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DOI
10.1016/j.cities.2022.103659

Publication date
2022

Document Version
Final published version

Published in
Cities

Citation (APA)
Nieuwenhuis, E., Cuppen, E., & Langeveld, J. (2022). The role of integration for future urban water systems: Identifying Dutch urban water practitioners' perspectives using Q methodology. *Cities*, *126*, Article 103659. https://doi.org/10.1016/j.cities.2022.103659

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Cities 126 (2022) 103659

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

The role of integration for future urban water systems: Identifying Dutch urban water practitioners' perspectives using Q methodology

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ARTICLE INFO

Keywords:
Future-proofing
Integrated urban water management
Perspectives
Q methodology
Systems integration
Water governance

ABSTRACT

Urban water systems are under increased pressure from ongoing developments like climate change, population growth and urbanization. While it is clear that current urban water challenges need a more integrated approach, practitioners disagree on what such an integrated approach means exactly. Integration could therefore be described as a wicked problem, with practitioners having different understandings of integration, as well as the opportunities and challenges they should focus on; e.g., climate adaptation, resource recovery or collective replacement. This lack of consensus challenges decision-making, and thus the implementation of integration. To foster urban water systems integration, this study uses Q methodology to explore the different perspectives that Dutch urban water practitioners have on integration for future urban water systems. Our analysis reveals four salient perspectives: perspective 1 sees coordination as a means to make the system future-proof, perspective 2 focuses on climate adaptation, perspective 3 aims for recovery, and perspective 4 is all about efficiency and being in control. While all perspectives acknowledge that traditional urban water practices need to change, they differ on which sustainability challenges are considered most important and what means should be used. Practitioners need to understand these differences to deal effectively with the wicked nature of integration.

1. Introduction

Urban water systems worldwide are seriously threatened by climate change, population growth and urbanization: changing weather patterns, increasing anthropogenic activities and more impervious surfaces lead to degradation of environmental quality and increased risk of urban flooding. In addition, existing urban water infrastructure is deteriorating, and resource limitations and tightening regulations further challenge urban water management (Butler et al., 2016). The ongoing changes put pressure on service levels for urban water systems. To prepare these systems for the future, the traditional urban water paradigm requires a shift (R. Brown & Farrelly, 2009; Pahl-Wostl et al., 2011).

Traditionally, urban water management has focused on providing safe, reliable, and cost-effective water services. In cities, water infrastructure has been gradually expanded in response to prevailing ideological and technological conditions. In developed countries this has resulted in urban water systems with centralized water supply systems, sewer networks, and large-scale water treatment facilities (R. Brown et al., 2009). While these traditional systems have been very effective in the past – i.e., significantly contributing to public health and protecting cities from flooding – current sustainability challenges now reveal their limitations (Wong & Brown, 2009). For example, they seem to have a limited ability to cope with extreme climate conditions (e.g. Ashley et al., 2005; Rijke et al., 2013), have a high net energy consumption (e.g. Mo & Zhang, 2013), and lead to the deterioration of the environmental quality (e.g. Chocat et al., 2007).

Alternatively, urban water systems can also be designed in such a way that they are more resilient to the consequences of heavy storm events, flooding and periods of drought, enable the recovery of valuable resources like nutrients, energy, and water, and provide wider social and environmental benefits. Rather than another (technological) add-on, the future-proofing of urban water systems calls for a change to the socio-technical system: current challenges need innovations that extend to other urban disciplines, such as urban planners and road authorities (R. Brown et al., 2009; Kiparsky et al., 2013). Accordingly, both scholars

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https://doi.org/10.1016/j.cities.2022.103659
Received 24 December 2020; Received in revised form 26 January 2022; Accepted 28 February 2022
Available online 8 March 2022
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and practitioners agree that we need a more integrated approach to prepare the urban water system for the future (R. Brown & Farrelly, 2009; e.g. Ferguson et al., 2013; Pahl-Wostl et al., 2011).

Although an integrated approach is clearly needed for the future-proofing of urban water systems, there is no consensus on how such integration should look like. We see at least three issues that contribute to this lack of consensus:

- First, there is no agreed definition of what an integrated approach to urban water management is (Nieuwenhuis et al., 2021). This complicates communication about the role that integration could play for future-proofing. In response to the multiple sustainability challenges, different approaches to integration have been developed. The approaches focus for instance on storm water, resource recovery from wastewater, the rehabilitation of water infrastructure, the urban water cycle,[1] and the optimization of urban wastewater systems (Nieuwenhuis et al., 2021). This diversity in focus illustrates the lack of consensus on what a more integrated approach means.
- Second, even *if* actors have a shared understanding of what is meant by integration, it is likely that they disagree on matters such as the drivers of integration, the level of urgency or the means for integration. Integrated urban water solutions involve many different actors, each of them having their own responsibilities, perspectives and interests (e.g. Fratini et al., 2012; Roy et al., 2008). Molenveld et al. (2020), for example, studied the viewpoints among non-governmental stakeholders on the governance of integrated storm water management – more specifically, on the governance of climate adaptation. They found that actors have fundamentally different views on the need and sense of urgency, as well as how to realize climate adaptation (Molenveld et al., 2020). This illustrates the "wicked" (Rittel & Webber, 1973) or "unstructured" (Hisschemöller & Hoppe, 1995) nature of integration, with different parties disagreeing not only about the solutions, but also about the nature of problems.
- Third, and related to the wicked nature of the issue, uncertainty about the future (e.g., climate change, and technological and institutional developments) contributes to the lack of consensus on integration in future urban water systems (Nieuwenhuis et al., 2021). The inherent uncertainty may make that actors hold different views on the requirements that future systems need to meet, which in turn influences their view on (the need for) integration.

These three issues imply that among urban water practitioners, i.e., professionals involved in the management of (various parts of) the urban water cycle who work at water boards, municipalities, drinking water companies, knowledge institutes, and consultancy firms, there will be different views about integration in future urban water systems. These differences could stem from practitioners' organizations, local conditions or other issues. To work towards future-proof urban water systems, practitioners have to cope with this diversity and wickedness in decision-making on integration. To foster the implementation of integration, and thus to contribute to the future-proofing of urban water systems, we need a systematic understanding of the different perspectives on integration that exist among practitioners.

This study explores the different perspectives of Dutch urban water practitioners on the role of integration for future urban water systems. We use Q-methodology to empirically identify the perspectives, and subsequently analyze the role of integration therein based on a typology of urban water systems integration (Nieuwenhuis et al., 2021). Analyzing real-world perspectives allows us to reflect on the extent to which predominant perspectives in the literature mirror reality, and to go beyond preconceived viewpoints that are commonly juxtaposed in urban water literature, such as the sustainable and technocratic viewpoint (see e.g. Chocat et al., 2007).

The paper is structured as follows. Section 2 explains the concept of urban water systems integration and briefly describes the context of the Dutch urban water sector. Section 3 explains the theory of Q methodology and how it was applied in this study. Section 4 presents the four perspectives. In Section 5, we analyze the perspectives based on the concept of urban water systems integration. Additionally, we discuss them in the light of the current literature. We conclude with the implications of our research, as well as ideas for future research in Section 6.

2. An integrated approach to future-proofing urban water systems

2.1. Urban water systems integration

Urban water systems integration (Nieuwenhuis et al., 2021) is defined as "the physical, social, and institutional interlinking of (parts of) the urban water system with other urban systems." Nieuwenhuis et al. (2021) introduced a typology of urban water systems integration based on analysis of urban water literature. This typology distinguishes four types of urban water systems integration: geographical, physical, informational, and project-based systems integration. Each of the types are related to specific object(s) of integration (Table 1).

- *Geographical systems integration* is based on the spatial alignment of different urban infrastructure systems, and aims at preventing the (undesirable) interference between them. This alignment is of particular importance for high-density urban areas where many functions have to be combined in the same urban space. Moreover, emerging sustainability challenges, like the energy transition and climate adaptation, are expected to put even greater pressure on this space. Solutions, such as district heating, (additional) storm water sewers and infiltration facilities require space on top of what is already demanded today (Merkx, 2020). This illustrates the variety of (conflicting) spatial interests involved. Geographical systems integration aims to address these, focusing on the coordinated spatial organization of urban systems.
- *Physical systems integration* involves the physical linkage of two or more urban systems, and can be based on either resources or infrastructures.
  - In the case of integration based on resources, the product generated or transported by one system (output) is required for the functioning of another (input). An example is the recovery of resources from wastewater, such as the local reuse of municipal wastewater effluent for industrial purposes (Majamaa et al., 2010).
  - In the case of infrastructure-based integration, one infrastructure uses the other to fulfill its function. Examples include multi-utility tunnels that co-locates cables and ducts in one tunnel (Hunt et al.,

Table 1
Characteristics of the different urban water systems integration types.

