b. Do you think it is gaining momentum?
    c. What actors were involved in the emergence of this approach?
8. Focussing on the RWH mandate in 2009.
    a. The mandate was introduced in 2009 but the deadline for implementation was extended multiple times. Do you know any reason why this happened? May I know at what point in time this mandate was being enforced and monitored?
    b. Can you tell me why this mandate received a lot of resistance and from whom this came?

c. Is there a particular reason why the rainwater harvesting mandate got introduced in 2009? If so, why?
d. Almost half of the buildings that were required to have a rainwater harvesting system within their premises had installed such a system in 2013. Do you know what the current situation is right now? Is this technology widely accepted and put into use in Bangalore?

9. Groundwater recharging became less of a topic in the media from the year 2012 onwards. Do you know why there was little attention in the media related to groundwater recharging in the last 5 years?
    a. From 2012/2013 onwards, there is a downward trend in the spread of knowledge and the creation of awareness regarding groundwater recharging. Do you know what the reason for this could be?
    b. Are there any signs of groundwater levels rising again after several regulatory efforts to improve this? Please explain.

Prospects

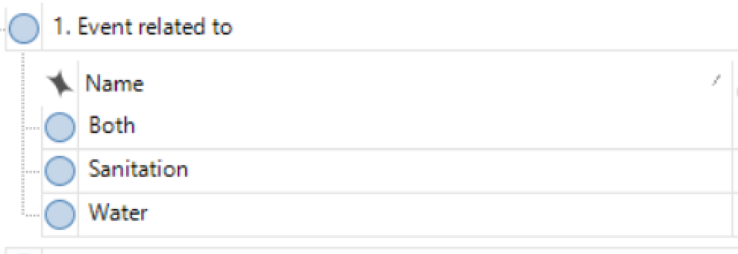
1. From your point of view, how do you foresee the development of these decentralized socio-technical trajectories into the near future?
    a. Will implementation and legitimation issues always be a struggle, or would it soon move towards more effective governance? Why?
    b. What do you think is needed to make these developments more effective in Bangalore? Why?

Snowballing

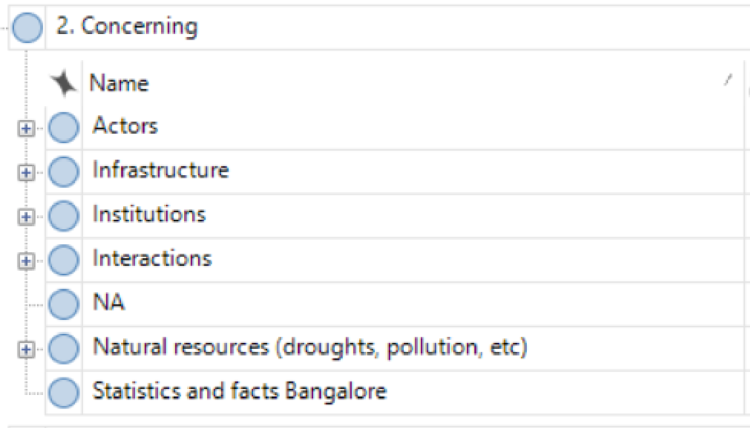
1. Do you think there is anyone important that I should talk to? Could you refer me to this person?