Type of systems integration	Object of integration	Description
Geographical	Space	Spatial alignment of urban systems in the same area
Physical	Resources	Shared use of a resource for multiple functions
	Infrastructures	Shared use of an infrastructure system
Informational	Data	Use of data from different urban systems in operating those systems
Project-based	Planning	Alignment of rehabilitation and construction plans for multiple urban systems

From Nieuwenhuis et al. (2021).

[1] The urban water cycle includes the "man-made" changes to the natural water cycle, such as the infrastructures developed for drinking water supply and the collection and treatment of wastewater.

2014), and storm water solutions that are integrated into other urban systems, such as living walls (Riley, 2017).
- *Informational systems integration* is based on combining data from different urban systems, also referred to as a smart-city or digital-city initiatives. Such initiatives are typically aimed at increasing the efficiency of systems, through integrating information and communication technology (ICT) and physical infrastructures. An example is that of smart roofs, which provide dynamic water storage based on real-time weather data and remote-control operation (Rainproof Amsterdam, 2018).
- *Project-based systems integration* focuses on the possible synergies between urban infrastructure systems in rehabilitation and construction planning. This comprises, for instance, the planning of replacement and maintenance projects for different infrastructures such that they take place at the same time, or immediately after each other (see e.g. Tscheikner-Gratl et al., 2016).

2.2. Urban water management in the Netherlands

As a background to our empirical analysis, we briefly discuss the context of the Dutch urban water sector. The Netherlands is a flat, densely populated delta area, with large parts of the country below sea-level. Fifty-nine percent of the country is susceptible to flooding, and flood control has therefore long been a national priority (PBL, 2010). There are two main types of landscape: low-lying, flat polders in the western and northern part of the country, and slightly higher sandy areas towards the east and south. While specific urban water challenges depend on local conditions, both areas are facing similar issues: practitioners have to find solutions for increasing drought, heat and extreme storm events in complex, built-up urban areas. In addition, they are faced with deteriorating infrastructure (RIONED Foundation, 2013).

When it comes to the management and operation of urban water systems, drinking water companies, municipalities and water boards are the key actors, while the central government is in charge of protecting the country from flooding from the sea and main rivers.

- Drinking water companies are responsible for the production and distribution of water, including the operation and maintenance of the infrastructure required for this purpose. The service areas of the ten drinking water companies in the Netherlands range from about 350 km^2 to 15.000 km^2.
- Municipalities are responsible for the collection and transport of wastewater, as well as the management of storm water and groundwater in public space (residents and businesses carry the responsibility for their own properties). Dutch municipalities range in population size from about 1.000 to 870.000.
- Water boards are in charge of the quantity and quality of surface water, the management of polder water levels and flood defenses, and wastewater treatment. The water boards are among the oldest local government bodies in the Netherlands and operate independently from the national government. In total, there are 21 waterboards throughout the Netherlands.

3. Method

We applied Q methodology (S. Brown, 1980; Stephenson, 1936) to identify the different perspectives of Dutch urban water practitioners on integration for future urban water systems. Q methodology is a useful method for our study because it allows researchers to identify the variety of shared perspectives in a certain policy discourse (Molenveld, 2020). This makes Q methodology particularly suitable to investigate wicked policy issues, such as the future-proofing of urban water systems. In contrast to conventional survey research, Q methodology allows the researcher to explore the perspectives without hypothesizing them in advance, and thus to go beyond preconceived viewpoints. In the field of water management, Q methodology has been previously used to identify different perspectives on future flood management (Raadgever et al., 2008), public participation processes (Webler & Tuler, 2006), governance of storm water (Cousins, 2017), as well as that of climate adaptation (Molenveld et al., 2020).

In a Q study, a diverse group of participants is selected and asked to rank a set of statements on a particular subject into a prearranged, normally distributed, grid (see Fig. 1). First, each participant sorts the set of statements according to his or her own perspective. Then, the individual sorts are grouped into shared perspectives using factor analysis. To give researchers an in-depth understanding of the perspectives, each participant is subsequently interviewed to elaborate on their sorting. By so doing, Q methodology combines the strengths of both quantitative and qualitative research techniques: while its quantitative character allows the diversity of perspectives to be statistically analyzed, the qualitative character of the Q methodology allows researchers to stay close to the perceptions of participants.

Q methodology is an adaption of Spearman's method of factor analysis. Stephenson inverted the factor technique by applying by-person factor analysis instead of by-variable factor analysis (Stephenson, 1936). As such, Q methodology focuses on correlations between Q sorts. It treats individuals as if they are "the variables," creating factors that explain the variation among particular Q sorts (Stephenson, 1936). Rather than a relationship between particular statements, correlations in Q indicate a relationship between the entire sets of statements.

The method consists of 5 steps: (1) selecting the Q statements, (2) selecting the participants, (3) conducting the Q interviews, (4) performing the factor analysis, and (5) interpreting the factors (Cuppen, 2010; Watts & Stenner, 2012). Below, we will discuss each of these steps, and explain how we carried them out in this study.

3.1. Step 1: selecting the Q statements

The first step comprises the concourse definition and the Q sample selection. The concourse is the full range of discussions and discourses on the particular issue under study (McKeown & Thomas, 1988). It is constructed by collecting statements that represent the wide array of subjective viewpoints on the issue. Thereafter, the final set of statements, the Q sample, needs to be selected. This Q sample must be "broadly representative of the opinion domain" and should "demonstrate good coverage in relation to the research question" (Watts & Stenner, 2012, p. 67). Watts and Stenner (2012, p. 59) distinguished a structured and an unstructured Q sample, either developed using a deductive or an inductive approach. Irrespective of the approach employed, it is key that participants understand and recognize the statements (and thereby the meaning of statements). Preferably, the wording of Q statements should therefore stay close to the wording of participants (S. Brown, 1980).

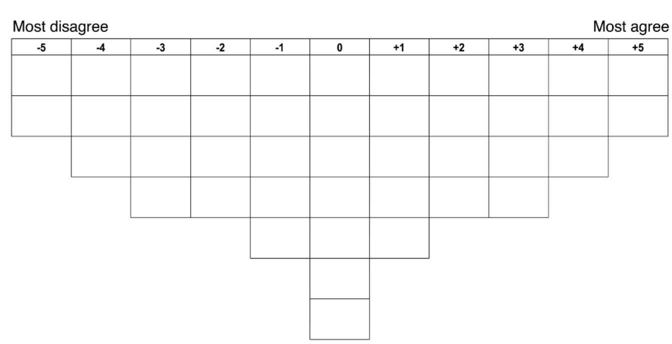

Fig. 1. The sorting grid used for this study. Each participant received 43 statements and had to rank them. The Q distribution ranges from −5 to +5 and indicates the number of statements that can be assigned a particular ranking value.

In this study, the concourse covered all subjective viewpoints on the role of systems integration in preparing the urban water system for the future. We used an inductive approach to develop our concourse. Statements were collected from six semi-structured interviews with urban water practitioners, as well as from workshops and presentations attended by the first author, scientific articles, Dutch newspapers, industry magazines and columns. During the interviews, we noticed that the concept of integration was not always understood by practitioners. Although practitioners stressed the need for cooperation and alignment with other urban systems, they were often confused by the word integration, suggesting it did not fit their language. Hence, we decided to collect both statements explicitly about integration, and statements about future-proofing in general. This included topics such as future urban water challenges, expectations about future service levels and changes required to meet these levels. In the next step, we subsequently identified the statements that were either implicitly or explicitly about integration. This approach allowed us to explore the concept of integration in an empirical way. Statements were collected until saturation was reached. This resulted into a concourse of 649 statements.

For the Q sample selection, we then took a semi-structured approach. We evaluated for each of the 649 statements whether it was about integration. We searched for words with a similar meaning, such as "collaboration" or "cooperation", and for statements describing integration in a more implicit way. All 649 statements were categorized into three sub-themes: the meaning of integration, drivers for integration (or drivers for non-integration), and the challenges and opportunities to integration. Statements that did not fit one of these categories were rejected, and duplicates were removed, reducing the set to 150 statements. By iteratively categorizing the statements based on their subject (e.g., financial matters, human resources, public health, and guidelines and regulations) and merging similar statements, the set was further reduced to 65 statements. We then repeatedly discussed the statements with five urban water professionals and a Q researcher, resulting in a preliminary Q sample of 48 statements. After piloting this sample in five interviews, we made a few more alterations to the statements. This resulted in a final Q sample of 43 statements.

To further check the validity of our sample, we asked the participants after each interview whether they felt the Q sample covered the relevant issues. Most participants were satisfied and did not wish to add anything. Those who did want to add something elaborated on an issue they had already mentioned in relation to one of the other statements. This confirmed that the Q sample included the variety of relevant issues and ideas.

3.2. Step 2: selecting the participants

Step 2 consists of sampling the P set: the group of participants. Earlier it was explained that Q research aims to discover and explicate relevant viewpoints on a particular topic. This implies that a P set needs to be diverse, capturing the different viewpoints that participants have on a particular topic, rather than a representative sample that accurately reflects particular characteristics of a population (S. Brown, 1980). Q methodology therefore typically relies on a strategic sampling strategy, in which participants are selected if they have a defined and relevant viewpoint on the issue at stake (Watts & Stenner, 2012, p. 70). In addition, a Q study does not require a large number of participants: there are generally fewer participants than statements, with interviews continuing until no new perspectives emerge (Watts & Stenner, 2012, p. 73). This is supported by the inverted factor analysis that is part of Q methodology (see Step 4), in which participants are the variables rather than the statements.

We defined our P set as follows: Dutch urban water practitioners who are actively involved in policy-making, such as policy-makers, strategic advisors and policy practitioners, working in (semi-)governmental and private organizations. Aiming to include all relevant perspectives, we used a strategic heterogenous sampling approach. We selected participants from different organizations and backgrounds, and from across the county, maximizing diversity with respect to contextual variables (e.g. geographical location, soil conditions, municipality size, and local taxes for urban water services). Participants were selected in three ways: we approached people via our own network ($n = 18$), we used LinkedIn ($n = 5$), and we approached referrals based on the snowball sampling technique ($n = 7$).[2] This resulted in a final group of 30 participants, employed at water boards, municipalities, drinking water companies, knowledge institutes, and consultancy firms (Table 2).

3.3. Step 3: conducting the Q interviews

Step 3 comprises the Q interviews. First, the participants sort the set of statements, from their own perspective, into a fixed normal distribution (see Fig. 1). This forces them to reflect on each statement and to prioritize which statements they find most important with respect to the issue at stake. Thereafter, a post-sorting interview is conducted to get a more profound and qualitative understanding of the participant's perspective.

The first three interviews were conducted face to face in December 2019. The remaining 27 interviews were conducted via video conferencing from April to August 2020 due to COVID-19 restrictions. For the online interviews, we sent a printed set of statements together with the sorting grid (Fig. 1) in advance, and subsequently guided the participants through the Q sort during the video call. Both the in-person and the Online interviews were performed in a similar way and each participant received the same instructions. All interviews were recorded and transcribed.

We first introduced the aim of our project. We explained that we were interested in the different perspectives of practitioners on future urban water systems, and that we were particularly interested in the role integration could play in future systems. We then asked the participants to sort the statements according to the question: "which statements do you (dis)agree most with regarding a future-proof urban water system?" We formulated this question in terms of "future-proof" rather than "integration," as we had learned early in the project that the term integration was not well understood by all practitioners (see Section 3.1). By using "future-proof," which is a common term in Dutch ("toekomstbestendig"), in combination with our introduction about integration, we made sure that each participant would understand what was meant.

The participants subsequently read through the 43 statements one by one, and sorted them into three piles: those they agreed with, those they felt neutral about and those they disagreed with. We then asked them to return to the piles, and to sort them into the sorting grid, starting with the statements they agreed with (at the rightmost side of the grid), then the ones they disagreed with (at the leftmost side of the distribution), and lastly, the statements they felt "neutral" about. After the sorting, we

Table 2
Overview of participants per actor type.

Type of organization	Number of participants
Municipality	12
Water board	7
Drinking water company	3
Knowledge institute	3
Advisory company/Consultancy firm	5
Total	30

[2] Snowball sampling is a technique in which interviewees suggest other potential interview candidates. Each participant was asked to suggest other urban water practitioners with a defined, either similar or different, viewpoint on the future-proofing of urban water systems.

asked the participants if they felt the Q sort reflected their point of view, or if they wanted to make any last adjustments.

In the post-sorting interviews, we asked the participants about the positions of statements, in particular the most (dis)agreeable ones – thus the statements sorted into the two outer columns at ±4 and 5 (see Fig. 1). In addition, we asked them how they viewed an integrated approach to urban water management, and the role this could play in preparing the system for the future.

3.4. Step 4: factor analysis

The aim of the fourth step (factor analysis of the Q sorts) is to look for participants who have sorted the statements in a similar way, and thus who have a shared perspective on the issue at stake. In Q method, factor analysis is an iterative process, in which researchers identify and evaluate different factor solutions, aiming for factors that could be interpreted as meaningful perspectives. There are two methods of factor extraction: centroid factor analysis and principal component analysis. Although these are two different methods of extraction, they are found to produce similar factor results (Harman, 1976). The next step in factor analysis comprises factor rotation, which can be done using varimax rotation or by hand (manual rotation). Varimax rotation uses statistical criteria that maximizes the amount of study variance that the factors altogether account for. In Q methodology, however, the best mathematical solution is not always the most meaningful solution; i.e., the solution that best explains and explicates the variety of perspectives. It is therefore suggested to use varimax rotation at the outset, followed by a manual rotation using the substantive knowledge of the data gained during the process of Q analysis (Watts & Stenner, 2012, p. 126). To facilitate the evaluation of different factor solutions, a weighted average ranking of the statements is computed for each of the rotated factors – a so-called *factor array*. This factor array shows the "ideal" Q sort for that factor, i.e. how someone with a Q sort that would load 100% on that factor would have ranked the statements. The factor arrays could be used for interpretation of the factors, each representing a perspective that is shared by the participants who load uniquely and significantly on that factor.

To analyze our Q sorts, we used the open-source software Ken-Q v.1.0.6 (Banasick, 2020). We defined the most meaningful clustering of Q sorts, using an iterative approach: we looked into various factor extraction and rotation options, and went back and forth between the quantitative and qualitative data. Eventually, we used principal component analysis and varimax rotation, followed by three by-hand adjustments.[3] This resulted into four interpretable factors. The decision for a four-factor solution was supported by two criteria that are commonly used to evaluate how many factors to keep after extraction: each of the factors had at least two Q sorts that loaded significantly upon that factor alone (S. Brown, 1980, pp. 222–223); and the cross-product of the two highest loadings on that factor (ignoring signs) exceeded twice the standard error of that factor, also known as Humphrey's rule (S. Brown, 1980, p. 223).

In the final four-factor solution, 29 out of 30 Q sorts loaded significantly on one or more of the factors, of which 18 were *defining* ones; i.e., Q sorts that were uniquely associated with a particular factor (see Appendix B for an overview). Factor 1 had the highest number of defining Q sorts, with eight participants loading significantly. Both Factors 2 and 3 had four participants loading significantly, and Factor 4 had two.

3.5. Step 5: factor interpretation

The fifth step is the interpretation of the factors into unique perspectives. The output from the factor analysis (step 4) generally forms the basis for the perspective descriptions. Additionally, the post-sorting interviews (step 3) facilitate the in-depth interpretation of the perspectives and is used to enrich the descriptions.

Section 4 presents the descriptions of our four perspectives. To develop the descriptions, we drew on the *defining* and *distinguishing* statements. The defining statements are the most (dis)agreeable statements, i.e. those ranked at ±4 and 5. The distinguishing statements are those ranked significantly different at the 0.05 level (for the formula, see S. Brown, 1980, p. 300), and ranked highest or lowest compared to any other factor. In addition, we used quotes from the post-sorting interviews to further explicate the perspectives.

4. Results: four perspectives on integration for future urban water systems

This section presents the four perspectives identified with Q methodology: *Future-proofing through coordination: finding space for urban challenges* (perspective 1), *Future-proofing through climate adaptation: creating livable cities* (perspective 2), *Future-proofing through recovery: challenging institutional structures* (perspective 3), and *Future-proofing through efficiency: being in control* (perspective 4). For each factor, we provide a narrative, together with the defining and distinguishing statements. We end the section with a summary of the perspectives. The factor scores per statement could be found in Appendix A. Appendix B provides an overview of the participants and their factor loadings.

4.1. Perspective 1. Future-proofing through coordination: finding space for urban challenges

Table 3 provides an overview of the defining and distinguishing statements for perspective 1, *Future-proofing through coordination: finding space for urban challenges*. This perspective is represented by eight participants, working at municipalities ($n = 3$), consultancy firms ($n = 2$), a knowledge institute ($n = 1$), a water board ($n = 1$) and a drinking water company ($n = 1$).