Appendix C – Coding scheme Nvivo

Step 1

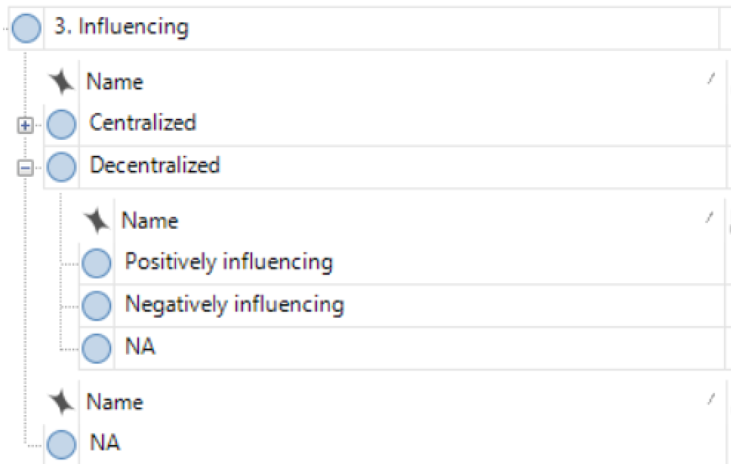


Step 2



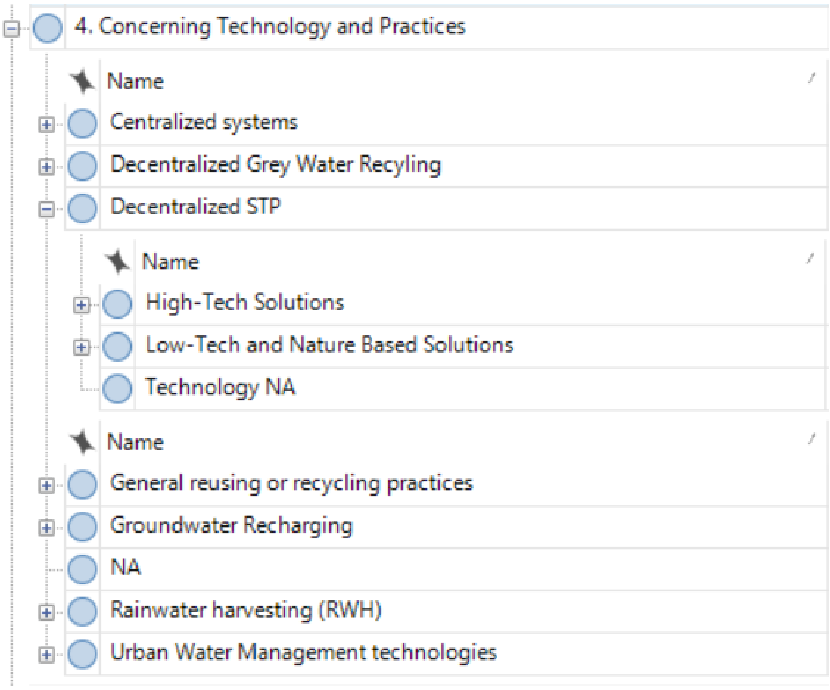
Each parent node is subdivided into several child nodes. For example; actors are split into several actor groups and institutions are split into soft or hard institutions.

Step 3



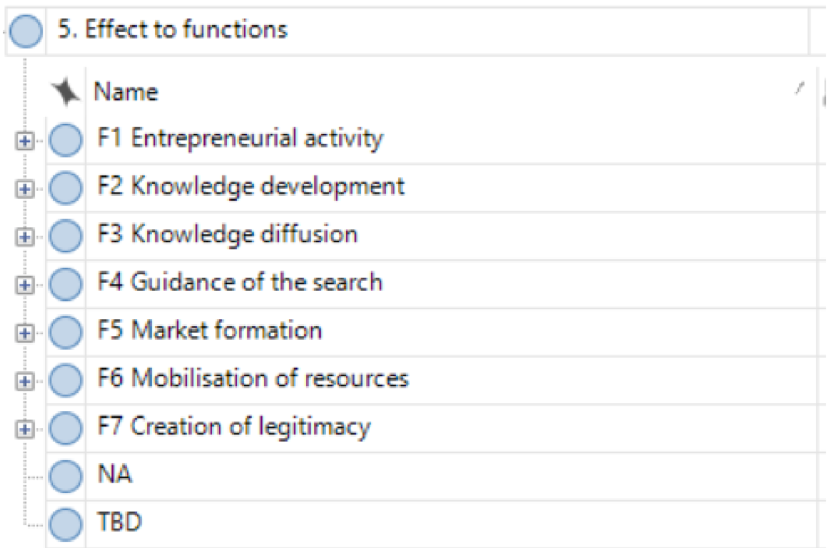
Each parent node is subdivided into either positively influencing, negatively influencing or Not Announced.

Step 4



Each parent node has several child nodes in which the code is further categorized. For example, Decentralized STP is subdivided into High-Tech technologies, Low-Tech Technologies and Technology NA.

Step 5



Each parent node has several child nodes in order to specify to which indicator the code matches. All codes that could not be coded into one of the seven functions were coded at the TBD (To Be Determined) node, which is later specified in consultation with the supervisor.