At the heart of this perspective is better coordination of different urban challenges: working beyond organizational boundaries and finding space for challenges related to water, while not overlooking those related to other domains. Hence, these practitioners are conscious of the urban complexity in which the urban water system has to be managed. They believe that new technologies could play an important role (28), but they stress, above all, that we need to change the way we work. The practitioners argue that the implementation of integrated solutions is currently hampered by a lack of collaboration, both between sectors (5) and between phases (37). As such, the urban water sector should operate beyond traditional roles (1,10,20). It should not only rely on the cooperation with water partners (29), but also actively engage with the various parties in the city (39), not forgetting its inhabitants (13). This issue is reflected by respondent 26:

[3] We first used varimax rotation to explore the dominant viewpoints among our participants. This resulted into 15 Q sorts with a significant factor loading ($p < 0.01$) on a single factor; loadings exceeding ±0.3934 are significant at the 0.01 level (for the formula, see Exel van & Graaf de, 2005). The varimax rotation was evaluated by an initial interpretation of the factors, looking at all Q sorts that loaded significantly on one or more factors. It then emerged from the qualitative data that three Q sorts that loaded (borderline) significantly on two factors, namely Q sorts 1, 12 and 13, actually had a better fit with only one of these factors. In accordance with the rotation procedure outlined by Watts and Stenner (2012, p. 126), we therefore decided to make three by-hand adjustments: we rotated factor 1 and 4 two degrees clockwise, factor 2 and 3 three degrees anti-clockwise and factor 3 and 4 two degrees anti-clockwise. This raised the number of Q sorts associated with our four factors from 15 to 18 out of 30, with Q sort 1 loading significantly on Factor 3 (with a factor loading of 0.49), and Q sort 12 and 13 on Factor 1 (with factor loadings of 0.58 and 0.59, respectively). Other than these three Q sorts, the by-hand adjustments had no further impact on the composition of the factor groups.

Table 3
Overview of the defining statements (±4 and 5) and distinguishing statements (at $p < 0.05$) for perspective 1. Statements significantly different at the 0.01 level are indicated with an asterisk. Rel.position stands for relative position, indicating if the ranking value is, on average, higher (>) or lower (<) compared to other factors.

Type of statement	Ranking value and rel. position		Statements (including their number)	
Defining statements *(most agree)*	+5	>	39	The only way to climate-proof our city is making connections to other projects and parties in the city, and linking climate adaptation to their goals.
		>	5	Separate budgets for maintenance of green facilities, roads and water hinder the implementation of integrated solutions.
	+4	>	37	The careful transfer between the various phases of policy, design, implementation and management remains a challenge to successfully integrating the design of the public space.
		>	7	The challenge of collaboratively achieving a future-proof public space is not so much agreeing on the actual design, but rather in agreeing on the moment of replacement.
		>	13	Creating support and awareness among residents is crucial to achieve a future-proof urban water system.
Other disting. statements	+1	>	38*	By dwelling on larger issues, such as defining risk profiles, we miss obvious opportunities for improvement.
	0	>	26	The future of the urban water system depends on how the energy transition is implemented and how fast.
	−1	<	40*	To achieve future-proof urban water management, clearer rules are needed about who is responsible for damage and how to prevent it.
		<	29	In order to prepare our urban water system for the future, agreements between the various water partners is more important than between the parties involved in spatial planning.
		<	10*	Everyone talks about climate proofing and circularity, but we should first ensure that our gullies, the sewage system and the receiving water system function properly.
	−4	<	1	The water sector's ambition to be sustainable comes at the expense of its core business: caring for public health, guaranteeing dry feet and protecting water quality.
		<	28	We should not apply innovative solutions until we have identified their risks.
Defining statements *(most disagree)*	−5	<	20	The focus on climate adaptation diverts attention away from traditional management tasks.

* Distinguishing statements at $p < 0.01$.

> The traditional management duties are, of course, very important, but those will all work out. We are so good at it in the Netherlands that these traditional management tasks can be carried out easily. The next step is simply to collaborate.

This perspective sees (timely) coordination as an effective means of dealing with contemporary urban water challenges, irrespective of the challenge. The coordination extends, for example, to climate adaptation projects for which a major challenge lies in spatial planning (39), but also to that of the subsurface, such as with respect to the energy transition and the space needed for district heating (26). The practitioners see cooperation as a means, as the vehicle, of identifying what is at stake, negotiating with the different parties involved, and collaboratively deciding on the trade-offs. This is illustrated by respondent 12:

> It is all about space. … So, you will have to make choices. … In fact, as a city, we have to learn to… just as much as we look at a particular area for the water system, we should look at the whole urban area for the city and think of our priorities: what are the priorities for the different systems?

In this context, this perspective does not see a role for generic rules, as these do not acknowledge this urban complexity (40). Instead, they argue that a process of interaction should provide input for (location-specific) solutions. They believe that such a process will eventually result in a design that could safeguard different urban interests. They, however, see a hurdle for the final implementation; i.e., the planning (7). Respondent 12 reflects on this issue*:*

> I believe that in terms of content, when it comes to technical matters, you can always find a solution – you can always come up with things. But the discussions are always about planning … especially if there are different organizations involved.

4.2. *Perspective 2. Future-proofing through climate adaptation: creating livable cities*

Table 4 shows the defining and distinguishing statements for perspective 2, *Future-proofing through climate adaptation: creating livable cities*. The perspective has four significantly loading Q sorts. The participants are employed at a municipality ($n = 3$) and at a water board ($n = 1$).

In this perspective, future-proofing relates to climate adaptation and an integrated approach to storm water management. The practitioners see an important role for including urban water infrastructure in the spatial design to improve the livability, as well as the biodiversity of cities. To this end, they are in favor of "non-piped", preferably nature-based, urban drainage solutions that process the water locally by means of infiltration, delay, and/or storage (31). Respondent 4 explains that such future systems preferably have other social and environmental benefits as well:

> In my view, a future-proof water system is one that is able to deal well with our future climate and all the weather conditions associated with it. So, it should be able to resist a warmer climate, but also to other weather extremes. … Furthermore, I think it is very important that it serves a wide range of societal goals, and preferably it should be a system that proves its added value already now.

Hence, next to preparing for a changing climate, this perspective finds healthier urban ecosystems important. This is reflected by respondent 6: "I really see it [the urban water system] much more as an ecosystem that needs to be in some kind of balance so that it functions well." Healthy surface water is part of such a balance, for which this perspective sees a shared responsibility for the water authorities and the municipalities (29). Above all, however, this perspective stresses the need for an integrated approach to spatial planning – and thus taking climate adaptation measures – to keep the city ecosystem in balance. The practitioners underline that the urgency of climate adaptation requires connecting with other projects and parties in the city (39), seeing the rehabilitation of whatever type of infrastructure as an opportunity to design the public space in a climate-proof way (7). In addition, they argue that a broader framing of climate adaption could contribute to a future-proof city, such as reflected by respondent 7:

> In my opinion, you should not use climate adaptation to summarize it, but rather the livability of the city, so then you have "healthy

Table 4
Overview of the defining statements (±4 and 5) and distinguishing statements (at $p < 0.05$) for perspective 2. Statements significantly different at the 0.01 level are indicated with an asterisk. Rel.position stands for relative position, indicating if the ranking value is, on average, higher (>) or lower (<) compared to other factors.

Type of statement	Ranking value and rel. position		Statements (including their number)	
		>	9*	Strict regulation of spatial developments, such as the "compensation rule" for water storage or a minimum construction level, are essential to create more space for water.
	+5	>	31*	Any storm water solution that reduces the amount of water in the sewerage system is a step in the right direction and will help to change our way of thinking.
		>	18*	To prepare the urban water system for the future, we have to discard the idea that this should not cost more than our current system.
		>	39	The only way to climate-proof our city is making connections to other projects and parties in the city, and linking climate adaptation to their goals.
Defining statements *(most agree)*	+4	>	34	Climate adaptation needs a clear captain who can combine issues like flooding, heat stress and drought.
	−1	>	29*	In order to prepare our urban water system for the future, agreements between the various water partners is more important than between the parties involved in spatial planning.
Other disting. statements	−3	<	7*	The challenge of collaboratively achieving a future-proof public space is not so much agreeing on the actual design, but rather in agreeing on the moment of replacement.
		<	28	We should not apply innovative solutions until we have identified their risks.
		<	32	Using legislation to enforce climate adaptation measures is undesirable.
	−4	<	26	The future of the urban water system depends on how the energy transition is implemented and how fast.
		<	17	At street level, it is best to work on an individual basis – because coordinating with other sectors costs too much time and money.
Defining statements *(most disagree)*	−5	<	3*	Municipalities do not have sufficient knowledge and experience to properly manage the process towards a future-proof urban water system.

* Distinguishing statements at $p < 0.01$.

> urban planning," that kind of slogans. … Only if you say you're going to make the city more attractive, and pleasant, and livable, then you can make people enthusiastic.

As climate adaptation is so urgent to these practitioners, they are not bothered by the potential higher costs the integration of storm water infrastructure in the spatial planning brings along (18, 17). There is no time to wait until future innovative solutions can be implemented, neither to wait for the energy transition (26, 28). Hence, municipalities have to come into action, and appoint someone who can take the lead to accelerate actual implementation (34). According to this perspective, municipalities are the right and the only party to organize the transition to a more climate-robust urban water system (3), using regulation to steer on the objectives for the water system (9,32).

4.3. Perspective 3. Future-proofing through recovery: challenging institutional structures

The defining and distinguishing statements for perspective 3 (*Future-proofing through recovery: challenging institutional structures*) are presented in Table 5. Perspective 3 has four participants loading significantly, working at a water board ($n = 2$) and a drinking water company ($n = 2$).

In this perspective, future-proofing is about closing cycles, making a "sponge" of urban areas and recovering the resources that are present in

Table 5
Overview of the defining statements (±4 and 5) and distinguishing statements (at $p < 0.05$) for perspective 3. Statements significantly different at the 0.01 level are indicated with an asterisk. Rel.position stands for relative position, indicating if the ranking value is, on average, higher (>) or lower (<) compared to other factors.

Type of statement	Ranking value and rel. position		Statements (including their number)	
Defining statements *(most agree)*	+5	>	34	Climate adaptation needs a clear captain who can combine issues like flooding, heat stress and drought.
		>	33	Active management of groundwater, both in terms of the replenishment and discharge of groundwater, is a requirement for a future-proof urban water system.
	+4	>	35	Knowing that everything we build now will have to last for many decades, our ambitions for a future-proof system should be much higher.
		>	13	Creating support and awareness among residents is crucial to achieve a future-proof urban water system.
		>	23	In order to make our system future-proof, shifting to a district-oriented approach is vital; replacing at the neighborhood level rather than street level.
	+3	>	21	When choose to renovate sewers, we are indirectly opting to maintain our current system; continuing to develop renovation technologies, such as relining, is thus a threat to future-proof urban water systems.
	+3	>	25*	Decentralized wastewater systems are better able to meet the objectives of a future-proof urban water system than centralized ones.
	0	<	27*	If we want to achieve our spatial ambitions in the future, the space under the ground needs to be the starting point for the above-ground design.
Other disting. statements	−1	<	37*	The careful transfer between the various phases of policy, design, implementation and management remains a challenge to successfully integrating the design of the public space.
	−4	<	32	Using legislation to enforce climate adaptation measures is undesirable.
		<	28	We should not apply innovative solutions until we have identified their risks.
		<	17	At street level, it is best to work on an individual basis – because coordinating with other sectors costs too much time and money.
	−5	<	29	In order to prepare our urban water system for the future, agreements between the various water partners is more important than between the parties involved in spatial planning.
Defining statements *(most disagree)*		<	8*	The Environment and Planning Act will improve the coordination between different urban infrastructures.

* Distinguishing statements at $p < 0.01$.

wastewater. Water management practices need a fundamental change according to this perspective. The urban water sector should put its ambitions high (35) and think twice before renovating systems that in fact are outdated already now (21). To prevent decisions that lead to technological lock-in, the water sector should focus on long term goals and make a strategic plan that looks at a bigger spatial scale (23). Rather than sticking to traditional systems and roles, it should look for innovative solutions (28) and be open to new types of institutional arrangements, for example local initiatives together with companies. As such, respondent 9 believes that "you need to start thinking on a smaller scale and apply more small-scale solutions, and then you will automatically arrive at the level of residents or companies." Hence, this perspective sees a role for decentralized solutions in future urban water systems (25), and finds support from residents essential, because local solutions can also require effort from them (13). Along these lines, participant 24 reflects on the position of large-scale treatments plants that we have today:

> If we look at the future, perhaps we should change our system, and that means that we deal with our wastewater in a different way, or that there is perhaps a much more logical place to recover resources. Hence, we should not pin ourselves down on that-end-of-pipe too much, by doing all kinds of things there. There may well be other places where we can do much better.

Increasing drought is a strong new driver to focus on recovery, and the replenishment of aquifers is therefore key to these practitioners (33). They underline that drought does not only decrease the water availability, but also changes the patterns of demand. Accordingly, they argue that drought-related issues cannot be solved with the water partners alone, and that they should therefore shift their attention to parties involved in spatial planning (29,17). They argue that this needs central coordination. Hence, they see an important role for a captain who could pull the different disciplines and organizations together (34), combined with legislation to support change towards more sustainable urban water solutions (32). This is reflected by respondent 24:

> There are people who say that you will make it, but you need leadership and the right stimuli to make that change happen. It does not happen by itself. It is not going to come slowly. … There has to be some pressure, there has to be urgency and there has to be leadership, regulation, otherwise you cannot get it done.

This quote also explains why this perspective is critical to the new Environmental and Planning Act (8), which will be effectuated in January 2022 as to facilitate integrated spatial planning, and focuses on a decentralized approach. The practitioners doubt whether the new law can really bring about the change required, such as reflected by Respondent 24: "I hear all kinds of things about the Environmental and Planning Act, that it is going to change everything. … But then one is talking about the instrument, but not about the purpose behind it."

4.4. Perspective 4. Future-proofing through efficiency: being in control

Table 6 provides an overview of the defining and distinguishing statements for perspective 4, *Future-proofing through efficiency: being in control*. The perspective has two Q sorts uniquely associated with it. Its participants are working at a consultancy firm ($n = 1$) and at a municipality ($n = 1$).

In this perspective, asset management is the main priority: the practitioners have a strong focus on managing the subsurface space efficiently (27), and thereby take a technical-financial view with respect to future-proofing. According to respondent 20, "future-proof is simply that you are in control, that you know what is going on, that you have your act together." Hence, these urban water practitioners are not bothered by deeply rooted habits that prevent change (6), as they find it

Table 6
Overview of the defining statements (±4 and 5) and distinguishing statements (at $p < 0.05$) for perspective 4. Statements significantly different at the 0.01 level are indicated with an asterisk. Rel.position stands for relative position, indicating if the ranking value is, on average, higher (>) or lower (<) compared to other factors.

Type of statement	Ranking value and rel. position		Statements (including their number)	
		>	23	In order to make our system future-proof, shifting to a district-oriented approach is vital; replacing at the neighborhood level rather than street level.
	+5	>	27	If we want to achieve our spatial ambitions in the future, the space under the ground needs to be the starting point for the above-ground design.
		>	16*	The water sector should adopt digital advances and fully exploit the opportunities that smart technology offers.
		>	37	The careful transfer between the various phases of policy, design, implementation and management remains a challenge to successfully integrating the design of the public space.
Defining statements *(most agree)*	+4	>	40	To achieve future-proof urban water management, clearer rules are needed about who is responsible for damage and how to prevent it.
	+2	>	10*	Everyone talks about climate proofing and circularity, but we should first ensure that our gullies, the sewage system and the receiving water system function properly.
	0	<	13*	Creating support and awareness among residents is crucial to achieve a future-proof urban water system.
	−1	>	28*	We should not apply innovative solutions until we have identified their risks.
	−1	<	18	To prepare the urban water system for the future, we have to discard the idea that this should not cost more than our current system.
	−2	<	6*	In the final analysis, deep-rooted habits are what prevent the realization of future-proof systems.
	−3	<	33*	Active management of groundwater, both in terms of the replenishment and discharge of groundwater, is a requirement for a future-proof urban water system.
Other disting. statements	−3	<	9*	Strict regulation of spatial developments, such as the "compensation rule" for water storage or a minimum construction level, are essential to create more space for water.
		<	26	The future of the urban water system depends on how the energy transition is implemented and how fast.
		<	29	In order to prepare our urban water system for the future, agreements between the various water partners is more important than between the parties involved in spatial planning.
	−4	<	31	Any storm water solution that reduces the amount of water in the sewerage system is a step in the right direction and will help to change our way of thinking.
		<	25	Decentralized wastewater systems are better able to meet the objectives of a future-proof urban water system than centralized ones.
Defining statements *(most disagree)*	−5	<	35	Knowing that everything we build now will have to last for many decades, our ambitions for a future-proof system should be much higher.

* Distinguishing statements at $p < 0.01$.

most important that we operate the system in a smarter way, thereby considering all phases of the development process (37). Digital tools could contribute to this (16), as well as clearly defined responsibilities (40). A future-proof system is thus by no means about setting higher ambitions (35), but rather about a better management of the current system (10).

Saving costs and efficiency is important to this perspective (18). One of the reasons that these practitioners do not see a role for decentralized wastewater infrastructure (25), nor for local storm water measures (31), is based on the principle of "economies of scale". To this end, the perspective is in favor of collective solutions. This also explains why support from residents is less important to them (13), Respondent 6 reflects on this issue:

> In my view, there are already a lot of possibilities underground. And in that case, indeed, depending on the situation, it is not an absolute necessity to involve residents, as they are not bothered by it at all. Moreover, I have more faith in district-focused measures than in street-focused measures, and the larger the scale, the less important it is to involve individual residents.

Additionally, respondent 20 explains that collective solutions allows the sector to be in control, which is at the heart of this perspective:

> Most above-ground solutions require quite a lot of maintenance and also require people who live there to be careful. … That means that, if it works now, it does not have to work in five years' time. … Yet, I believe that, on the long run, we will look for it [space] in the underground again, because this is easier, as a government, to keep the control.

The focus on efficiency, which characterizes this perspective, is also reflected in the call for the collective replacement of systems. For example, this enables the implementation of climate adaptation measures at little additional costs. The practitioners argue for taking a good look at the subsurface and the existing infrastructures, preferably on a district level, to facilitate collective replacement (23, 27) – and thus to save costs. Moreover, they underline that coordination with parties in charge of these infrastructures becomes even more important (29), since the pressure on the subsurface is only increasing further in the future. They find collective replacement important; nevertheless, own goals and targets should not lose sight of. For instance, other parties should invest as well (e.g. green authorities), and they do not want to pay for the energy transition, nor want to wait for it, if the need for (sewer) replacement is high in a particular area (26).

4.5. Summary of the perspectives and their understanding of future-proofing

Table 7 presents the key characteristics for each perspective. This reveals that the perspectives have different understandings of future urban water management. Perspective 4 (*Future-proofing through efficiency: being in control*) is most distinctive from the other perspectives. This is also shown by the factor score correlations (Table 8), as these were considerably lower for factor 4 than for the other factors. We first provide a recap of perspective 4 and subsequently summarize the other three perspectives, for which the differences are more nuanced.

Perspective 4 (*Future-proofing through efficiency: being in control*) has a clear idea of the way to become future-proof; i.e., being in control, having good insights into the system and opting for efficiency. At the same time, it also has an idea of how future systems should look like, with centralized solutions dominating future urban water systems. They only see a minor role for decentralized solutions in future urban water systems, as they argue that the drainage capacity of decentralized storm

Table 7
Overview of the perspectives. The table provides the key characteristics for each perspective. P stands for perspective.

Perspectives	Key characteristics
P1: Future-proofing through coordination: finding space for urban challenges	- Finding space for urban sustainability challenges - Dealing with urban complexity - Putting a collaborative process central
P2: Future-proofing through climate adaptation: creating livable cities	- Climate-proofing urban space - Creating livable cities and healthy ecosystems - Using regulation to accelerate climate adaptation
P3: Future-proofing through recovery: challenging institutional structures	- Closing cycles and dealing with increasing drought - Challenging current institutional structures - Guiding change through leadership
P4: Future-proofing through efficiency: being in control	- Operating urban water infrastructure in a smarter way - Putting a better understanding of the system central - Increasing efficiency through collective replacement and solutions

Table 8
Factor score correlations. KenQ automatically calculates the correlations between factor arrays. A higher factor score correlation indicates a greater similarity in content between two factors – and thus the perspectives.

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1.00	0.47	0.41	0.31
Factor 2	0.47	1.00	0.41	0.11
Factor 3	0.41	0.41	1.00	0.00
Factor 4	0.31	0.11	0.00	1.00

water solutions cannot be guaranteed, making them financially unattractive. This does not imply, though, that these practitioners do not see the need for climate adaptation, or do not acknowledge other (non-water-related) benefits decentralized storm water solutions could bring. According to them, however, other involved parties (e.g. green authorities) should contribute to these solutions as well.

Perspective 1 (*Future-proofing through coordination: finding space for urban challenges*) acknowledges that climate adaptation is essential for future-proofing, but it puts climate adaptation next to other urban challenges. The main concerns of this perspective are the many urban challenges that have to be addressed simultaneously, and the limited space available. Rather than strict regulation, the practitioners see a collaborative process as the critical means of future-proofing. They believe that regulation in fact threatens the room for negotiation with other parties, arguing that a proper process will yield a proper solution. They consider the physical solution thus subordinate to the collaborative process, and mainly have a strong vision of the way to become future-proof (coordination), rather than what the future urban water system should look like.

Perspective 2 (*Future-proofing through climate adaptation: creating livable cities*) has its main focus on climate adaptation and sustainable storm water measures when it comes to future-proofing. The perspective considers climate adaptation key to improve the social and environmental conditions of cities. Hence, it has a strong focus on processing storm water locally, and the practitioners have a clear picture of how future systems should look like; i.e., a climate-proof urban space, for which the urban water infrastructure is included in the spatial design. They argue that regulation is key to enforce that much needed adaptation measures will be taken in time, and see a key role for municipalities to take the lead.

Perspective 3 (*Future-proofing through recovery: challenging* *institutional structures*) displays some similarities with both the first and second perspective: it emphasizes the need for climate adaptation to become future-proof (perspective 2), and thereby sees an important role for (new) collaborations (perspective 1). Different from perspective 1, however, this perspective is less concerned with urban complexity and mainly focuses on the urban water system, also in relation to the wider, regional, water system. Increasing drought is a central theme, and according to perspective 3, the urban water system can only become future-proof if we treat both storm and wastewater more carefully: storm water should be utilized, and the resources present in (industry) wastewater should be recovered.

In addition, compared to perspective 2, perspective 3 has a different view on climate adaptation: rather than redesigning urban space to create livable cities, perspective 3 focuses on "redesigning" the urban water cycle to address the consequences of drought. Perspective 3 thus operates at a larger spatial scale than perspective 2. This may be related to the fact that perspective 3 is only represented by water authorities ($n = 2$) and drinking water companies ($n = 2$); i.e. organizations with service areas extending beyond city boundaries, and that are primarily concerned with water-related issues. This could account for the perspective's strong focus on the water system itself, rather than how the water system needs change in relation to other urban challenges (perspective 1); how and when infrastructures need to be replaced (perspective 4); or, how public space should be redesigned (perspective 2). For the other perspectives, we did not find any surprising results with respect to the participants defining that perspective.

None of the perspectives were represented by participants from only one organization, or by participants from organizations with similar contextual variables (e.g. geographical location or municipality size). This suggests that perspectives are not (only) dictated by the practitioner's organization or other local conditions. Further research, e.g. involving a larger group of practitioners and using quantitative methods, is needed to determine the influence of these factors.

Altogether, we found that the perspectives on future-proofing mainly differ with respect to their view on future systems, i.e., which sustainability challenges should be addressed, and the means to be used. Despite these differences, our results reveal a basis of mutual agreement among urban water practitioners: practitioners generally agree that traditional urban water management practices need to change to prepare the system for the future. Furthermore, we could not identify clear conflicts between the perspectives. So, despite their different values and interests, our results suggest that the intentions of one perspective do not necessarily rule out those of the other perspectives.

5. Discussion

This section first discusses the role each of the perspectives sees for integration in future urban water systems, using the typology of urban water systems integration (Section 2.1). Second, we analyze how each of the perspectives relates to the literature.

5.1. The different views on the role of integration in future urban water systems identified

The different understandings that the perspectives have of future-proofing (Section 4.5) are reflected in the role they see for integration in future urban water systems (Table 9).

In perspective 1 (*Future-proofing through coordination: finding space for urban challenges*) integration is viewed as a means to safeguard different urban interests, and thereby to become future-proof. This is also reflected in the types of integration identified for perspective 1: geographical, physical and project-based integration. For perspective 2 (*Future-proofing through climate adaptation: creating livable cities*), all types of integration are focused on climate adaptation. They either relate to the measures themselves (geographical and physical integration), or to the path towards it (project-based integration). Perspective 3 (*Future-proofing through recovery: challenging institutional structures*) sees integration as a vehicle for future-proofing: geographical and physical integration can serve as a solution to address the increasing drought, by closing resource and/or water cycles. In perspective 4 (*Future-proofing through efficiency: being in control*), integration is viewed as a way to increase efficiency, e.g. in the case of project-based integration to bring financial gain; or to have more control, for example with geographical integration to get better insights into (the location of) various physical systems.

Some types of integration are more commonly referred to than others. We did not identify the informational type of systems integration, for example, while the geographical type of systems integration was identified in each of the perspectives. This suggests that urban water practitioners have a common understanding that the spatial alignment of systems is key to future-proofing. Likewise, one could argue that practitioners do not see a role for the integration of information (yet); however, we only included the types of integration that were explicitly mentioned in the interviews. For instance, in the research project of which this study was part, we identified a project in Amsterdam (the RESILIO project) involving smart climate adaptation measures that combine real-time weather forecasts with dynamic water storage. This example of informational systems integration would fit the description of perspective 2, yet it was not mentioned in the interviews, and

Table 9
Overview of the different types of urban water systems integration that are identified for each perspective. P stands for perspective and UWSI for urban water systems integration.

Type of UWSI *(and the object of integration)*	P1: Future-proofing through coordination: finding space for urban challenges	P2: Future-proofing through climate adaptation: creating livable cities	P3: Future-proofing through recovery: challenging institutional structures	P4: Future-proofing through efficiency: being in control
Geographical *(space)*	Alignment of various urban infrastructure systems to fit in all demands	Designing streets in a climate-robust way, e.g., to prevent damage due to urban flooding	Fitting in storm water infrastructure across urban areas, allowing for natural replenishment	Better insights into the location of (planned) infrastructures to prevent costs from unnecessary damage or interventions later on
Physical *(resources)*	–	Green storm water solutions that provide social and environmental benefits as well	Resource recovery, e.g. decentralized water recovery in collaboration with companies	–
(infrastructures)	Multifunctional solutions as a means to align the various interests and to utilize all urban space available	Climate-proof solutions on roofs and buildings	–	–
Informational *(data)*	–	–	–	–
Project-based *(planning)*	Collective replacement through better coordination, creating a moment to balance between the different interests and objectives	Collective replacement to gain momentum for a climate-proof redesign of the street	–	Collective replacement, preferably on a district level, to save money and time

therefore not included.

Furthermore, we found that a single type of integration could be characterized differently. For the geographical type of systems integration, for example, the drivers for integration, as well as their relevant spatial scale, are specific to each of the perspectives. In perspective 1, geographical integration is mainly about spatial alignment of the different urban infrastructures, considering the variety of interests and fitting in various system demands. Perspective 2 focuses on the inclusion of storm water infrastructure in the urban design, for instance, to prevent that other infrastructures interfere with the storm water flow and cause damage. Hence, while perspective 1 focuses on the scale of urban infrastructures and their challenges, we identified a smaller relevant spatial scale for perspective 2 (e.g. street-level). Likewise, the spatial scale and drivers differ for the perspectives 3 and 4: perspective 3 aims to fit in storm water infrastructure across urban areas to allow for natural replenishment, while in perspective 4, geographical integration is mainly about better insights into the location of physical infrastructures to prevent, for example, unnecessary damage.

5.2. Representation of the perspectives in the literature

All perspectives were, to some extent, reflected in the urban water literature. Perspective 1 (*Future-proofing through coordination: finding space for urban challenges*) resembles the literature that takes a systems approach to urban water management, for example Dunn et al. (2017). In addition, it has a link with the literature on urban (underground) space planning, concerning urban space limitations (e.g. Hooimeijer & Maring, 2018; von der Tann et al., 2019).

Perspective 2 (*Future-proofing through climate adaptation: creating livable cities*) corresponds to the body of literature that takes a more holistic approach to storm water management (see e.g. Fletcher et al., 2015). Various concepts such as urban drainage systems (SUDS) (Fletcher et al., 2015), sponge cities (Jiang et al., 2018) and blue-green systems (BGS) (Deletic et al., 2020) have been developed, all of which are based on integrating storm water infrastructure into the urban landscape in order to process water in a more sustainable way than conventional solutions do. Since perspective 2 sees climate adaptation as a means to create livable cities, it also bears similarities with the ideas of de Graaf and van der Brugge (2010) and Fratini et al. (2012), who argue that climate adaptation is actually key to improve the social and environmental conditions of cities.

The future-system depicted in perspective 3 (*Future-proofing through recovery: challenging institutional structures*) resembles the water cycle city state (Wong & Brown, 2009), which is the fifth of six developmental states that cities move through on their path towards increased water sensitivity. Likewise, the perspective overlaps with the literature on integrated urban water management (IUWM), aiming for a better physical and institutional integration of the water supply, storm water, and wastewater components of the urban water cycle (Mitchell, 2006). Similar to perspective 3, IUWM emphasizes the need for highly coordinated management to achieve such integration.

Perspective 4 (*Future-proofing through efficiency: being in control*) bears similarities with the view expressed by Marlow et al. (2013), who criticized the discourse on sustainable urban water management. They argued that consideration for changing urban water management practices should be based on "evidence-based arguments", and needs "valid economic assessments". This does not imply, though, that they are against change. They highlight, however, that the risks and benefits of innovations should be clear and that future systems should, in any case, be financially viable. Hence, similar to perspective 4, knowledge and efficiency are key to them. Along these lines, the perspective corresponds to the sewer asset management literature as well (e.g. Tscheikner-Gratl et al., 2019). For instance, with regard to risk-based management, but also concerning collaborative rehabilitation of infrastructures (Tscheikner-Gratl et al., 2016), as this offers financial benefits and provides the opportunity for future-proofing systems in a more efficient way.

Relating the perspectives to the literature, our results suggest that real-world perspectives are less conservative (i.e., less averse to change) than the traditional, technocratic viewpoint that is still depicted as the dominant perspective (see e.g. Dunn et al., 2017; Fuenfschilling & Truffer, 2016). We found that the ideas about more sustainable practices have a lot of support on the ground. Dutch practitioners generally agree that traditional urban water management practices need to change to prepare the system for the future, and they also have clear ideas about that. Moreover, perspective 4, which could be called the most conservative, is represented by the lowest number of participants ($n = 2$). So, while the urban water literature typically portrays the conservative viewpoint as the dominant perspective in urban water practices, our results show differently. In addition, the literature commonly juxtaposes the sustainable viewpoint and the traditional, technocratic viewpoint (see e.g. Chocat et al., 2007; Marlow et al., 2013). Our results indicate, however, that practitioners' views are less dichotomous: the discussion is not so much about conservative versus sustainable, but rather about which sustainability challenges are most important to address.

6. Conclusions

Urban water systems are under increasing pressure, facing challenges such as climate change, urbanization and population growth. Clearly, an integrated approach is needed to address these challenges and to prepare systems for the future. As integration is a wicked problem, practitioners disagree about the meaning of integration, as well as the opportunities and challenges they should focus on – for example, climate adaptation, resource recovery or collective replacement. A first step in future-proofing is, therefore, to gain a better understanding of the different perspectives that practitioners have about such integration. This could facilitate communication and structure the discussion about future urban water systems. In addition, insights into the differences between practitioner's viewpoints could help to build effective strategies that accommodate these differences, for example, by incorporating the various drivers that practitioners see for integration and considering different spatial scales.

This paper has used Q methodology to study these viewpoints: a group of 30 urban water practitioners ranked a set of 43 statements about integration in future urban water systems into a normally distributed grid. In addition, we conducted interviews to get a better understanding of how participants made their decisions – and thus of their viewpoints. Using factor analysis, we subsequently grouped the individual perspectives into shared ones.

This resulted in four real-world perspectives of Dutch urban water practitioners on the role of integration for future water systems. For each perspective, at least two out of the four urban water systems integration types (Nieuwenhuis et al., 2021) were identified, demonstrating that practitioners see an important role for integration in future systems. Furthermore, while the perspectives differ as to the opportunities and challenges to focus on, they all recognize that traditional water management practices need to change to prepare for the future. Perspective 1 focuses on coordination, perspective 2 on climate adaptation, perspective 3 on recovery, and perspective 4 on efficiency. We identified five key differences between the perspectives: their view on future systems, the meaning of integration, the role of it in future urban water systems, as well as the drivers and means to realize it. Despite these differences, we also see common ground between the perspectives. All perspectives recognize that sustainability challenges should be addressed, with collaboration shifting beyond sectoral boundaries. For example, practitioners generally agree that climate adaptation is needed, yet the sense of urgency, their motivation and the proposed means differ.

Further research is needed to generalize our findings, for instance, performing studies in different contexts (i.e., different environmental, technological and/or institutional conditions), or using quantitative methods like surveys, involving more practitioners and/or from outside policy-making, to understand how widely held each of these perspectives is. In addition, since urban water systems integration typically extends to other urban sectors, we recommend including practitioners from these related sectors (e.g., urban planners, architects and road authorities), and identifying their perspectives as well. Despite this, our study provides promising insights for the scientific debate on future urban water systems, as well as for decision-making on integration:

- First of all, the four real-world perspectives suggest that the urban water sector is less averse to change than the literature portrays. For future research, we therefore suggest shifting away from the dichotomy of conventional versus sustainable, and rather address the decision-making challenges related to the implementation of integration. An in-depth case study involving different urban actors and looking at successful strategies to deal with the wicked nature of integration could provide useful insights.
- In addition, the perspectives, both their similarities and differences, provide fruitful ground for developing negotiated knowledge (De Bruijn et al., 2010, p. 146) or collaborative learning (Cuppen, 2012), where the various parties collaboratively explore the perspectives, seeking a common interpretation of the policy problem and its solution. Although such collaborative processes might be cumbersome, the basis of mutual agreement among urban water practitioners looks promising. As such, developing negotiated knowledge could be an effective way to deal with the wicked nature of integration (Nieuwenhuis et al., 2021). Practitioners would collaboratively explore how integration can be defined and operationalized, while being aware that they may have different views of reality ("agree to disagree"). Recognizing the different perspectives of urban water practitioners presented in this paper contributes to reaching such a negotiated view.

The four viewpoints empirically identified in this study provide valuable insights for both practitioners and scholars, and represent a substantial step towards future-proofing urban water systems.

CRediT authorship contribution statement

Eva M. Nieuwenhuis: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Data curation, Validation, Writing - original draft.

Eefje H.W.J. Cuppen: Supervision, Writing - review & editing.

Jeroen G. Langeveld: Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by the Dutch "Kennisprogramma Urban Drainage" (Urban Drainage Knowledge Programme). The parties involved are: ARCADIS, Deltares, Evides, the cities of Almere, Arnhem, Breda, The Hague, Rotterdam, and Utrecht, GMB Rioleringstechnieken, KWR Watercycle Research Institute, Royal HaskoningDHV, the RIONED Foundation, STOWA, Sweco, Tauw, vandervalk+degroot, Waternet, De Dommel Water Board, and Witteveen+Bos.

Appendix A. Factor scores per statement

Table A1
Overview of the statements (in English) and their factor Q sort values (the factor arrays). The original statements were in Dutch. F stands for Factor.

#	Statement	F1	F2	F3	F4
1	The water sector's ambition to be sustainable comes at the expense of its core business: caring for public health, guaranteeing dry feet and protecting water quality.	−4	−2	1	0
2	It is undesirable that solutions for waste and storm water depend on the correct use and maintenance by residents or businesses.	−2	1	−3	1
3	Municipalities do not have sufficient knowledge and experience to properly manage the process towards a future-proof urban water system.	−3	−5	1	3
4	Continuously implementing innovative solutions leads to an unmanageable system at the city level due to the great variety of solutions.	0	0	0	1
5	Separate budgets for maintenance of green facilities, roads and water hinder the implementation of integrated solutions.	5	1	3	0
6	In the final analysis, deep-rooted habits are what prevent the realization of future-proof systems.	2	2	2	−2
7	The challenge of collaboratively achieving a future-proof public space is not so much agreeing on the actual design, but rather in agreeing on the moment of replacement.	4	−3	1	3
8	The Environment and Planning Act will improve the coordination between different urban infrastructures.	0	0	−5	2
9	Strict regulation of spatial developments, such as the "compensation rule" for water storage or a minimum construction level, are essential to create more space for water.	−1	5	2	−3
10	Everyone talks about climate proofing and circularity, but we should first ensure that our gullies, the sewage system and the receiving water system function properly.	−4	−1	−2	2
11	The local processing of storm water seems like a good idea, but in reality, without a storm water system, all undesired storm water, ground water and flushing water of aquifer thermal energy storage systems will be discharged to sanitary sewers – which would cause even more problems.	−2	−1	−3	0
12	By intelligent clustering of cables and pipes, we will be able to better manage public space in the future.	1	2	0	0
13	Creating support and awareness among residents is crucial to achieve a future-proof urban water system.	4	3	4	0
14	Municipal guidelines, for example for the design of public space, do not leave sufficient space to actually implement innovative solutions.	0	0	0	−1
15	If pipes are ready for replacement, we must focus on extending their lifespan to enable an integrated approach at neigbourhood level.	0	−2	−2	2
16	The water sector should adopt digital advances and fully exploit the opportunities that smart technology offers.	0	1	−1	4
17	At street level, it is best to work on an individual basis – because coordinating with other sectors costs too much time and money.	−3	−5	−4	−3
18	To prepare the urban water system for the future, we have to discard the idea that this should not cost more than our current system.	2	4	1	−1
19	The parties involved will not take the measures necessary to make our system future-proof, unless there are financial incentives.	−1	0	2	3
20	The focus on climate adaptation diverts attention away from traditional management tasks.	−5	−1	−3	−2
21	When choose to renovate sewers, we are indirectly opting to maintain our current system; continuing to develop renovation technologies, such as relining, is thus a threat to future-proof urban water systems.	−3	1	3	−2
22	Measures to prepare the system for the future, such as systems for local (re)use of water or water-permeable pavement, are often too demanding in terms of use and maintenance.	−1	−2	0	1
23	In order to make our system future-proof, shifting to a district-oriented approach is vital; replacing at the neighborhood level rather than street level.	3	3	4	5
24	More stringent privacy legislation hinders the optimal usage of sensors and data, thereby threatening the future-proofing of our systems.	−2	0	−2	−2
25	Decentralized wastewater systems are better able to meet the objectives of a future-proof urban water system than centralized ones.	−3	−3	3	−5
26	The future of the urban water system depends on how the energy transition is implemented and how fast.	0	−4	−1	−4

(continued on next page)

Table A1 (*continued*)

#	Statement	F1	F2	F3	F4
27	If we want to achieve our spatial ambitions in the future, the space under the ground needs to be the starting point for the above-ground design.	3	3	0	5
28	We should not apply innovative solutions until we have identified their risks.	−5	−4	−4	−1
29	In order to prepare our urban water system for the future, agreements between the various water partners is more important than between the parties involved in spatial planning.	−4	−1	−5	−4
30	If we want to achieve integrated solutions, we should put objectives, like circularity, climate resilience or energy neutrality, in the tendering process, rather than focusing on the instruments one should use.	3	0	3	−1
31	Any storm water solution that reduces the amount of water in the sewerage system is a step in the right direction and will help to change our way of thinking.	0	5	−3	−4
32	Using legislation to enforce climate adaptation measures is undesirable.	3	−4	−4	1
33	Active management of groundwater, both in terms of the replenishment and discharge of groundwater, is a requirement for a future-proof urban water system.	2	3	5	−3
34	Climate adaptation needs a clear captain who can combine issues like flooding, heat stress and drought.	1	4	5	0
35	Knowing that everything we build now will have to last for many decades, our ambitions for a future-proof system should be much higher.	2	−2	4	−5
36	Removing pharmaceuticals from wastewater will be a gamechanger for the reuse of effluent.	1	2	−1	0
37	The careful transfer between the various phases of policy, design, implementation and management remains a challenge to successfully integrating the design of the public space.	4	2	−1	4
38	By dwelling on larger issues, such as defining risk profiles, we miss obvious opportunities for improvement.	1	−3	−2	−3
39	The only way to climate-proof our city is making connections to other projects and parties in the city, and linking climate adaptation to their goals.	5	4	2	3
40	To achieve future-proof urban water management, clearer rules are needed about who is responsible for damage and how to prevent it.	−1	1	1	4
41	A future-proof urban water system requires a more business-oriented approach to the wastewater chain.	−1	−3	0	2
42	To prepare for the future, we need solutions that connect different systems, like aquathermal systems.	1	0	0	−1
43	Removing micropollutants from wastewater will have major consequences for how we deal with storm water.	−2	−1	−1	1

Appendix B. Factor loadings per participant

Table A2
Overview of the participants in the Q study, the organization they are working for, and their (rotated) factor loadings. The gray boxes indicate the defining sorts; i.e. the Q sorts that loaded significantly upon that factor alone.

#	Organization	Factor 1	Factor 2	Factor 3	Factor 4
1	Water board	0.2696	0.3872	0.4898	0.3022
2	Water board	0.5570	0.5915	0.1140	0.0613
3	Water board	0.5238	−0.0066	0.4876	0.0991
4	Municipality	0.2294	0.6096	0.0945	0.2522
5	Municipality	0.4287	0.2622	0.3531	0.5219
6	Consultancy firm	0.1335	0.2762	−0.1286	0.4561
7	Municipality	−0.0633	0.6768	0.0979	−0.0125
8	Knowledge institute	0.1699	0.0240	0.4950	0.6465
9	Drinking water company	−0.2165	0.0772	0.7051	0.1179
10	Consultancy firm	0.2089	0.2365	0.3565	0.3805
11	Municipality	0.2454	0.6961	0.2651	0.2317
12	Municipality	0.5759	0.2790	0.1671	0.3832
13	Water board	0.5934	0.3811	0.3783	−0.0124
14	Municipality	0.5583	0.0246	−0.0962	0.175
15	Municipality	0.0171	0.4008	0.1815	0.5876
16	Water board	−0.0317	0.4376	0.3759	0.0425
17	Consultancy firm	0.5847	0.3652	0.2656	0.2422
18	Municipality	0.4820	−0.1383	0.1581	0.0545
19	Knowledge institute	0.5754	0.1280	0.2986	0.2795
20	Municipality	0.2081	−0.1942	−0.1188	0.7391
21	Municipality	0.4953	0.4769	0.1312	0.0736
22	Consultancy firm	0.6083	−0.1689	−0.1341	0.1645
23	Consultancy firm	0.2417	0.2939	0.4019	0.534
24	Water board	0.3624	−0.0162	0.6837	0.0004
25	Drinking water company	0.1425	0.3304	0.5600	−0.102
26	Drinking water company	0.5491	0.3519	0.0925	−0.0473
27	Water board	0.6624	0.4477	0.1296	−0.0782
28	Municipality	0.4202	0.3836	0.4633	0.1624
29	Knowledge institute	0.4453	0.0981	0.4102	0.2665
30	Municipality	−0.0016	0.7082	−0.1119	0.4209
Explained variance (%)		17	14	12	10

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